Engineers organization and innovation: training systems and organization of the technical skill in japanese and french firms in the electronics and chemicals industries

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TRAINING SYSTEMS AND ORGANIZATION OF THE TECHNICAL SKILL IN JAPANESE AND FRENCH FIRMS IN THE ELECTRONICS AND CHEMICALS INDUSTRIES

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by
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THE JAPAN INSTITUTE OF LABOUR

PREFACE

No one disputes that a country's international manufacturing competitiveness in a given industry depends at least in part on the nature of the product and, to an extent, on exchange rates. However, country differences in the competitiveness of various products can be attributed in large part to differences in technology, product development ability, and mass production technology. Underlying the differences in technological ability are systems for developing engineers: educational systems, labor markets, and companies themselves. To clarify sources of international competitiveness, we set out to compare systems for developing engineers, as well as systems for the division of labor among engineers and technically skilled people within the firm.

We have planned, in conjunction with the French Laboratory of Economics and Sociology of Work (Laboratoire d' Ecomomie et de Sociologie du Travail), an international comparative research project. This project examines the labor market for engineers as well as their technical development within the firm upon employment. We have exchanged opinions frequently, basing our discussions on the actual surveys of educational systems, labor market structure, product development, and technical development systems for engineers within companies. We have expended a great deal of energy on the actual research on companies and in the exchange of opinions.

In the company research, we selected product lines within each country's relative comparative advantage and then conducted comparative research on the development of those products. The focus of the research was on four firms in the Japanese and French electronics and chemicals industries. These industries were selected because it is said that France has comparative advantage in chemicals while Japan has comparative advantage in electronics.

This is our first experience with basic international research, and the results took a great deal of time, but we were able to learn a great deal. We found that the competitiveness of those products was greatly influenced by two factors: 1) whether or not the systems for product development which give birth to the competitiveness of products conformed to the special qualities of the products, and 2) whether or not the systems for developing engineers conformed to the special qualities of the products .

Even though we were able to identify several aspects of the labor market and career development systems which contributed to a country's comparative advantage in certain products, we found that it is extremely difficult to transplant various elements of competitiveness from one country to another. It is particularly difficult to partially reform any given labor market or technical development system. In part, this is because product and human development systems in firms, are deeply intertwined with exogenous factors such as the education system and the labor market.

The various systems influencing technological advancement are complex. As a result, a country's handicaps tend to become embedded and it takes a great deal of time to reverse the comparative advantage of a country's product competitiveness or lack thereof. Hence, comparative advantage in the international competitiveness of industries tends to remain somewhat inert overtime.

The researchers participating in this international comparative research from the Japan Institute of Labor include: Toru Ishii, Minoru Ito, Naoyuki Kameyama, Tadashi Kudo, Shigemi Yahata. The researchers from the French Laboratory of Economics and Sociology of Work include: Caroline Lanciano, Marc Maurice, Hiroatsu Nohara, and Jean Jacques Silvestre.

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INTRODUCTION

The years following the Second World War saw first the development, then the blossoming and finally the breakdown of the way in which firms functioned,which was based on wringing productivity increases out of production factors and the conquest of markets through continuous fall in consumer prices. This method of managing firms was organized around a relatively passive and extremely divided work force engaged in execution tasks (manual workers and technicians). This work force,which was subject to rules and productivity targets and had to carry out tasks of an intensitive,repetitive nature,was augmented by a body of supervisory staff (still small in numbers),made up of engineers and foremen whose essential function was to improve techniques and,from the organizational point of view,to "supervise and give orders". There was a marked distinction between conception and execution.

For the past twenty yeas firms have been developing strategies for improving competitiveness. In this case, company growth is based on improvements in quality,product diversification, increasingly stint adherence to deadlines and savings on stocks. Markets are conquered through the confidence that is created between producers and consumers. The position and role of execution workers has changed. Differentiation between individual tasks has gradually given way to a greater emphasis on cooperation and the specialization associated with extracting high productivity gains from individual jobs is giving way to polyvalence; execution workers have to be more active and take a more global view of the functioning of the firms as a whole. The position and work of supervisory staff is also changing. In particular, engineers are having to create the conditions in which manual workers can be more autonomous. They intervene directly in breakdowns in production, which are often caused as much by poor human resource management as by technical problems. The collectivization of works is based on the importance given to learning processes. Supervisory staff are increasingly involved in training and assessment. In this model of competitiveness, employees responsible for technical matters (from semi skilled manual workers to engineers) remain in place, but their vertical and horizontal relationships, as well as the rules governing them, are gradually changing in nature. As we enter the 1990s, firms are devoting more and more resources to innovation, i.e. the development of new processes and the invention of new products.

These innovations mean that they can make headway in markets that become saturated increasingly quickly and in which competition consists of creating monopolies. The significant trend here is the proliferation within firms of groups of workers with very high levels of technical competence. These groups are sufficiently numerous and diversified for management of them to raise problems of organization, hierarchy, division of labor, assessment, etc... Workers' skills are less and less dependent on equipment and machinery and increasingly determined by their ability to organize teams, to succeed in collective gambles, to minimise the costs of a series of uncertain experiments, etc... The range of organizational choices is widening. The autonomy of workers involved in projects, prototype design and the solution of new technical problems is taking on increasing importance. Nevertheless, supervisory staff have an important guiding role to play in providing continuity and stability for the innovation that is expected. In any competitive, dynamic firm, workers are engaged simultaneously in a search for productivity, competitiveness and innovation. This is particularly true for those in technical jobs, whether they be manual workers, technicians, foremen, senior technicians, engineers or researchers. This group of jobs, and the workers occupying them, constitute what we call the "technical function" in a company. All these technical jobs are coordinated by the relationships that exist between research laboratories, the industrial development service, the planning office and supervisory and production staff. Research, particularly development and economic research, has an increasingly important role to play, since it is the dynamic of research that provides a company with the means to improve its ability to succeed in the face of competition. Such work brings many dimensions into play, including workers' skills and training, the organization of work and authority relationships, work force mobility and the functioning of teams. The articulation of these dimensions defines what we call the "technical professionality" which is both an individual and a collective reality.

Past research has shown that this technical professionality, which was restricted to manual workers and their immediate supervisors, differed from firm to firm, from sector to sector and, particularly, from country to country. Our hypothesis in this study is that the inclusion of research, development and the planning office could only reinforce this trend. The importance of training and work organization issues in these services is well known. It is for this reason that we are engaged in an international comparison between two countries, such as France and Japan, which differ enormously in these two areas of training and organization

This introduction will be divided into two sections. The first section will outline the basis of our approach to the problem. This outline will be divided into two parts:

1. the approach to innovation as we conceive it, based on four choices;

2. the problems raised by innovation in the genesis of a firm's dynamic

The second section will present the methodology that we have chosen in order to deal with these problems in an international comparison.

This introduction will conclude with a plan of the report.

1. INNOVATION : ACTORS AND ORGANIZATIONS

1-1. Innovation and technical professionality : an approach based on four choices

In our introduction to this research, we shall present four general choices that will give an overview of the way in which we approached research, development and technical studies, particularly in the company monographs. Some of the elements presented here will reappear in the second part of this section, which will be devoted to the problems raised by innovation in creating a firm's dynamic.

1. The first choice extends and completes the typology we put forward at the beginning of this introduction. This typology might at first sight lead to the conclusion that the actors involved in innovation are currently being incorporated into the functioning of firms, while at the same time remaining separate from the heart of the production process. This was not the choice we made. We decided, on the contrary, to regard innovation as a process influenced by the method of producing and organizing that characterizes a company or a country. At the same time, the way in which new products are created and then manufactured has an influence on the role of engineers in R & D, technical studies and production as well as on their relationships with technicians and manual workers.

Moreover, it should be noted that one of the research studies that provided the basis for this study described the way in which, in Japan, all workers, from manual workers to engineers, collaborated more or less intensively in the innovation process, thus contributing to its efficiency and reliability. As far as development and innovation processes are concerned, our approach is different from an organizational study of laboratories or technical teams which assumes that such teams are closed systems, in which the circulation of information or networks of contacts between agents are studied in great detail. It is true that such analyses of the way in which the actors in the innovation process work together and communicate lie at the heart of any research of the type under consideration here. Nevertheless, we are just as interested in the way in which functions or actors develop as groups of professionals entering into relationship with each other. The importance of this interdependence between functions and actors leads us to investigate the process by which a company's "technical capability" is constituted. Rejection of an approach in which innovation is studied as a closed system also implies rejection of an approach in which expenditure on R & D and technical studies is seen as an economic resource that can be isolated in order to study its effect on the company's prosperity. Expenditure on research (like that on education) is an indicator that cannot be ignored, but one which leads in both cases to consideration of the methods of organizing work and mobilizing actors. The effectiveness of such expenditure cannot be analyzed unless it is understood how it stimulates and shapes what we have called a firm's technical professionality.

2. The second choice concerns the ways in which we approach the resources, essentially human resources, that are mobilized in the innovation process. Many studies and theories have shown the extent to which the creation of the conditions under which human resources can be efficiently deployed is influenced by the interaction between firms and their employees. The work force engaged in production is a specific social, economic and professional construct, even if workers' characteristics such as age and formal qualifications may play an important role. In the case of research, development and technical studies, we are dealing with a high level work force, particularly in respect of scientific training. On the other hand, it is a work force

that is very carefully selected by firms. Thus these resources might be considered to be "finished products", available in external labor markets at a level of development that creates the ex ante conditions for their productive efficiency. This may be true in the case of particularly well defined groups of specialist workers, whose skills are purchased in order to launch a new industrial program, for example. However, these cases are very much a minority. In general, in addition to the recruitment of engineers and technicians, firms are engaged in a process of skill reconstruction which has at least two dimensions. It has an individual dimension when each worker within the organization he enters develops competencies which will become effective in a given context. These competencies will be formed through "learning on the job". This learning on the job is influenced by the way in which each firm envisages team work, the exercise of hierarchical authority and the mobility of its work force. This reconstruction of initial skills also has a collective dimension. Industrial innovation is the result of team work, and the collectivization of competencies can only be done within the firm. This collectivization is the result of a division of labor and interaction between engineers, technicians and manual workers. Group work creates new competencies which transcend individual skills and can be differentiated from them.

Nevertheless, we know that this learning on the job defined as a set of individual and collective processes may take very different forms depending on the firm and country in question. There are no universal rules that define what is often described as an innovative environment. The cooperation, competition and competencies that develop in such an environment are contingent. The hypothesis of a high level of contingency in innovative environments ties in with some of the most recent advances in innovation theory developed by specialists in industrial economics. In these theories, the continuous emergence of new products reflects the way in which the productive system specifies actors' competencies, both internally, in terms of work organization, and externally, in relation to product markets. This contingency or specificity in respect of organizations and skills is not restricted to what takes place within a firm in the strict sense of the term. It also involves the relationships between companies and public sector research and the university system. These relationships are differently structured in each country. The same is true of relationships with high level subcontractors (in computing, for example). In all these cases, the general resources are obtained from outside but utilized in different ways by the firm in accordance with its internal organization and the competencies of its engineers and technicians. The firm's environment is also internalized.

3. The third choice, linked to the previous one, is to give analytical power to the history of organizational structures and to the way in which they change as the firm evolves. In the production sphere, the organization of work changes, but only marginally. Production plants are shut down, but such closures are implemented through redundancies and only limited numbers of staff are transferred. In research, development and technical studies, work teams, hierarchical forms and pockets of old technologies are, it seems to us, much less stable. The relative newness of the innovation process, and the importance of the human factor, disrupt the organizational structure in a way that does not occur elsewhere. Laboratories or teams involved in technical studies are reorganized frequently, depending on the predominant spheres of

scientific interest and the preferred directions of industrial development. The skill of engineers and advanced technicians is developed through a succession of learning processes that cut across these changes; the relationship between organization and the accumulation of knowledge is a complex one.

There are two dimensions of great importance.

The first is the development of a bank of knowledge and know how. The mobility of individuals within structures may destroy or transmit this knowledge and know how, depending on the way in which the micro organizations are renewed and articulated. Time is experienced differently by each individual. Some keep up with or even cause organizational changes. Others, whether in central research laboratories or in technical teams, tend to prefer stability in structures, specialists, products or markets. In other words, here more than elsewhere, socialization and organization are indissociable. Nevertheless, the way in which they are articulated certainly requires more subtle analysis in both time and space than is the case with assembly lines, for example.

The second dimension involves the relationship between a certain level of organizational complexity and the simplicity of certain principles of worker stratification. The principles of stratification are based not only on differences in function but also, and more decisively, on differences in status. This is very obviously the case with the distinction between engineers and technicians in France. Here there is a dual distinction between initial formal qualifications and the institutional categories "manager" and "non manager". These distinctions may be the result of professional experience. There are also more continuous differences which are managed by supervisory staff rather than being imposed from outside. Nevertheless, these differences may be just as strong as those rooted in formal qualifications. Examining the relationship between organizational dynamic on the one hand and the accumulation of knowledge and the stratification of actors on the other involves us directly in questions of mobility and career path. This is the subject of our fourth point.

4. An innovative environment is not simply an organizational network which builds up and disintegrates over time, leaving behind a bank of knowledge. It is also a space in which socialization takes place. There is, therefore, a very strong link between socialization and the way in which each individual carries out his job and cooperates with his colleagues. We are dealing essentially with people with advanced technical training, and career problems assume even greater importance here than they do elsewhere. As in other research studies, there are three aspects to the emphasis we have placed on mobility.

- Mobility exposes a struggle for positions and jobs.

- Mobility is linked to the way in which certain types of employees involved in the innovation process plan, organize, adopt and persist with their career paths. These career paths are valued differently depending on the technical, managerial and research elements they contain.

- Mobility is also linked to the way in which each employee accumulates competencies and extends his skills. This accumulation is both an individual and a collective process. From this point of view, any study of mobility must be two dimensional.

The first dimension relates to training in the course of a career. The way in which it is carried out and the stages at which workers are involved in it influence the success of the innovations in which they are engaged.

The second dimension relates to the opportunities for contact between engineers and technicians with different specialists. Cooperation between them , if achieved , creates hybrid collective competencies that produce new industrial products that would be inconceivable without such "cross breeding".

The organization, the processes by which knowledge is accumulated and competition for promotion up the hierarchy., all these dimensions are linked to the way in which each employee is more or less inventive or creative. Nevertheless, this creativity, like the accumulation of knowledge and the career strategies, has to be planned on a collective level, since it is also the result of the management of people and of their resources.

These four choices lead us to approach innovation within a firm as the outcome of both the organization of work and the socialization of individuals. In this sense, technical professionality is the result of actors' strategies and of their incorporation into management strategies, which both constrain and energize them. This leads to the notion of organized creativity , study of which requires a great deal of lengthy analysis and observation. The same is true of the origins and level of costs associated with any process of innovation and industrialization. Any discussion of whether they are justified or effective also has to be accompanied by a great deal of analysis and observation. This should reveal their origin, the mechanisms by which they become apparent, the actions that raise or lower them, etc. These costs are difficult to measure, except in artificial or mechanical ways. On the other hand, it is possible to rethink the forms and modes of functioning, the cooperative or conflictive relationships between actors and relationships to time which, through mediations that remain to be identified, increase or reduce them. They are not regulated by a market in which prices and quantities mix. In our view, they are regulated by the functioning of a professional space. In this case, we have to understand how the actors are constructed and how organizations direct their actions. The costs and returns are then socialized differently depending on the firm and country in question.

The use of the terms "actor" and "organization" brings us to a point that seems to us important, namely assessment of the relationships between two dimensions. The first relates to what is generally known as a research and industrialization strategy, which is decided at the highest level in companies. These strategies involve decision making, the establishment of structure or projects, etc... The second relates to the way in which these strategies, decided at the highest level, are made possible by the behavior of employees at all levels. It might even be asked how these managerial strategies are driven by the competencies of the actors in the company. This reveals once again the utter inadequacy of indicators such as the level of expenditure on research and development, the size of the central laboratories, employees' formal qualifications or the number of projects launched for an understanding of what distinguishes two firms or of the way to assess the innovator dynamic of one of them. What we call innovation strategies arise out of the intertwining of decisions, actions, actors and organizational responses. What we call strategic plans are one of the elements, among others, in the understanding of a whole.

The difficulty of putting forward the ideas outlined here in an international comparison should be readily apparent. The interactive and iterative dimensions of issues such as profitability, rationality or the relationships between the different levels of a company makes comparisons of quantitative indicators meaningless. Nevertheless, it is possible to make headway by focusing on the problems that the inception of innovation and the dynamic of what we have called technical professionality pose for all firms. These problems will be considered in the second part of this introduction.

1-2. Innovation and technical professionality: the problems that affect all firms

The problems cited here will not necessarily be dealt with in order of importance, but they all lie at the heart of the dynamic of innovation and of the conditions for its realization.

One of the first problems is the conditions in which collective learning processes are realized through on the job training. This learning on the job exists in all companies, but it does depend, for example, on the confidence that firms have in formal qualifications and their hierarchy. Thus it must be wondered whether initial training determines the way in which employees work together, or whether everything depends on experience and seniority. The conditions in which collective learning processes are realized also depend on the division of labor. Nevertheless, this depends on the mobility of individuals and the circulation of information. This is what happens, for example, through polyvalence and cooperation between different hierarchical levels.

There is another problem closely akin to this one. It concerns the way in which a firm separates and coordinates the functions that we shall label managerial, scientific and technical. For example, managerial functions can be clearly isolated and assumed by individuals who have the appropriate status and specific powers. On the other hand, these managerial functions may be distributed in a more diffuse way. In the second configuration, each engineer and his capacity to manage constitute a professional space in which his technical and scientific competencies are of secondary importance. Analysis of the functioning of the firm is a question of identifying the structures that are put in place in order that technical and scientific cooperation can be developed across these juxtaposed spaces. There has to be a compromise between the collectivization of technical work and individual strategies for promotion through the hierarchy. In the first configuration, in which managerial functions are the prerogative of a small number of supervisory staff, individual strategies are organized around the extension of technical and scientific polyvalence. The juxtaposition of management spaces is replaced by the superimposition of zones of competencies. This superimposition encourages continuous progress in the industrialization of new products and the improvement of processes. In both cases, the problem to be solved by firms is the establishment of types of work organization that produce innovation and provide a link between two dimensions.

The first of these is the way in which each individual defines his personal skill and his commitment to work. This definition may place more or less emphasis on managerial autonomy or technical cooperation.

The second is the way in which these types of skills are organized at the collective level. How is the hierarchy of supervisory and technical functions arranged? Through what types of mobility is this hierarchy made concrete and legitimized?

This brings us to a notion that is central to R & D and technical studies. This is the way in which firms implement innovative industrial processes. The implementation of such processes requires cooperation between engineers, technicians and even manual workers with different backgrounds and specialists. Such an operation lasts a limited time and represents something of a gamble. It requires assessment and monitoring procedures that involve individuals outside the operation itself. These innovative operations are of limited duration and are constantly replaced. Finally, they require a constant shuttling to and fro between various functions within the firm: market research, production, technical studies, research, etc...

The question that must then be asked is whether the organization of the company hierarchy which is by definition fairly rigid and closed in on itself is able to take on such operations. Can hierarchies services mobilize a range of individuals with different competencies and persuade them to cooperate? Can they renew operations of variable duration and do they have the resources to assess their progress? If the firm's organization is not suited to such a form of collective work, the project system may well provide an alternative solution. In this case, an ephemeral, ad hoc structure is created. The creation of such a structure mobilizes individuals with the appropriate skills and establishes more or less standardized evaluation and monitoring procedures. The functional services cooperate frequently throughout the duration of the project. In our experience, all companies make use of both methods of organization. This gives rise to two series of questions:

1. How are these two modes of organizing collective work made to interact within a company? What are the relationships between those with hierarchical responsibilities and project managers? How do engineers deal with their involvement in two structures one ephemeral, the other permanent. How does the mobility of individuals and their evaluation develop?

2. How, at the collective level, does the firm manage the failures and successes of industrialization operations? Is the stable structure of a hierarchical organization more likely to encourage the accumulation of experience? Does a project system allow a greater variety of collective assignments and does it give a higher profile to successes and failures?

None of these questions is specific to one firm or to one country. They are questions of general significance, and all the more so since the answers to them provide information on the way in which firms implement their innovation policies. This is the case, for example, with one fundamental dimension of these policies, namely the speed and reliability of product and process renewal cycles. Shortening these cycles while maintaining the quality of the industrialized product is one of the fundamental elements in the creation of strong market positions. In the face of such a challenge, firms may choose different ways of organizing actors and their contributions. These differences may relate to time management. One extreme example of an organizational model may emphasize the early mobilization of all those involved in the industrialization process researchers, engineers, production and sales staff, etc. An intermediate product is produced and its faults and possible solutions and adjustments evaluated. In this case, work is collectivized immediately and the dynamic is the result of cooperation between individuals with different specialists and different levels of experience. The circulation of information depends on the coordination of activities, which is a problem to be managed by the hierarchy. In a second extreme example, an industrialization program is implemented sequentially. The various functions make their contributions one after the other. This process starts with a very general product design phase, proceeds through a research phase and finishes with the gradual development of a prototype and then the finished product. The central problem here is the transmission of experience and knowledge, which may well be lost unless the various actors communicate with each other. Such communication offsets the disadvantages of compartmentalization.

These two extreme models for managing the chronology of the various phases of the development and industrialization process also have a spatial dimension: the relationships between people are different in each case. In the first model, highly integrated patterns of professional behavior will have to be developed. This integration may be put at risk by differences in status and initial training if such factors have a powerful segregating capacity. In the second case, in contrast, the actors are deliberately distinguished by their function, status and training. The success of the innovation process depends on the way in which the system of work organization uses these differences in order to foster leadership and to develop individual patterns of mobility that are sufficiently motivating to have a positive effect on collective learning processes.

In this latter example, therefore, it can be seen that the success and speed of a product renewal cycle can be regulated in very different ways. The challenge to firms is a general one, and their success or failure can be assessed quantitatively.

The underlying resources, procedures and collective learning processes are specific and are best approached in a much more qualitative way. They can, nevertheless, be compared, provided that the interdependencies and dynamics that make them intelligible are clearly understood. This is the fundamental problem with international comparisons, the methodology of which as we conceive it will be examined in the second section of this introduction.

2. INNOVATION, TECHNICAL PROFESSIONALITY AND SOCIETAL EFFECT

This section will outline the general analytical framework used in this research, which reflects the theoretical concerns set out elsewhere, and the comparative methodology, which is rooted in the so called " societal effect approach ". The methodology adopted will be compared with other types of international comparative approach in order to highlight the theoretical implications (and assumptions) of each one.

2-1. The general analytical framework

In this comparative research project, the innovation space and the "social construction" of competencies and of "organized creativity" are analyzed empirically on the basis of studies of firms in two different sectors, the chemical industry and electrical and electronic engineering.

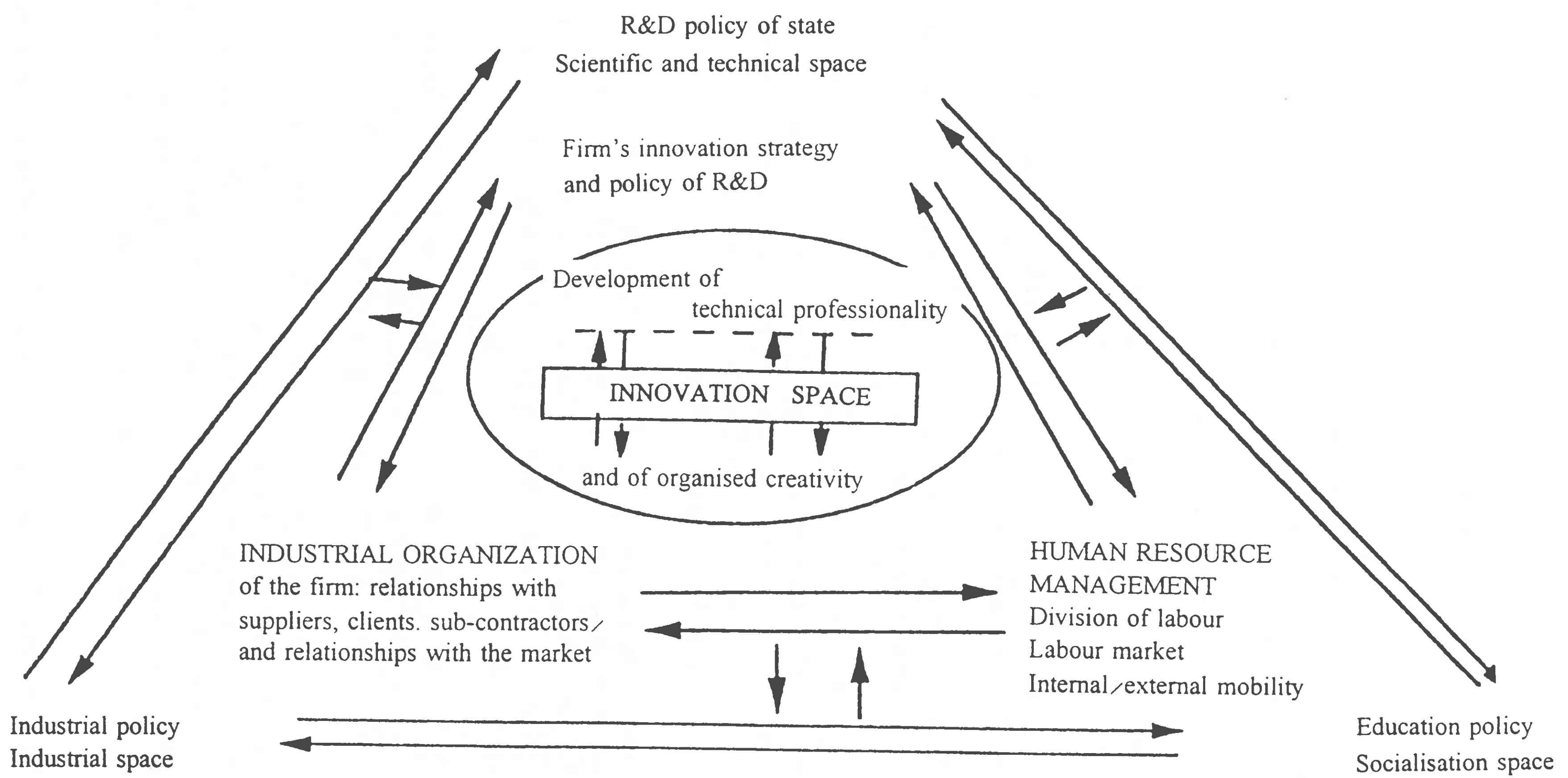
The approach also involves an examination of the firm in relation to the society of which it is a part. In other words, we take into account the interdependence between the firm and society , a process which helps to produce the innovation space and technical competencies (which we will denote by adopting the concept of "technical professionality").

Thus the industrial, R & D and education policies of each country help to form the "innovation spaces" and to produce the "technical professionalities" that we observe in the companies studied.

There are of course many mediating factors intervening between these various "policies" (which themselves stem from institutions and categories of actor specific to each country) and firms. Each firm has its own autonomy which enables it to manage its relations with its "environment" or its societal "context"; each firms makes its own choices and defines its own strategies with respect to innovation, the formation of professionalities and the organization of competencies and creativity.

Diagram below shows, in simplified form, the main relationships of interdependence by means of which firms, operating within a given society, construct their innovation space and the technical professionality of their actors, notably engineers and technicians.

The relationships between the firm and society :
the construction of the innovation and technical professionality space



Note: The larger triangle represents the firm's societal context; the firm itself is represented by the inner triangle, in the centre of which is the innovation space, which is produced by the interdependencies between the developement of the "technical professionality"(particularly that of engineers) and of "organise creativity". The innovation space is thus constructed within the interdependencies between "actors"and "space", at the level of both firm and society.

In this diagram, the largest triangle represents the society of which the firm is a constituent part. The circles at each corner of the triangle represent "policies" that emanate largely from the state but which also constitute "spaces" in which public and private programs (the latter organized, for example, by private organizations, national or regional, that make a contribution to vocational training or to the development of scientific and technical research). Thus these three points of reference are defined both in terms of "policies" and in terms of "spaces":

1) R & D policy/space (scientific and technical);

2) Industrial policy/space (organization of industrial sectors, or networks of firms, of subcontracting, etc...);

3) Education and socialization policy/space (education and training system, public and private organizations contributing to the development of knowledge, ...).

Relationships of interdependence exist between these three reference points and between each one of them and firms.

In other words, all these relationships contribute, in each country, to the constitution of what might be called an "innovation space" and of a more extensive space, articulated to the innovation space, in which technical and scientific professionalities are developed and from which each society's dynamic and potential for technical and scientific creativity flows.

The intern triangle represents the firm, with the three points of reference corresponding to those in the outer triangle described above. Each firm defines its own R & D and industrial strategies and its relationships to the market, as well as its strategy for managing human resources and the division of labor between different categories of actors.

The center of the internal triangle is where the firm's innovation space is created by the interdependencies between the development of a technical professionality and the dynamic of organized creativity .

It is thus at the heart of these multiple relationships that the social constitution of engineers takes place ; as actors in the innovation process, they operate within the cooperative and competitive relationships that they maintain with other categories of actors (technicians, supervisory staff, manual workers, etc.). It is through the processes by which creativity is organized and professionality is socialized and that the professional and social identity of engineers receives its legitimacy.

2-2. International comparative method and societal analysis

International comparisons are now conducted in all the social sciences, and there is increasing interest in them today as a result of the growth of international trade and increasingly strong international links.

Their heuristic significance has made comparisons between countries an instrument for the acquisition of reciprocal knowledge. However, we need to pay attention to the use of this methodology, since it can be implemented in various ways, each of which is based on theoretical conceptions, often implicit, of the notion of comparability .

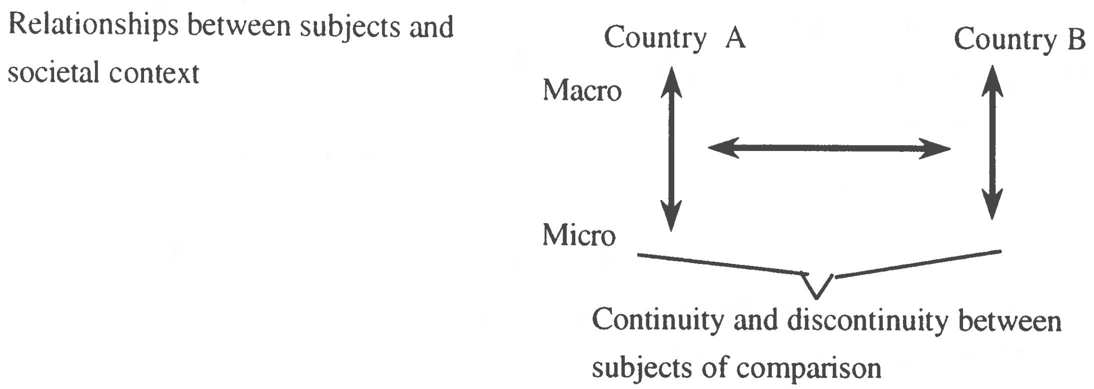
What are the criteria by which comparability is defined? If it is accepted that the aim of any international comparison is to bring to the fore analysis of the national context and the phenomena observed in each country, it is possible to point to two dimensions of analysis on which "comparability" is based.

The first of these is the relationships within each country between the phenomena or subjects observed and their societal context, in other words the relationships between the macro level of analysis (the societal context) and the micro level (that of the phenomena or subjects observed). In this case, the central question is whether these subjects are exogenous or endogenous to the society in which they are observed.

The second dimension is the type of continuity or discontinuity that may or may not be discerned between phenomena observed in one country and those observed in another. In other words, can they be considered sociologically homogeneous or heterogeneous?

It is the combination of these different types of relationships (macro/micro, continuity/discontinuity) that defines the character attributed to "comparability", which in turn reflects the (more or less implicit) theoretical referent adopted.

The following schematic representation summarizes these different criteria for comparability:



As we shall see, there is a logical connection between these criteria, depending on the type of theoretical approach adopted. Without examining these different approaches in any detail here. (Cf. M. Maurice. "Methode comparative et analyse societale", in Sociology du Travail , No.2, 1989, pp. 175-191.,,) We will summarize their main characteristics. Broadly speaking, there are three main types of approach to international comparisons: the functionalist universalistic ("cross national") approach,The culturalist particularistic ("cross cultural") approach, and the societal approach (inter and inter national). A schematic representation of each of these three approaches will be found at the end of each part.

2-2-1. Functionalist universalist approaches

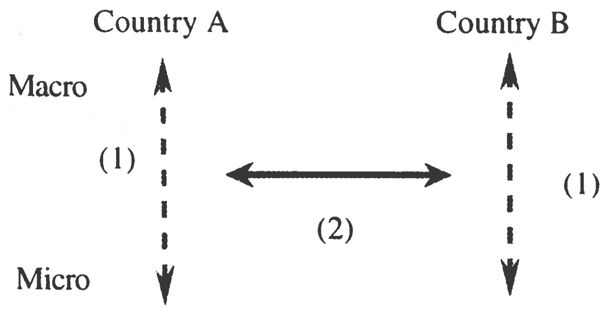
These approaches are undoubtedly the most highly developed in the social sciences, and are based on the functionalist or "rationalist" theories to be found both in certain schools of thought in the sociology of organizations or political science and in neo classical economics.

In this case, the macro micro relationship is not really a central issue . The "country' or "nation" is merely the location of the phenomena observed, and there is no a priori assumption that this context has any effect on the subjects observed.

Comparability is based essentially on a principle of rationality that is compared, term for term , from one country to another. Any differences that may emerge between countries are thus considered as mere residues of the rational "model", or are described as "functional equivalents", which, ipso facto, confers on them the status of "comparability". This type of "rational" approach is very often adopted in order to express opposition to approaches of the culturalist type. Examples of this can be found among both French and Japanese authors, particularly in the debates surrounding the "Japanese model" of the firm.

I. The functionalist-universalist approach (cross national)

Relationships between subjects observed and societal context (levels of analysis)



(1) Absence of analysis between macro and micro levels

(2) strong continuity,term for term,between subjects

2-2-2. Culturalist particularist approaches

The common factor in these approaches is that they contrast sharply with the previous ones in each of the dimensions of comparability as defined above.

Thus "national culture" tends to replace the principle of rationality as a referent, and even forms the basis for the relationship between the macro and micro levels of analysis. In other words, the phenomena or subjects observed merely reflect the national culture of which they are a part .

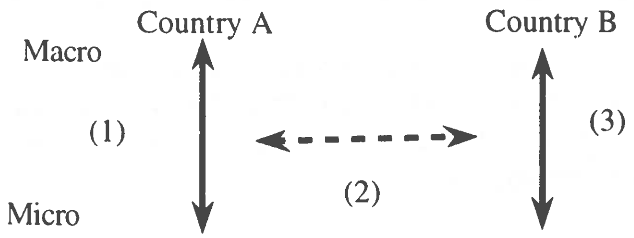
This consequently gives rise to great discontinuity between the subjects of comparison from one country to the next. They are heterogeneous, since they originate within the "national culture" of which they are a part. Both of the approaches outlined above are found in France and Japan, although sometimes in different contexts. Thus in Japan in the 1970s there was a critical reaction against culturalist interpretations of the "Japanese model", illustrated in particular by J.C. Abegglen's book The Japanese Factory: Aspects of its social organization (1958), and the work of sociologists such as H. Mannari and R. March (Modernization and the Japanese Factory , 1976) and economists such as H. Shimada (1983) and K. Koike (1988) (see Bibliography). It should be noted that the culturalist school is still widely acknowledged. It is associated with the Nihonjin ron tradition ("theories" on Japan and Japanese uniqueness), which promulgates a somewhat backward looking ideology in respect of Japanese society. This tradition is also the subject of a certain amount of interest among foreigners.

This Japanese debate is echoed in France, where the "Japanese model" is regarded with a mixture of attraction and repulsion, which does little to enhance understanding of Japanese society.

So how can these opposing positions be transcended? Are we condemned to being either "rationalist" or "culturalist", as if it were possible to be only one or the other?

II. The culturalist-particularist approach (cross cultural)

Relationships between subjects observed anc societal context (levels of analysis)



(1) Strong determination by [national culture]

(2) Lack of continuity between subjects compared,made unique by [national culture].

This dilemma extends beyond the comparison between France and Japan, since it lies at the heart of the debate currently taking place in the social sciences. It is thus hardly surprising that it should surface again in the methodological approaches under discussion here. One way of resolving this dilemma was put forward in the late 1970s by a team of researchers at LEST, Marc Maurice, François Sellier, Jean Jacques Silvestre, Politique d'éducation et organization industrielle en France et en Allemagne , PUF, Paris, 1982 (English translation published as The Social Foundation of Industrial Power, A French German Comparison , MIT Press, Boston, 1986)., in what they called the " societal effect approach " or, more accurately, " societal analysis".

2-2-3. The societal approach (intra or inter national)

This type of approach differs from the two previous ones not by attempting the impossible task of integrating their respective paradigms but rather by shifting the main thrust of the analysis.

Thus the functionalist universalist approach (based on the principle of rationality) tends to "desocialise" the subjects of analysis by assuming that they are homogeneous (or continuous) from one country to the other.

Conversely, as we have seen, the culturalist approach uses the very logic of the principle of "national culture" to put forward the notion that there is a high degree of discontinuity between the subjects being compared in the various countries under investigation.

A device familiar to social scientists is being used in each case: in the functionalist universalist approach it is "undersocialisation", in which the social context is played down, while in the culturalist approach it is "undersocialisation", in which the social context is given exaggerated prominence.

The societal approach, for its part, gives priority to the principle of placing the subjects of analysis in their social context, while at the same time establishing a certain degree of continuity between then in order to ensure comparability.

In other words, compared with the previous two approaches, the societal approach tends to shift the location and status of comparability.

The functionalist universalist approach compares "facts that are meaningless because they have been torn from the system of intelligibility that gives them meaning"; the subjects of analysis are made "universal" and thus comparable because they have been "desocialised".

In the culturalist approach, the subjects of analysis are considered exclusively in their social context, which makes them so specific that they are no longer really comparable. In both cases, therefore, the notion of "comparability" is problematic and limits the usefulness of the comparative methodology.

In the societal approach, on the other hand, non comparability no longer represents a technical difficulty to be overcome ; rather, it becomes the subject of analysis .

The societal approach to comparative analysis is based on a sort of paradox: it seeks to compare the non comparable . To quote J.M. Berthelot's pertinent observation on this approach: "If, term for term, there is non comparability, it is because the differences identified are part of a system of societal interactions that produces them as so many aspects of its specificity", J.M. Berthelot, "Ecole et entreprise" (critical note), in l'Annexe sociologique , 1987, pp. 408 411.,. This is in fact our interpretation of the paradox noted above, the effect of which is to shift the location (or the level) of comparative analysis while at the same bestowing a new status on comparability itself.

However, in contrast to the culturalist approach, societal analysis does not stop at the mere empirical recording of national specificities (it emphasizes rather the processes by which these processes are constructed, which the culturalist approach really does not do). It should be noted here that the historical references used by the culturalist approach in order to take account of the transmission of values over time does not constitute a real explanation. Furthermore, it is remarkable that "culturalism" and "historicism" tend to invoke each other in their common search for the origin and essence of social phenomena.

The aim of societal analysis is to transcend specific national characteristics, even if they provide partial explanations for the differences observed.

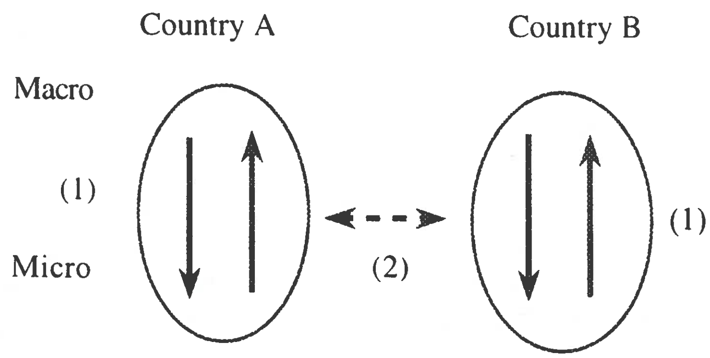
It may be judged that societal analysis, which fully accepts the existence of cultural phenomena and recognizes their importance, leads to an understanding of how such phenomena are constituted in a given society and to the identification of the social processes that contribute to their production and their always limited reproduction.

The relative stability of the "national consistencies" revealed by analysis of the interdependencies between the subjects or phenomena studied and society is interpreted not as a relic of value systems inherited from the past but as a unique form of more general relationships that are part of a given time period and space. In this sense, the "national consistencies" observed at any given moment, far from being the expression of a static "model", reflect the internal logic of a set of potentialities that mutually reinforce each other and provide the basis for each society's own dynamic of change. Consequently, the experiences that each society accumulates in the course of its history are reinterpreted by the actors who constitute it as a set of capabilities in order to define strategies and choices that enable them to confront the new challenges lying before them. Every society develops in this way, not by simply reproducing the past but by configuring its own spaces for action and its own actors through processes of learning and innovation. It should be noted here that this configuration does not make everything possible. It is relatively limited, in that the interdependencies between different dimensions exclude certain social forms to the benefit of others. Moreover, these relationships tend to stabilize partially over time, thus introducing certain rigidities which limit the range of choices that can be made in the future.,. Nevertheless, a society is not an "isolate", imprisoned within its own social construction. Not only does it enter into a multiplicity of exchanges with other societies, but it also participates, in its own way and at its own level of development, in societal groups that share the same forms of economic, political and social organization. And in addition to this empirical observation, each society also participates in societal forms made up of analogous dimensions and structures that are universal in character: family, religion, education, political life, trade, etc... Taking these universal dimensions as its starting point, societal analysis makes it possible to highlight the particular configuration of them within which each society expresses its own uniqueness through its internal and external exchanges. Thus such an approach reflects a particular process of generalization that tends to construct the "general" from analysis of the "particular", proceeding from the "national" to the "societal". One of the benefits of such a comparative approach is that it highlights the (limited) variability in time and space of the societal forms through which the various categories of actors express their own strategies and decisions.

Such variability (or such a configuration) not only encourages understanding of each particular societal group but also leads to more general understanding of the conditions in which societal groups (macro and micro) are established: it can be said that these groups, in their various elements, constitute a universe that is finite in both time and space.

III. The societal approach (intra and inter-national)

Relationships between subjects observed and societal context (levels of analysis)



(1) Strong interaction between macro and micro levels that constitute [national consistencies].

(2) Comparative analysis of [societal groups] in order to reveal both specific characteristics and general elements.

2-3 Some methodological remarks on this report

Based on the methodology previously described, a study was made by the Japan-France Research Team to compare Japanese and French engineers consisting mainly of macro statistical analysis of engineers and of micro analysis of the information obtained from a company survey conducted to find their current state of operation. This report is based on the findings of the company survey, the nucleus of the project, and does not deal with the results of the macro statistical analysis, which will be presented at a different time. From each country two major companies, one from the chemical industry and the other from the electrical machinery industry were selected and surveyed, totaling four from the two countries. The companies selected may not deserve to be called "statistically significant representations" since they were not derived form a strict sample design. However, the fact that each of these companies was a leading business entity in the said industry of the countries under study, we felt, They would reasonably substantiate their appropriateness as samples for a study of the general nature comparing two countries.

With the company survey, it was intended to make a comprehensive analysis by looking at three aspects of corporate activities: the corporate dynamism with respect to technological innovation related primarily to the development of new products; behavioral patterns of engineer groups; and corporate strategic personnel management. To be specific, interviews were held at each company with engineers and the Personnel Department staff. A wide range of engineers at all levels within the company (from the management to engineers active in the first line) were investigated in departmental groups (Research, Development, Production and Sales), and each individual engineer was asked to reply to a set of questions including as to his or hers educational background, professional career, educational and training experience, job organization and performance development. The Personnel Department staff was requested to provide information about the personnel management systems and how they were implemented and maintained, and a variety of statistical data on the particular company were collected. The information and material gathered by the stated methods were compiled into monographs as shown for the four companies after discussions among the Team members.

Micro-level international comparative studies based on methodologies and survey designs like the ones we used have not been widely undertaken. In Japan, attention has been given to comparison with Anglo-American models and little study made to compare the state of Japan and France. For further development of social sciences, more and more comparative studies need to be undertaken. The publication of this report will hopefully serve this purpose.

The last section of this report presents a conclusive but provisional summary of the study with hopes that this will provide the basis for the development of more elaborate study hypotheses.

PART I THE CHEMICAL INDUSTRIES

1. A CASE OF THE FRENCH COMPANY

1-1. PRESENTATION OF THE FC COMPANY

This part will seek to characterize the subject of our investigation, namely the firm and its environment, to describe the organizational actors in the innovation cycle and, finally, to present the human resources available to the firm.

1-1-1 THE CHARACTERISTICS OF THE SUBJECT UNDER INVESTIGATION

The chemical industry, and the French chemical industry in particular, is sufficiently specific and significant for its particular characteristics to be taken into account before an individual firm is investigated : the chemical industry differs from other industrial sectors because it has a strong identity that in itself explains some of the phenomena found in any particular firm.

a. La chimie

The French term "chimie" can be translated both as "chemistry" and as "chemical industry" ; this ambiguity, which is not shared by the English term "chemistry", means that the French term is a common referent in the worlds of industry, education and science. It denotes a jointly constituted and delimited sphere (school of chemistry, public laboratory, firm) and, in so doing, reinforces the interrelationships between the various spaces of which it is composed (industrial, scientific and technical, educational). Thus university and other public-sector researchers will look to industrial firms, while production engineers will base their work on "science" ; the scientific sub-disciplines will permeate firms, while product line management will permeate laboratories and schools. The different spaces pervade each other, leading in particular to an expansion of the space denoted in English by the term "chemical industry" and making it possible to understand the relationships between that industrial space and its environment.

The chemical industry is a process industry, described particularly aptly by F. Vatin ([1]) as an "industry of flows". The production process is continuous : production takes place in a more or less complex way within an industrial plant, but without any direct or obvious human intervention. Such intervention does occur upstream of the production process, in the preparation of the plant, the introduction of raw materials into it, the ordering of the product and the control of the process, but subsequent human intervention is associated largely with maintenance and safety ; to quote F. Vatin : "It is

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[1] *La fluidité industrielle. Réponses sociologiques. Méridiens Klincksieck.*

not a question simply of the marginalisation of work within the productive space but of a real reversal of the relationship between work and production : work is no longer proportional to production. On the contrary, the relationship is an inverse one, since it is only when production stops that human beings intervene". It follows from this that an increase or decrease in production does not have a direct effect on labor costs or on the intensity of work, although such a variation may bring about a change in the organization. The type of actors in such a process will also be different from those encountered in an electrical or mechanical industry, for example ; thus the role of the engineer in this type of impenetrable, totally automated workshop will be highly specific. Nevertheless, it is important to stress that this type of production, based on flows, and the specificity's arising out of it, are tending to spread with automation beyond the chemical industry to manufacturing industry as a whole.

The chemical industry to which we are referring is that of the large conglomerates which manufacture intermediate rather than finished products. This sector is not in direct contact with any great "mass" market but with a producer market in which its products are used as raw materials in the manufacture of other products. The firms making the finished products are generally smaller ; they sometimes require a particular intermediate product that is specific to their production, and in that case they are often in the position of being the large firm's sole outlet for that type of product ; conversely, of course, they may be dependent on a single producer for their raw materials. Their roles and strategies will influence the cycle of product innovation.

b. The chemical industry in France : its position, structure and specificity

• The French chemical industry is the fifth largest in the world ; in France, it is one of the leading industrial sectors. The growth in its output between 1980 and 1988 was very considerably greater than the overall growth in industrial production ; this positive evolution can be explained by the greater share of chemical products in industrial products, particular of plastics. This type of growth is particularly dependent on the general state of the economy, and so the rate of growth has tended to slow down since 1988.

The basic chemical industry accounts for a large proportion of the French chemical industry as a whole. Its profitability is subject to wide variations, although profits are usually substantial since low margins are offset by the large volumes produced. The sector remains fragile, and is particularly sensitive to fluctuations in raw material costs and the widening of competition. At the moment, for example, world production of ethylene has almost reached the stage of overcapacity at a time when demand for plastics is falling and the countries producing the raw materials are getting ready to enter the market. Within the French industry, this fragility has led to the development in recent years of a specialist chemicals industry (fine chemicals, "chimie d'application"...) in an attempt by firms to bring their product ranges back into balance. This trend is also to be found at world level, where chemical firms are trying to free themselves from "commodities" - bulk products sold at low prices - in order to develop "specialities" that are considered much less vulnerable to economic circumstances ([2]) ; however, at the present time (1989-90), while the basic chemical industry remains vulnerable, the specialist products traditionally produced in France have seen a considerable decline in sales ; nevertheless, these specialities are still considered to be a sector for the future. In 1990 the only buoyant segment of the French chemical industry is pharmaceuticals : the growth rate of 2.4% for the industry as a whole is based on growth of 8.9% in the pharmaceuticals segment.

• This sector is structured by large firms (69% of turnover is produced by firms with more than 500 employees ([3])) belonging to the sector that is nationalized or controlled by the state. The homogeneity of industrial policies in the sector is explained by the fact that the basic elements of industrial strategy are decided by the government in a quasi-technocratic manner. Through the intermediary of the Ministry of Industry, government policy is expressed in terms of a dual model :

* French firms are too small to compete effectively against the large German, American and British firms ; it is therefore necessary to concentrate the national effort on a few groups specializing in a limited number of products.

* French firms suffer from a lack of capital. The market is unstable, and it is therefore in the interests of the state, as shareholder, to link the chemical industry to other, less fragile sectors. "In a world context characterized by increasing concentration, the merging of certain groups of chemical firms and their attachment to the oil firms has emerged as the only credible response to the development of the world market" Government statement, 2 January 1990 ([4]).

Thus the state is going to apply itself to the task of refocusing activity in the chemical industry, which is going to lead to a permanent, possibly endless restructuring of the sector : 1983-1988-1990... This policy of rationalization and specialization is being imposed from outside upon the sector ; its aim is to limit competition in the domestic market in order to improve the competitiveness of French firms in Europe. This policy is leading to the construction of industrial groups as independent territories that do not compete with each other ; this is strengthening the sector within a "chemical" industrial space which gives coherence to the whole set of divided, but not necessarily energized firms/territories.

Most of the managers of these firms are direct products of the state technocracy, placed in charge of an industrial territory in order to manage it in accordance with the policy laid down for the sector. Very few have had long careers within the

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2 *Usine nouvelle, 7 March 1991*

3 *L'industrie chimique et pharmaceutique française dans la perspective de 1992. Documentation française.*

4 *Libération, 3 January 1990.*

firms they manage, although a not inconsiderable number of them did spend some time in the firm before taking up their duties.

• The identity of this space is more significant than those of the individual firms, which are more or less durable or shifting. It is the principal referent of the various actors involved ; thus a considerable number of the engineers currently employed by A began their careers in the same speculums, possibly in the same factory, which at that time belonged to R or T, although they have not changed employer. There are many similar career paths which often join up with each other ; as a result, workers often see themselves as part of the chemical industry rather than as an employee of a particular firm.

c. FC COMPANY : its position, strategy and specificity

FC company(5) comprises the larger part of the chemicals output of a large oil group E, of which it is a wholly-owned subsidiary ; the activities of this group are divided into three sectors :

* hydrocarbons, which covers the exploration, production, refining and distribution of petroleum products ;

* health, beauty and biological products ;

* chemicals, which comprises mainly FC company and some American subsidiaries.

These sectors have a great deal of autonomy, although this does not preclude possible intervention by the "group" if one or other of them experiences difficulties. Thus the share of each sector in the group's net results varies considerably.

TABLE 1-1 NET RESULTS (source : financial report)

	Hydrocarbons	Chemicals	Health	
1986	84.2	5.3	10.5	100 %
1987	64.0	10.5	25.5	100 %
1988	19.5	76.0	19.5	100 %
1989	75.0	5.6	19.4	100 %

Financial report 1989 - E

In 1988, hydrocarbons received support from the group, while in 1989 and probably in 1990 it was the chemicals sector's turn to be propped up.

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5 *FC company is the chemical company studied; it is a subsidiary of oil company E, and in 1990 it assimilated the chemicals and fertilisers side of group O's activities.*

Overall, the share of chemicals in total group sales is increasing :

TABLE 1-2 EVOLUTION CHEMICALS IN THE GROUPE

	1985	1986	1987	1988	1989
Sales of chemicals	18.0	19.7	21.1	26.1	26.1
Group sales	100 %	100 %	100 %	100 %	100 %

Financial report 1989 E

Like other firms in the sector, FC company has been built up gradually through a series of restructurings in 1980, 1982, 1989 and 1990.

In 1981, group E, the sole shareholder in two chemical companies that had not yet totally recovered from the 1980 restructuring, had no desire to incorporate another nationalized company, or even merge the two companies it owned. Nevertheless, the government designated it the "main pivot of the restructuring of the French chemical industry". The oil group was able only to insist on there being a certain degree of coherence in terms of product line and to lay down certain financial conditions.

At the end of the negotiations between the state and the industry, the newly constituted FC company had to readjust its portfolio of activities and rationalize its product range. It adopted a policy of reducing the share of basic chemicals and increasing production of specialist products ; as a result, it was forced, product line by product line, plant by plant, to eliminate overcapacity, duplicate jobs, marginal products with no direct links with its main product lines and even obsolete, unprofitable processes. As a result of its "attachment" to the oil group, FC company was able to rationalise without requiring additional government funds and in accordance with government strategy.

By 1988, the restructuring had been successfully carried out, and with an upturn in the economy good financial results began to appear. In 1989, however, the government launched a new reorganization of the chemical industry, of which group E was once again to be the "pivot". As before, FC company is going to have to rationalize, product line by product line, close down plants, etc. As before, the employees of the "losing" companies incorporated within FC companywill suffer "great disillusion", while the company's established employees will fear for their jobs. At no time before the decision was taken was the human cost of these restructurings, the cost to the firm and its employees, so much as mentioned, at any level at all ; management of the human problem and the merging of the work forces is organized after the event, "in a crude fashion", by making plants and individuals compete with each other, and waiting for the "best one to win".

Like the French chemical industry as a whole, the chemicals division of group E is seeking to increase its production of specialist products and reduce its reliance on basic chemicals, all the more so since the latter was strengthened in 1990 by the assets of company O when it became part of FC company: "Our petrochemical products depend on the motor vehicle market (currently in a downturn) but also on construction (fairly stable) and packaging (always buoyant)". Chairman and MD of A (6). "Commodities" have national or European markets, whereas "specialties" have world outlets linked to exchange rate fluctuations ; despite this, the strategy has not been changed :

TABLE 1-3 TURNOVER CHEMICALS

	1987	1988	1989
Petrochemicals	30	29	28
Chlorochemicals	22	23	22
Chemicals and polymers	36	36	40
Downstream	12	12	10
total	100 %	100 %	100 %

Within these choices, the firm is pursuing a policy of specialization in specific market niches and products. The logic of government policy means that it has little domestic competition in the "territories" that are its preserve. This territorial logic has hitherto been of particular importance in the specialist chemicals market, but with the arrival of part of company O, followed by a new policy of rationalization and specialization in basic chemical products, this logic may be extended to the firm as a whole, because of the stability of the clientele.

The importance attached to research and development in the interviews is not reflected in the ratio of R & D expenditure to turnover, which was 2.9% in 1986 and 2.3% in 1989. The figure for the sector as a whole is 5.5% (7). Moreover, the various actors involved in research stress the difficulty of introducing radical innovation - new products - and the need to complete improvements to production processes.

FC company is trying to combine internal and external growth. Thus in 1989, petrochemical production capacity was considerably increased as a result of a major investment program, and new capacity for the production of CFC is planned for 1991. At the same time, however, the firm acquired an American company in order to increase its share of the American CFC market. It would seem that from year to year a certain balance is maintained between these two types of growth, without one being abandoned in favor of the other.

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6 *Usine nouvelle, March 1991.*

7 *L'Industrie chimique et pharmaceutique dans la perspective de 1992. Documentation française.*

At the beginning of this part, we said that "la chimie", with its dual meaning of chemistry or chemical industry, had a stronger identity than the companies within the sector. Group E also has a higher profile than FC company, which is a composite subsidiary, a collection of "territories". For this reason, the firm is going to try to create its own unity, but it cannot use the notion of "vocation" as a catalyst, since it is identified with the industry as a whole. It is attempting to introduce a firm culture, but has had little time between two restructurings for developing either coherence or cohesion.

1-1-2 DESCRIPTION OF THE ORGANIZATIONAL ACTORS IN INNOVATION CYCLE

Our first task will be to describe the organization of FC company ; we will then locate the main sites at which our research was carried out within that organizational framework.

a. The organization of FC company

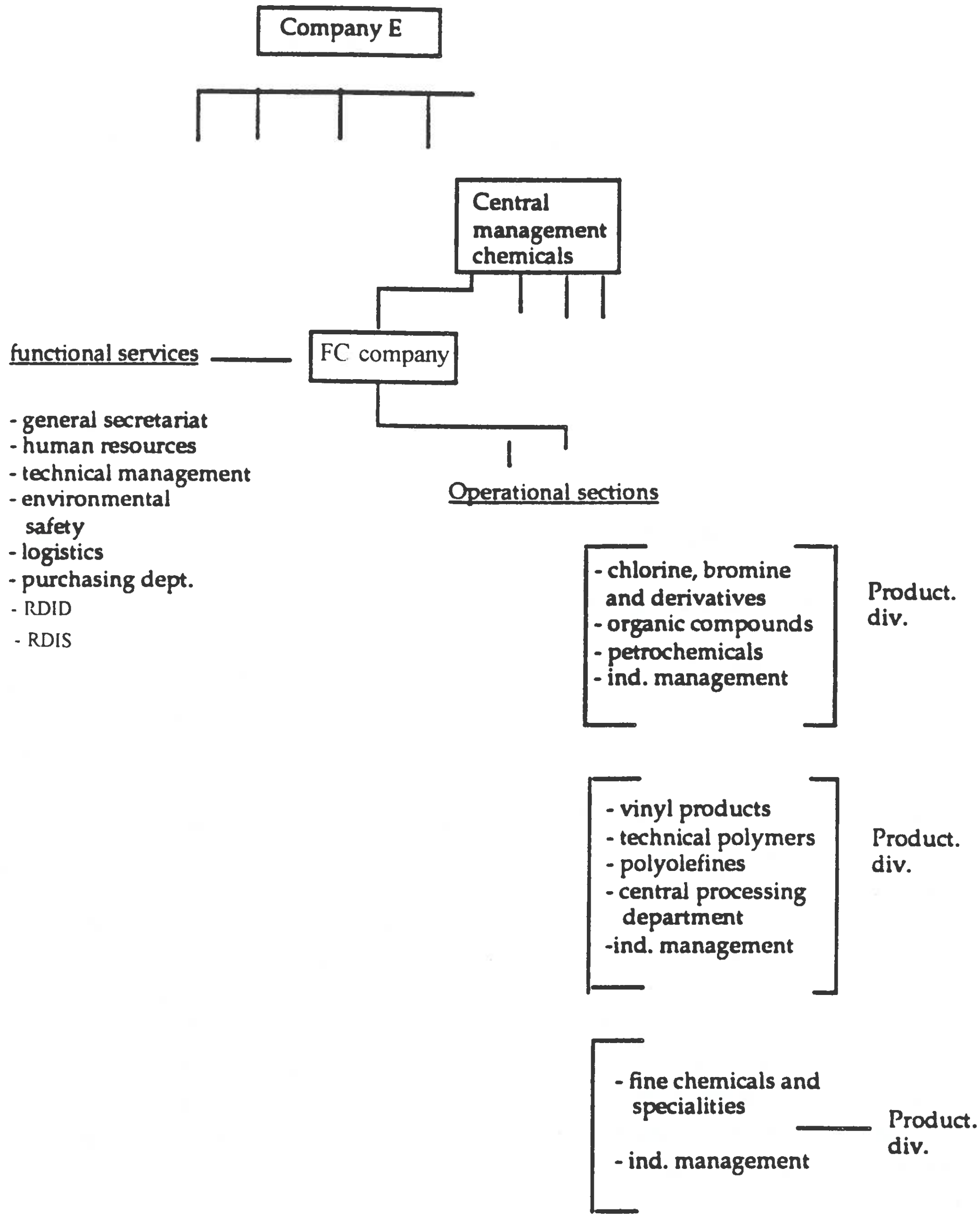
The company's organization is based on a so-called "rake" system, which is divided into :

- functional services : human resources, logistics, technical services and research and development and innovation, which report to one of the assistant directors or directly to the chairman and MD ;

- operational sections, three in all, under the supervision of the assistant directors : basic chemicals, plastics and processing, and fine chemicals and specialties. Each of them includes one or more product divisions and an industrial management department (cf. Figure 1-1). The product division plans the development of the product line, lays down objectives, initiates research and finance and deals with the purchase of raw materials and the sale of the finished product. The industrial management department manages the plants, production processes and the work force. Thus the product division "encircles" the industrial management department, operating both upstream and downstream of it. Their respective responsibilities are strictly defined. For the research center and the manufacturing plant, "the product division" is the customer ordering the product : it represents both the customer and the product markets, provides information on the state of competition, the evolution of demand, etc. It is those in charge of the product division who, on the basis of developments in the markets and in the competition, initiate new products or modifications to existing products, monitoring its progress and taking responsibility for it until the point at which it is marketed.

This organizational structure leads to areas of "vagueness" and "disorganization" at each of its various levels. The functions of each service or section are not totally defined ; responsibilities overlap, and there are even areas for which no part of the organization has responsibility. This system is likely to enable the actors to assume their place and function, but does little to make the real functioning of the firm transparent to the various actors. Thus the role of the product division is not always understood by them.

FIGURE 1-1 The organization of E and FC company



The research, development and innovation service (RDIS) reports directly to the firm's managing director. It seems obvious to everyone that management "treats research fairly well" ; of the 10,000 people employed by FC company, 1,000 (10%) work in this area. The function of the RDIS is to monitor the potential for innovation both within the firm and outside and to develop a dynamic research and development policy that is integrated into the firm's industrial strategy : between 80 and 90% of research is financed and carried out by the operational sections. The research managers are experts in the "scientific market", both inside and outside the firm ; their task is to cover the firm's three main operational sections as well as some of these strategic themes. They are career researchers, specialists in a particular scientific area ; they provide the link between the firm's various laboratories in their specialists, and with research outside the firm (public sector research, other private research, international research). They coordinate and orientate the research needs expressed by the "market", that is those in charge of product development. These research managers also play a part in stimulating new research not arising directly out of the market and in supporting researchers' own initiatives ; 10 to 20% of the research budget is financed by the RDIS for these purposes.

The RDIS is directly responsible for three research centers. The first of these, the CA, is a research and development center that concentrates on applications ; the other two concentrate on different scientific areas, the CE on polymers and the CR, which is our concern here, on catalysts, mineral chemistry (ceramics, halogens, hydrazines, phosphorous, oxygenated products), fluorinated polymers and organic synthesis.

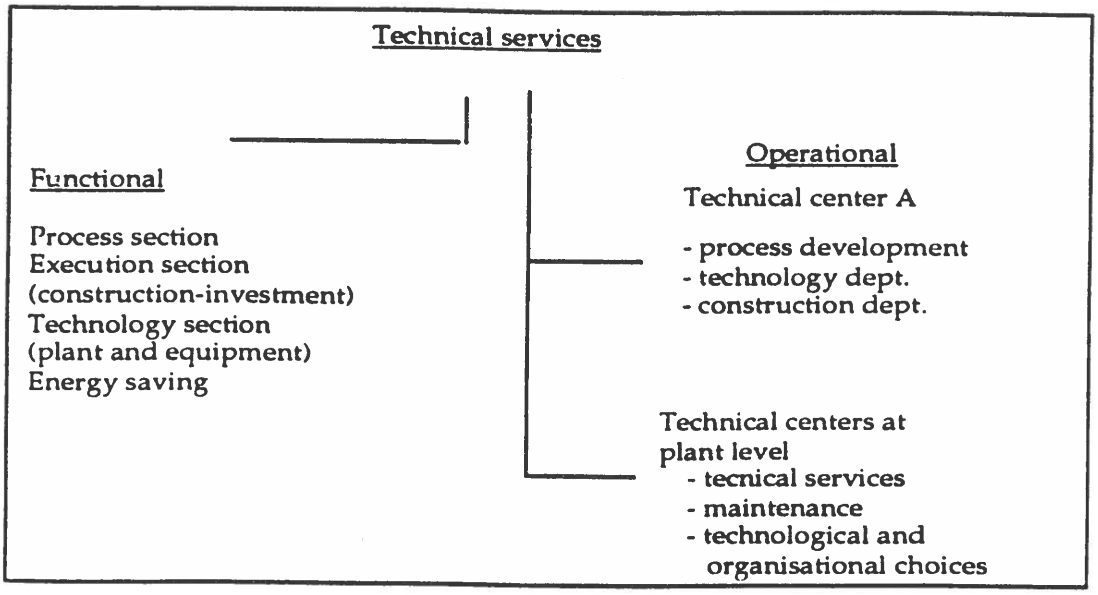
A proportion of the funds available to the RDIS is reserved for financing collaboration with the "world of science and technology" (research contracts, secondment, etc.). Although significant, this part of the budget is small compared with the investment in research within the firm.

Company E and its subsidiary chemicals firm have not organized their research around a central laboratory, in order that research can, to a large extent at least, "be guided by the market". It may also be that this type of research is more obviously necessary in the chemical industry.

The technical service is the "guardian of all the manufacturing processes in the firm (**director of technical center**). It is responsible for process development, the construction of production plants on the basis of those processes and for monitoring the implementation of processes in production plants. It is centralized, studies all technical investment in close cooperation with the research services and works essentially with the manufacturing plants. The construction service is the "project manager" for all new plants in the firm, and is responsible for that budget ; it monitors progress at construction sites through the intermediary of the "construction" section of the technical center. The process section is responsible for the choice and development of processes at the technical center, in production plants and sometimes even in pilot plants (which report to the factory manager, but on the basis of plans drawn up by the technical service). Thus the technical center is the operational heart of the technical service, although in discharging its responsibilities the TS also uses certain plant-level departments. Thus the technology manager uses the technical center department of the same name as well as the technical and maintenance service at plant level in order to keep a check on the firm's technical installations.

Responsibility for managers is centralized in the Human Resources Service, while other categories of employee are managed at plant level. The degree of independence from head office varies depending on sector and type of function (research, technical services, production...).

FIGURE 1-2 The organization of technical department



b. The units studied

Within this organization, we decided to investigate units that would give us a better understanding of the product innovation cycle. We thus attached ourselves to an industrial location that enabled us to observe this process in a research center, in the technical center and in the production unit (cf.Figure 1-3).

Each of these three units has links with the others, but is also dependent on the links it maintains with its environment. Thus the research center, which is connected through the hierarchy to the RDIS, participates in the scientific and technical space through its links with basic research, for example, as well as in the industrial space, since these activities are also generated by the group's strategy vis-à-vis the market. And the recruitment policy it adopts connects it to the educational space, the labor market etc.

A - THE RESEARCH CENTRE

There are currently 300 employees in the center, 64 of whom are engineers. It is headed by a director and a deputy director who, together with the administrative director, form the "management team". This team is made up of "researchers" rather than of research administrators.

The research center is made up of specialist research laboratories, operational sections and sections known as "functional services" and "pilot section". Each of these sections has its own head. These heads of section are themselves researchers, experts in their own fields, and sometimes described as such ; from our interviews, it would seem that their role and position between management team and researchers are ill defined.

The center is made up of six research laboratories : inorganic and electrochemistry ; physical chemistry ; organic chemistry ; fluorine derivatives ; fluorinated polymers ; dielectric. They vary widely in size - 43 people in organic chemistry, 5 in dielectric - and their form changes depending on the strategic importance of the research being conducted (considerable increase in numbers in the fluorine derivatives laboratory at present). They may also be abolished or regrouped (the electrochemical laboratory has merged with inorganic chemistry). Each laboratory is itself made up of several research teams, each one containing an engineer and between one and three technicians and working on a well-defined type or range of products.

These laboratories use various services provided by the center :

• The information service is responsible for the center's general documentation and for providing information on patents and old technology for the firm and the center. The documentation is concentrated in the firm's own data banks and also provides access to all the data banks within the same discipline ; the data banks are consulted through the intermediary of a member of staff in the information service, with most requests made by heads of section, although all researchers have access. The technical reports and vocabulary generated by the center are stored in the firm's documentation. The information on patents is provided mainly by subscription, on specific subjects and by request from researchers : the engineer in charge of this work scrutinizes all the patents that emerge, or should emerge, arranged by subject from an international data bank : "my work consists of detecting these patents and sending the information to correspondents chosen according to the subjects of interest to them" IIR.

• The analytical laboratory has the task of identifying a molecule or a product. It provides services for the other laboratories in the center and for the firm as a whole ; these services involve a system of internal invoicing. The laboratory offers its customers analyses based on different techniques, depending on the nature of the problem ; the results are returned to the commissioning laboratory, which may possibly request that the investigations be continued. All the identifications made on a piece of apparatus, a mass spectrograph, for example, "are stored on computer" IIR "We can send a query to the library when we have our spectrum on the machine, the

FIGURE 1-3

VISUALIZATION OF THE ACTORS IN THE ORGANIZATION

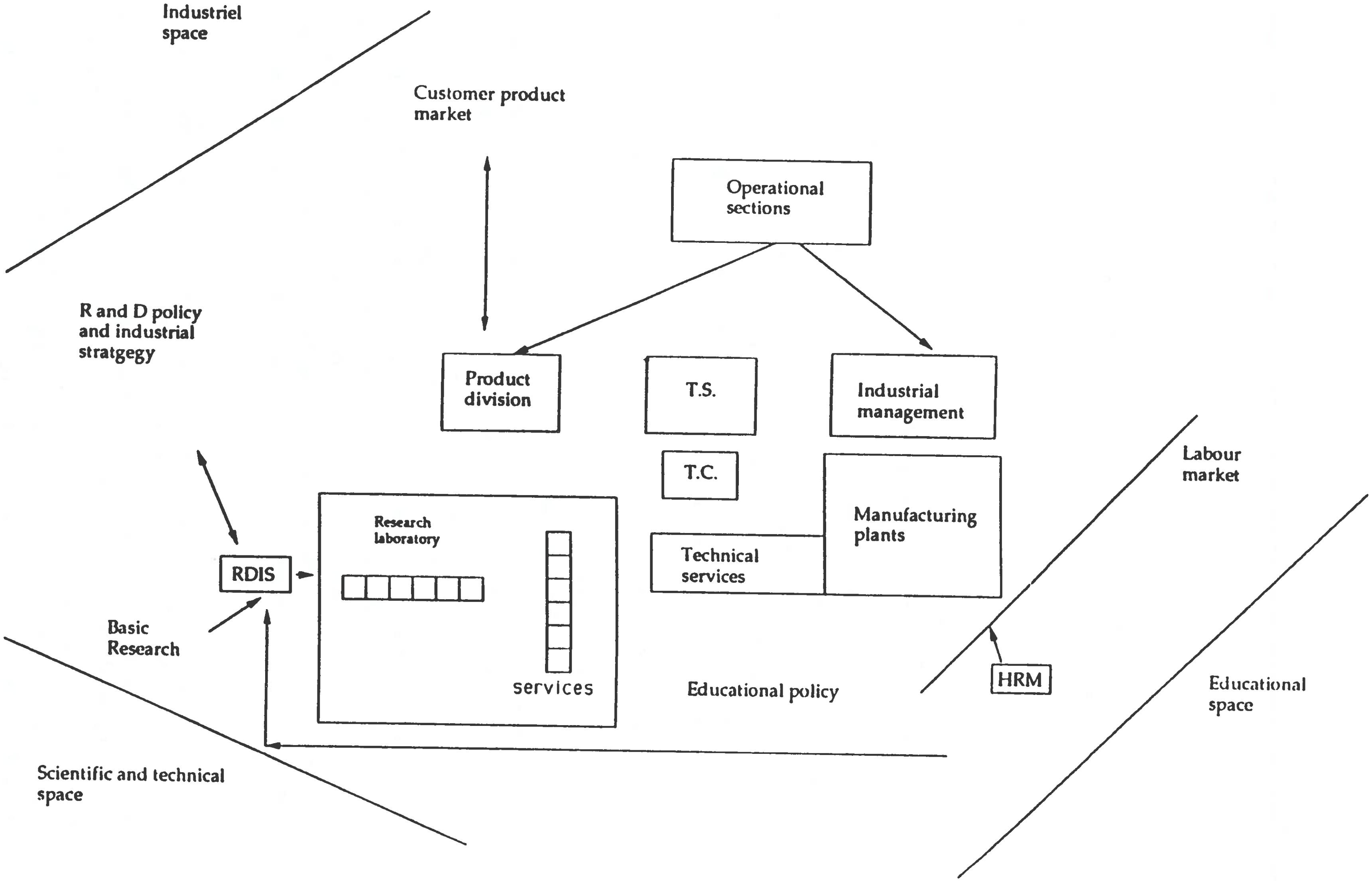
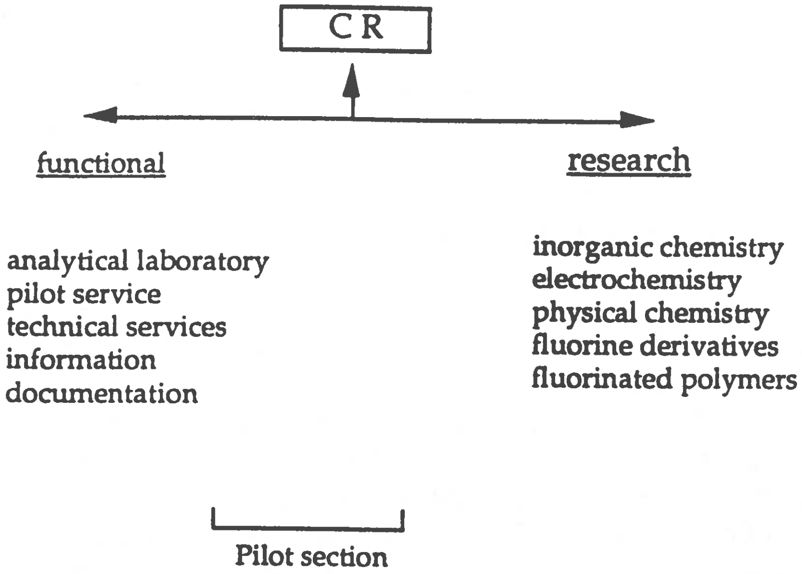


FIGURE 1-4



manufacturer's data and our own, and if we identify a new product its spectrum can be stored in the machine data bank" IIR. Some sections, such as fluorine derivatives and the pilot service, have their own small analysis department, which enables them to carry out simple identifications rapidly.

• Technical services (26 employees) is linked hierarchically to the pilot service. It is responsible for both the maintenance of the center (boilers, pipework, mechanics, adjustments, electricity...) and the installation and connection of certain pieces of apparatus (for example, the fluoridation beds in the fluorine derivatives laboratory) ; there is also an electronics laboratory and a planning office.

• The pilot section is half-way between an operational unit and a functional department ; it takes part in research, but is also used by all the laboratories in the center. "The feasibility of carrying out a chemical reaction in the laboratory is not in itself sufficient for a complete assessment of the industrial viability of a process ; it is the pilot section's job to be a reducer of uncertainty by enabling the actors to express themselves not "confidentially" but within the setting of industrial reality" **Revue Positif**. "The pilot section in I no. 11". The pilot section repeats the chemical reaction on a larger scale for two reasons : "when a sample batch is needed, and if the process discovered during research is a good one for which the firm might possibly wish to set up a manufacturing unit ; the pilot section is used to see how it would work" **IIR**. The pilot section checks the results obtained in the research laboratory in conditions that are less exceptional but not yet those found in a manufacturing unit ; it clarifies the knowledge obtained and may start "production". "The pilot section is asked to define the industrial reactor, or at least to study the reaction in a specific piece of apparatus and to define the physical rules, so that the results can be extrapolated on a large scale" **I IPi**.

There are four pilot teams in the R.C., each headed by an engineer ; each team also has one or two technicians and two or three operators. There is also a team responsible for process safety and a small analytical laboratory. "There are usually two pilot teams that alternate continuously, one for each campaign and one that is being wound down..." **IIPi.**

B. THE TECHNICAL CENTER

The center is part of the technical service and is located near the research center and FC company's factory (D). It employs 210 people (70 engineers, 110 technicians and 30 clerical staff) and is responsible for the firm in charge of building new industrial installations (800 million francs' worth of investment and 600,000 hours of design work and planning, carried out directly or by sub-contractors). Its function is to enable "products to be developed in cooperation with the research departments and the various divisions" **Director of the TC**. It provides technical assistance for manufacturing plants : "when a plant has been installed, we provide the technical assistance ; our experience and our monitoring of plants means we can suggest improvements for future installations" **Director of the TC**. The center has three departments dealing, respectively, with processes, construction and technology.

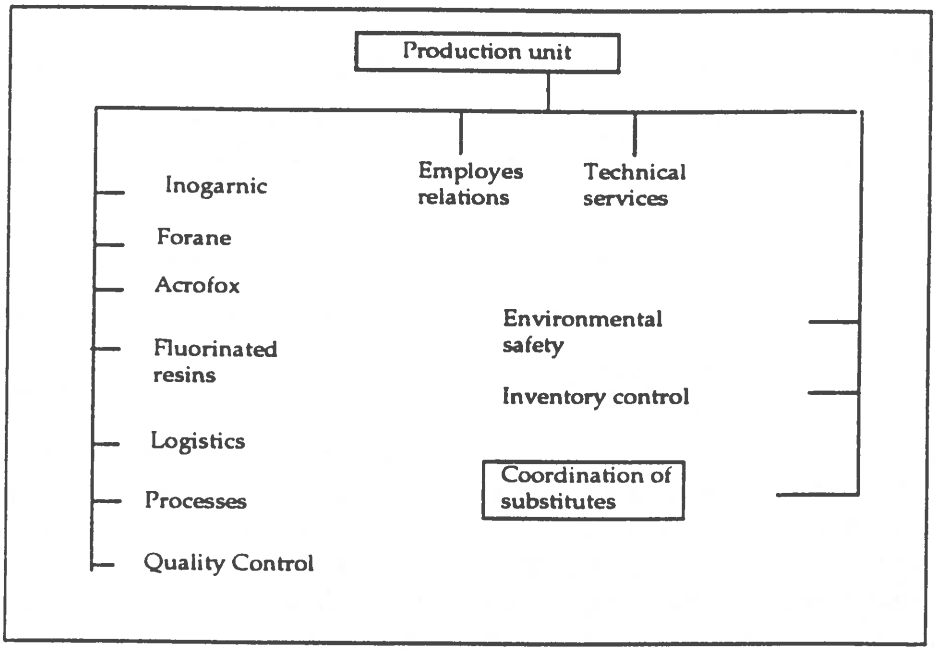
Whereas the pilot section's task is to confirm the feasibility of an innovation on an industrial scale, it seems to us that the process department is responsible for organizing the introduction of that innovation once management has decided to implement it. "Our project study work enables us to design the machines and to indicate and assess the problems that may arise", **IIR**. The installations thus defined are built by the construction department.

C. THE PRODUCTION UNIT

This factory is part of the same establishment as the research center ; the production unit, laboratory and pilot section interlock on the same site. The production unit employs about 850 people, including 45 engineers and managers. It is a major producer of sulfuric acid (85% of total French production), but it is turning increasingly to the production of fine chemicals and "specialties", particularly fluorine compounds and products derived from oxygenated water.

The director is assisted by a management team made up of the deputy directors in charge of the operational sections, the logistics service and the process development and quality control departments, the head of employee relations and the head of technical services (construction, maintenance, repair) ; there is also an environmental safety group, inventory control and a group set up to coordinate the "substitutes" project. There are four operational sections : inorganic chemistry, Forane, Acrofox and fluorinated resins.

FIGURE 1-5 The organization of production unit



Each of these sections is run by a head of section and includes several production lines ; the production engineer supervises one or more of these lines. The factory produces small quantities of highly specific intermediate products (fine chemicals), although they are catalogued, stabilized and marketed to a known clientele. The production lines are thus multiple, relatively small, flexible and coordinated.

The internal organization of the whole establishment changes considerably over time and varies from section to section ; production line organization, in particular, constitutes a permanent problem for the various actors involved. We will examine this aspect in greater detail in Part Three, when we will attempt to clarify the type of division of labor and cooperation in the innovation cycle. Nevertheless, two tendencies should be underlined at this point :

a/ The type of orientation found in the product lines was applied a few years ago to the factory as a whole, at the request of the people in charge of product development and sales. The purpose of this was to make the product more visible and to make production staff understand the logic of the market. The head of the fluorinated resins section (FRS) has been reconsidering this type of organization because "the business of producing monomers is different from that of producing polymers" and because in each product line there are several marketable products and thus the market logic is not necessarily the same :

Thus Forafax (a monomer) is both a marketable product and an intermediary in the production of Foraperle (a polymer). The debate that has grown up around these two types of solution is one of the important issues between the actors to which we will return later.

TABLE 1-4 SIMPLIFIED PLAN OF FRS PRODUCT LINES

	MONOMER	POLYMER
1. Product line 141 B, 142 B, VF 2 Trichloroethane------	FC 142 B -- VF2	PVDF---Forablon
2. Product line 22$ C2 F4	RFI-- Fora Fax--	Foraperle

b/ It seems there is a desire on the part of management to homogenize the various forms of technical management, to rationalize them and make the production line pure, smoothing away any rough edges. Thus the small analytical laboratories that exist in most sections, usually managed by a technician, are to be merged into a central laboratory ; similarly, all production engineers, together with the design engineers who used to work alongside them, making modifications and innovations to the production lines, were integrated several years ago into the "process development department", although even within this structure particular engineers are allocated to the various production lines. Even longer ago, each section had its own maintenance and works departments ; this function is now the responsibility of the Works and Maintenance Service, which is organized according to "zones" of intervention covering the operational sections. Similarly, safety and environmental matters, which were one of the production engineers' responsibilities, are now a separate function and a section in their own right.

We shall see that his policy also plays a part in the construction of certain types of engineer (cf. Part Two).

1-1-3 PRESENTATION OF THE COMPANY'S PERSONNEL

Most of the data analyzed in this document relate to the position as at 31 December 1989, before the restructuring of FC company and the arrival of part of company O. We will briefly survey the personnel figures for group E and then those of FC company before examining in greater detail the engineers employed by FC company.

1/ The number of people employed by group E was 78,000 in 1978 (an increase of 8.3% over 1988) ; the recruitment figures for 1989 take account of most of the new foreign acquisitions and the need for managers.

Hydrocarbons account for 35.6% of the group's work force, chemicals 32.4% and health 27.9% ; more jobs have been created in the last two sectors than in the first, in accordance with the group's overall policy.

2/ FC company has 10,000 employees distributed as follows :

TABLE 1-5 Distribution of employees

	Men	Women	Total
• Engineers and managers	1145	120	1265
• Technicians and supervisory staff	2973	737	3710
• Manual workers and clerical staff	4363	629	4992
	8481	1486	9967

Company Report 1989 - A

The trend seems to be towards the employment of more highly skilled personnel : there has been a decrease in the number of manual employees relative to technicians and supervisory staff.

TABLE 1-6 Evolution of employees by category

	1987	1988	1989
• Engineers and managers	11.8%	12.2%	12.7%
• Technicians and supervisory staff	35.5%	36.4%	37.3%
• Manual workers and clerical staff	52.7%	51.4%	50.1%

Company report 1989 A

In 1989, average gross annual pay in FC company increased by 5.5% from 13,076 F to 13,797 F, while the profit-sharing bonus rose by 5.7% from 2480 F to 2625 F. The pay scales for engineers, techniciand and manual workers remain highly differentiated :

TABLE 1-7 Distribution of gross annual pay by occupational category in 1989

350	329	329		
350-300	288	262	6	
300-250	246	213	33	
250-200	642	197	442	3
200-150	2574	58	1844	672
150-120	3344		1041	2303
120-100	1366		99	1267
100-80	278		9	269
80-70	7			7
Pay 1000 French francs	All categories	Engineers/ managers	Technicians/ supervisory staff	Manual workers/ clerical staff

Company report 1989 A

The increase in pay has tended to narrow the gap between executive workers and non executive workers ; on the other hand the gap between technicians and engineers increase..

TABLE 1-8 Evolution and distribution of average gross monthly pay by occupational category Company Report 1989

	1987	1988	1989	89/87
Engineers and managers	24.881	25.841	26.914	8,17 %
Technicians and super-virory staff	12.711	13.225	13.759	2,24 %
Executive workers and clerical staff	9.553	10.017	10.675	11,74 %

Moreover, the system of human resource management clearly separates these two categories : technicians and supervisory staff are managed, as we have seen, at local level, along with manual workers and clerical staff, whereas engineers and managers are managed from head office. There is little movement between the non-managerial and managerial categories : only 11.4% of the latter group have no formal qualifications. Although management states that the promotion rate from one to the other is 5% per year overall, it seems to us that movement is less difficult in the administrative and commercial sections than in the technical functions

TABLE 1-9 DISTRIBUTION OF ENGINEERS AND MANAGERS WITHOUT FORMAL QUALIFICATION

	Proportion of engineers and managers without formal qualification
Industrial sections	8.2 %
Product management	18.7%
Technical services	7.48 %
Research services	3.0 %
Administrative services	17.0 %
TOTAL	11.4 %

This extreme separation between engineers and technicians and the lack of data on this latter category makes it impossible to carry out a general analysis of the actors in the technical sections, forcing us to concentrate on the engineers.

3/ Engineers in FC company are distributed as follows between the various sections.

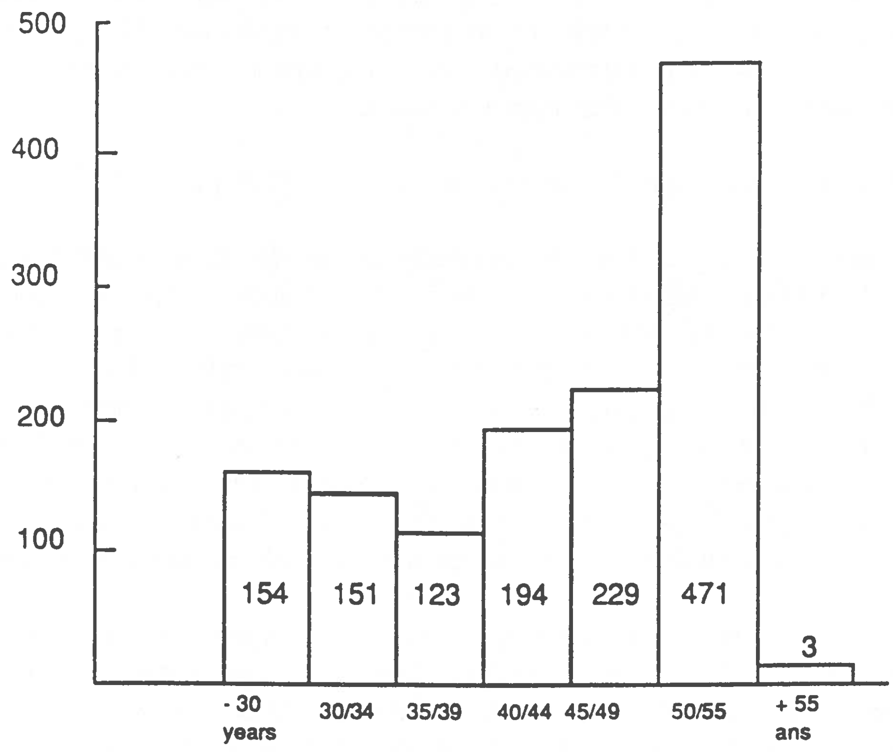
The technical sections directly involved in production, that is research and technical services proper, contain 59% of the engineers employed by the firm. However, it can reasonably be assumed that a not inconsiderable proportion of the engineers in the product divisions, which are responsible for project management, should also be included in this category. On this basis, the various technical sections in FC company contain between 59% and 82% of all the engineers in the company.

TABLE 1-10 Distribution of engineers by section

	Industrial sections : MANUFACTUR ING		Product sections PLANNING MARKETING	
	33 %	+	23 %	= 56 %
Basic chemicals				21 %
Fine chemical				8 %
Plastics				27 %
Technical section				11 %
RDIS/Innovation				15 %
Other sections : sales, HRM, administration				18 %

The average age in the engineer and manager category is high at 44.03 years : moreover, the age pyramid shows a relatively small number of engineers in the 35-39 age group and large number in the 50-55 age group.

FIGURE 1-6 The age's pyramid of engineers



This age profile is going to have serious consequences for the technical sections in the firm in the years to come : when those in the 50-55 age group (35% of the engineer category) retire, they will not have ensured the reproduction of their function since the age group below them is smaller in number. It should be noted that the under 30 age group accounts for 11.6% of the engineer category in the firm as a whole, but for 14% of the category in technical services and the RDIS. A comparison of direct entries by career path between 1985 and 1989 confirms that there has been a bias in favor of the sections expected to produce innovations :

TABLE 1-11 Distribution of direct entries by technical path between 1985 and 1989

• TECHNICAL (technical services, process development, project study)	30%
• RESEARCH (and application)	23%
• COMMERCIAL	13%
Production	12%
Accounting/Management	10%
Human resources	2%
• Others (computing, administration, etc.)	10%

A comparison between the age and seniority pyramids within the firm shows that engineers enter FC company at a young age and make their careers within the company. Most of the recent entrants are concentrated in production, where those with long seniority are least well represented ; in comparison, research has a more homogeneous curve and the technical sections a median curve.

The average seniority in the engineer category is at 16.6 years.

Taking the category as a whole, engineers do not remain more than 5 years in the same job (57% of the category had less than 5 years' seniority in their jobs) and very few stay in the same job for life (5% have more than 16 years' seniority). Nevertheless, analysis of the seniority pyramid reveals some marked differences : more than 60% of those in manufacturing have at least 5 years' seniority in their jobs, while engineers in this seniority group represent only 54.5% of those in research and 58% of those in the technical section. On the other hand, 90% of the engineers in these two sections have more than 16 years' seniority in their jobs. Similarly, engineers in the research and technical sections rarely change career path, unlike engineers in production.

Unlike the sections to which they belong, the units studied can more or less serve as statistical "models". Thus the research center offers an extreme situation : few young engineers, despite increasing recruitment in recent years, large numbers in the higher age groups and little mobility ; for its part, the technical center is representative of the technical section as a whole, while the factory slightly accentuates the features that are characteristic of production as a whole.

This brief statistical survey of the work force will be pursued in greater detail as the basis of part two.

1-2 THE MANAGEMENT OF ENGINEERS AND THE DEVELOPMENT OF THEIR SKILL

Human resources management policy in FC company is dependent on industrial management. This means that the agents of that policy are the operational sections : the human resources service merely implements the directives that are issued.

However, this does not mean that such a policy does not exist, but rather that it is rarely presented as such within the firm ; it receives little publicity, is often not written down, is seldom formalized and as far as the actors are concerned is largely self-evident. It will be described in this section as decentralized, not directive in character ("soft"), belonging to the sphere of "relational do-it-yourself", but also (cf. the interviews with engineers) as subject to norms, which is demonstrated, for example, by the value attached to formal qualifications. These characteristics seem to us to be linked to the diversity and complexity of the firm's structure ; thus this type of management cannot be considered characteristic of the sector as a whole, although it is not wholly atypical either.

We have seen that human resource management is centralized at head office in the case of engineers and managers, but is devolved to plant level in the case of supervisory and clerical staff and manual workers. As far as engineers and managers are concerned, it is organized according to the career path to which they belong ; thus the managers' section of the human resources service is divided into three departments, one for research engineers, one for production engineers and one for engineers and managers working at head office. These three departments have widely differing management practices, as do the various human resources departments at local level.

The type of policy that we have described leads us to observe the actors directly as they react to management directives, but also to make clear distinctions between the production, technical and research sections. It is against this background that we will discuss the initial training of engineers and their entry into the firm, the acquisition of their professionality and the mobility, assessment, creativity and efficiency of engineers.

1-2-1 THE INITIAL TRAINING OF ENGINEERS : HOMOGENEITY AND SPECIFICATIONS

The category of "engineer" is relatively uniform, in the sense that the majority of its members have been through the traditional initial training of the French engineer : preparation for the élite grandes écoles, competitive examinations, engineering school... and that any other training route is considered atypical. Thus university graduates ranked as engineers and former technicians who have been through engineering school as part of the continuing training process are not well represented within the firm ; as for engineers without formal qualifications who have achieved their status through internal promotion, there are virtually none in the manufacturing section.

This homogeneity will also be found within the various training paths and types of training, although there are differences between the various functions within the firm.

a. Choice of training

• The firm does not openly favor one type of educational institution over another, and the human resources service says that it does not recruit from a classified list of engineering schools ; in general terms, however, it does say that it favors engineers from "the most highly rated schools" : 35% are graduates of engineering schools to which access is gained from the "classes préparatoire"s, the classes in "lycées" that prepare students who already have the "baccalauréat" for entry to the "grandes écoles". This hierarchy of schools leads to engineers being classified according to the institution they attended and then, after the initial training period, to the definition of different careers and career trajectories, as we shall see.

Most of the recruits are chemical engineers, and this tendency is growing. Engineers trained in the universities, particularly if they have a doctorate, are increasingly highly valued (12% of the engineers have completed a doctorate), as are those who have undergone additional training (specialist school, DEA etc.) ; engineers who have qualified through continuing vocational training have usually taken a technical course (maintenance, construction) or one in chemical engineering.

TABLE 1-12 MANAGERS AND ENGINEERS BY TYPE OF INSTITUTION

Numbers as at 30 April 1989		Recruitment in the 5 years between 1984 and 1989
Chemical	38,2	42,1
Technical	20,0	17,7
General	8,2	10,4
Commerce/management	10,4	11,4
University	9,5	15,5
Agricultural	1,9	-
No formal qualifications	11,8	2,8
	100 %	100 %

• The engineers by training whom we interviewed clearly chose to go to engineering school ; they had been through the <u>classes préparatoires</u> of the <u>lycée</u>, and most of them reacted negatively to university training ; they preferred to acquire a "profession" rather than receive "general training" and in their interviews they valued the training provided in the <u>classes préparatoires</u> (theoretical role, importance of mathematics) and in the engineering schools ("you learn everything, in actual practice") above any other.

The type of school they attended depended on a multiplicity of factors : family and school background ; geographical location ; the reputation of the school, and its ranking ; the accident of position in the competitive entrance examinations ; specialty...

In a significant number of cases, engineers questioned about the development of their career trajectory said their careers began with their choice of school ; from that moment on, they began "to manage their careers". Others stated that they were never really aware of the importance of this ranking for firms, that they minimized the extent to which they discriminated in favor of certain highly ranked schools : "if I had known my school's ranking would stay with me throughout my career, I would have done another year in the class préparatoire, it was possible..." The hierarchical list of schools probably exists, but they all recognize it is not a formalized criterion : graduates of the Ecole Polytechnique enter the firm with a higher coefficient than other engineers, and their careers will be different, yet there is nothing in the collective agreement or internal regulations that decrees this should be so.

b. recruitment

• Most engineers are recruited after their initial training in chemical engineering ; only a few experts in areas not normally covered by the firm (electronic engineers, computer specialists, specialists in certain new product lines...) can hope to be hired in mid-career. FC company, which is the result of multiple restructurings in the chemical industry, has chosen to strengthen the homogeneity of its engineer population by recruiting from within one discipline and by attaching value only to experience acquired within the firm.

• Recruitment is carried out at central level, but the influence of head office differs from career path to career path within the firm. Thus a certain degree of autonomy is enjoyed by the managers' section of the human resources services, which is responsible for looking for graduates as they leave the engineering schools and also attends conventions and other meetings in order to attract future candidates. Production engineers are recruited by this publicity, through advertisements or through unsolicited applications ; particularly in recent years, they have been hired by age group and on the basis of criteria linked more to the institution they attended than to any individual characteristics. However, this centralized recruiting is confirmed by the unit manager and by an outside consulting firm. It is not firm policy to build up a pool of engineers in training ("certain establishments that might act as "breeding grounds" or training stations"IIR), and head office recruits for a particular establishment at a given moment, and not for the firm as a whole in the long term. Research engineers and those in the technical center are recruited from the labor market and are selected directly by the unit manager, with head office in Paris simply confirming the job offer. Thus the criteria for hiring are linked to a specialty, or to membership of a specific scientific and technical sphere (a particular school of chemical engineering ; studying with such and such a professor etc...). The recruitment of engineers for production, research and technical services takes place in separate labor markets, which are regulated in different ways but on the basis of the same basic discipline, chemistry.

c. The specifications for initial training

Engineers in FC company are all chemists, although their educational background differs according to their career path within the firm : the initial training of production engineers tends to be more varied than that of research engineers or those in the technical center.

Thus 60 % of the engineers in the **research center** are graduates of schools of chemistry (in the pilot service, of schools of chemical engineering) ; there seems to be a preference for recruits from the regions (24%). A considerable number of engineers hold a doctorate (53% in the research center, 39% in the RDID, 12% in the firm as a whole), and they are relatively homogeneous in age, which reflects the firm's wishes. Some more experimental disciplines (organic chemistry) recruit more engineers with doctorates than others (physical chemistry). They constitute a link between the laboratory and the scientific community and are elements in the policy of the research center ; in consequence, the director of the unit is responsible for their recruitment, to an even greater extent than is the case with other research engineers : "there is no recruitment, it's not a preliminary to hiring, but we do work regularly with certain laboratories, we know the people, their scientific level, we know that the experiments are interesting and reliable, that they are of great interest to the firm. It's either because they're working on data that interest us, or because they are good laboratories..." IIT. Some do their thesis at the center's laboratory, others in university laboratories : "I stayed at the university laboratory, I was lucky because normally theses financed by industrial firms are on industrial subjects, chosen by the firm. I had a free choice. It was A's wish to forge links with this laboratory, to put students into it ; moreover, S, the director of the center, knew the professor very well" IIR. One of the center's managers with a scientific background monitors the student's progress and is one of his examiners. Afterwards, the successful doctoral student is usually taken on at the laboratory ; recruiting remains with the center "before being a technical decision" IIT. The doctoral thesis plays a multiple role : it enables the center to improve its relations with the scientific and technical space and, conversely, to recruit a specialist researcher and to have freedom of choice. Those engineers with doctorates whom we met at the center were more dedicated than the others to their discipline : "I decided to do chemistry because I had a liking for it, it was a vocation, I had always wanted to be a chemist even as a small boy, it was the magical side that appealed to me..." IIP. They did not want to go into public sector research but had an ambition to make a career in industrial research, or at the very least start off there.

• **The technical center** presents itself as a nursery for engineers, and at the same time as a center of experience and expertise. The process service is particularly active in this role : most of the engineers here, like those in the pilot service, trained as chemical engineers ; few of them have doctorates, but some have done courses abroad. In the construction and technology services the educational backgrounds are less orthodox, but most have some been through some sort of technical training.

• **In production**, 65% of the engineers are graduates of schools of chemistry, while virtually none were trained in the universities ; 3% have no formal qualifications, and 8% have doctorates. **In the factory** we investigated, we found this type of characteristic : most of the engineers did not wish to waste time in college, but wanted to embark quickly on a "career". The engineers with a background in vocational training are often found in technical functions at production sites : maintenance, processes, etc.

Engineers from the major schools ("Ecole Polytechnique", "Ecole Central", "Ecole des Mines"...) promoted to managerial posts are to be found among the personnel of production units. On the other hand, little value is placed on the holding of a doctorate : "In France, it's better to be a graduate of the "Ecole Polytechnique" than to have a doctorate. The fact that I have a doctorate on top of being a graduate of the "Ecole Polytechnique" means nothing to the firm - quite the opposite - but for me it's a positive thing..." I no. 27.

The initial training of the engineers in FC company is uniform and homogeneous in its form ("grande école"), even if the disciplines vary according to the career path within the firm. The various actors in A are agreed that the initial assessment of engineers, the hierarchisation of their training takes place within the traditional education system and by reference to it, and to the detriment of the other training routes (vocational and continuing training). This agreement forms the basis of the relationships between the firm, the grandes écoles and that part of its research that depends on these latter institutions.

1-2-2 THE ACQUISITION OF SKILL WITHIN THE COMPANY

As we have seen, educational institutions, particularly schools of chemistry, play a part in the recruitment of young engineers to the firm. Throughout their period of study they are introduced to the objectives of the world of industry through courses, teaching provided by people from industry, junior enterprise schemes, etc. Preparations are made on both sides for the engineer's move between the educational space and the industrial space ; in this way the socialization of the young recruit to FC company is facilitated, particularly since these two spaces will, as far as he is concerned, be intertwined.

Thus the quality of the technical training provided by educational institutions is so wholly accepted by the firm that it has handed over its role as a selector of competence to the education system. As a result, it considers the engineer as a "finished product" when he joins the firm, at least as far as his technical training is concerned. Quite naturally, therefore, the firm will attach greater value to the acquisition of the skills that will enable the young engineer to become a manager.

a. The initial socialization into the firm

The young engineer recruited by the firm is immediately allocated to a function ; for several years now, however, he has had to follow an induction course during his first year. The length of the course varies according to the service to which he is allocated and the date at which he was hired, but it is considered essential to the fulfillment of his functions that he should have a good knowledge of the firm. This course is theoretical, that is the firm is "taught" to the young recruit in a week ; this teaching is carried out by the highest level of the hierarchy (the functional and operational management) but does not include any practical or technical approach to the firm's activities.

There is no particular policy that defines how a young engineer is to be integrated into his service and function ; everything depends on the unit to which he is allocated. He may either be allocated immediately to a job or to a project, without any prior learning period or without being given any particular information : "I was agreeably surprised because I was just expected to get on with the job"IIR, or he may benefit from a more or less structured latent period : "it was a latent period for training me..." IIR Thus in certain sections in the Research Center, this type of gentle, carefully considered introduction to work is planned for and supervised by the head of section ; this period allows individuals to acquire the knowledge required to manage a team of specialists : "I spent two months familiarizing myself with the subject. I started by seeing what was being done ; I didn't have a technician, so I went through the vast bibliography I'd been given on the subject - this was to familiarize myself with fluorine and catalysis before starting with a technician" IIR.

In the TC, there is a real apprenticeship in the function of process engineer : the young engineer is asked to carry out a small study under the guidance of a senior engineer, whose task it is to initiate the new recruit gradually into his profession : "When I started I was given a little study to do on my own, supervised by an experienced engineer. He followed my progress in the factories and explained to me how to get assistance from the calculation department..." IIT.

This period of apprenticeship is carefully thought out and monitored by the hierarchy ; it is considered beneficial : "this period was intended to put me in the picture, to introduce me to people, to working methods, perhaps to test me out..." IIT, but it also serves to integrate the young engineer into the team and to facilitate the transfer of knowledge : "I think what happens in the first six months is a sort of patronage. If you had to learn it all by yourself, it would take longer. It's one of the strengths of the Technical Center, because the person who looks after you, your "patron", transmits knowledge to us and tells us how things are done" IIT.

In the factories, young engineers are often placed alongside a production engineer in functions such as <u>technical assistance (process)</u> or <u>study and trials engineer</u>. This type of organization is intended to build up a pool of engineers in training and to enable management skills to be transmitted gradually and technical competencies to be increased. In fact this system makes the integration of the young engineer dependent solely on a personal relationship with an experienced engineer, and there seem to have been several failures : "it's more an attempt at destruction really, than a real attempt to build up a pool of engineers in training ... I think they (the experienced engineers) had already been through the system and were trying to perpetuate it" IIP. The creation in some production units of process services separate from the factory floor will probably make it possible to establish a pool of young engineers in the process service ; these young engineers will be socialized on the shop floor without being dependent solely on the production engineer.

b. On the job training

This on-the-job training continues throughout the engineer's career. It is the product of relationships with the various actors in the innovation process : "I learnt from others by discussing things with them, by reading the reports they wrote and by talking to the hierarchy and to the technicians" IIR, and of the transfer of knowledge from the head of service, from the former job holder and from technicians :

"As for my relationship with the head of service, it was a piece of advice I was given ; I forced myself, I wasn't obliged to discuss the state of progress with him, to use him as an adversary in discussions ... I wanted to squeeze him like a lemon to make him pass all his knowledge on to me...' IIR : "There are some experienced technicians who could teach the engineer a thing or two" IIP. In particular, it is a product of the day-to-day experience gained from working on projects and repeating exercises as part of a team : "On-the-job training provides an opportunity to see how others do the job" IIR. "When I arrived, they (the technicians) taught me about the equipment, from the point of view of procedures, there are whole heaps of information that come up : how does a catalyst work, I watched, I asked questions. I discuss things as much as possible, and now the opposite is beginning to happen, and it's me who passes on information..." IIR ... "he's a good technician ; for two months at the beginning I watched and then we began to work together. He knows a lot...' IIR.

Some engineers who are oriented more towards a managerial career will tend to attach greater importance in this apprenticeship period to acquiring "knowledge about the firm", to the "role of the manager in the firm" or to "management" : "The best training for a project manager is to get to know people, to learn how to make them work. That can't be learnt in 4 days - you have to get to know people in the Research Center but also from outside (meetings, private contacts). That's why it's necessary to put young engineers on to small projects in order to harden them gradually, but that isn't what happens..."IIR. "I'm both the kind-hearted organizer and the interface with the outside world" IIP. The role of head of service and of the engineers' solidarity based on "professional identity" and social category will be decisive in that case.

Others, on the other hand, will tend to place the emphasis on the accumulation of specialist skills and in-depth knowledge ; such profiles are found in specialist jobs in the research center, in the process services of the TC or in production units, and sometimes among certain production engineers attached to technical services : "I've done a course in spectrometry ... the technician gave me the basic notions and then there was individual training in the technique ... I put a lot of effort into it, reading journals and attending conferences" IIR. They will perceive the development of a project in the same way as the process of product innovation, but also as a learning process in which the actors involved accumulate knowledge : "Sometimes we even know that a project is not going to lead to anything, but that it will help us to learn how to work on certain products and certain techniques that will be useful afterwards (e.g. high temperatures) ; even a research project that leads nowhere is never wasted - it always teaches us something" IIR. They are unlikely to experience a feeling of failure when a project is shelved, because for them the time scale of an innovation cannot be measured, because the process is a slow one and is not linear, because the project may be "resurrected" and because in any case it has already had a certain **utility**, namely their training. This will have benefited from the contributions made by experts within the firm, irrespective of their status, and will have taken place on the factory floor rather than in the canteen .

It should be stressed that the quality of on-the-job learning was described to us as "the effect of social relations within the firm" (IIP).

c. Initial training and on the job training

We wondered whether the initial training of engineers had influenced their apprenticeship within the firm. In the first instance, they seemed to think that this was not the case : "When you arrive you realize you don't know much, you're in an environment in which the people are very specialized" IIR. "After the "classes préparatoires" we perhaps thought we were just as good, that we could have gone straight into industry" IIR which perhaps reflects their confusion about the firm. Then they appreciate the general, encyclopedic knowledge they acquired during their studies, which enables them to adapt : "In college, we were taught to adapt to all situations. A person leaving a school of chemistry must be able to work equally well on the production or commercial side and in contact with people, engineers, those in the pilot service ...' IIR.

After twenty years, they end up by considering that the education system taught them a method that has been useful to them in their various tasks : "My training has served me well, because there are convergence's even between metallurgy and chemistry ; my scientific and technical training helped me to discuss and to understand what was asked of me...' IIR. Several of the engineers we met expressed their apprehension at the extent of the new professional and practical knowledge they had acquired in the firm, which they contrasted with the theoretical knowledge acquired during their training. This knowledge, which is too closely linked with the production process, might put them at a disadvantage relative to young people just leaving college : "The theoretical part is illuminated by my experience, but in general I'm losing out ; whereas when you arrive with only a general training you have ideas that the others no longer have..." IIR, and push them out of the innovative space in the firm towards management. These engineers are those who are oriented towards careers as experts and who thus fear the arrival of competition from recent graduates.

Those engineers more oriented towards managerial careers blame the education system for not having trained them in economics, management and human resources, whereas they think they are "up to scratch" in technical matters and do not have a lot to learn in the firm.

d. Permanent training

Despite the fact that 3.8% of the wages bill is spent on training and that there has been an increase in the number of hours set aside for training, this policy is poorly integrated into the general policy on personnel management.

TABLE 1-13 Permanent training

	Evolution of numbers in training			Evolution of number of hours' training		
	1987	**1988**	**1989**	**1987**	**1988**	**1989**
Engineers and managers	508	600	601	22 822	27 351	28 333
Technicians and supervisors	1 786	1 895	1 988	101 974	105 996	131023
Manual workers and clerical staff	1 859	1 609	1 865	114 941	110 302	106897
	4 153	**4 104**	**4 454**	**239 737**	**243 649**	**266 253**

Most of the training courses on offer are chosen by engineers for their own personal benefit, in the belief that they will further their careers and improve their functioning as managers. Only seldom does the firm have a specific objective in mind when it offers a course ; its training policy is not integrated into its policy towards its managers.

The training courses can be divided into two types :

- courses intended to impart knowledge about FC company ; "Getting to know the company" ; "the project manager"....

-more in-depth courses in specific areas, which may be held in universities or in basic research laboratories. Researchers may also attend conferences in their specialty. Whereas the "firm" courses are of particular interest to those engineers oriented more towards "general" functions, the latter kind are of interest to experts.

For all the actors involved, the acquisition of the engineer's professionally within the firm is an instrument linked to mobility ; for engineers, on-the-job experience is often a means of enlarging their experience and developing their ability to adapt to new situations.

1-2-3 MOBILITY

Having explained how mobility within the firm is organized, we will analyze the various categories of mobility - geographical, by career path and thematic - in order to investigate the construction of the different types of engineers. It is evident that our distinctions between the various types of mobility are merely formal, and that in practice a change of post can represent both a geographical change and a change in career path, or one but not the other.

a. The organization of mobility

Although FC company wishes to retain its engineers within the group, it also wants them to be mobile. A change of post every 4 to 5 years seems to the firm to be beneficial both to the individual and to his employer : "a manager must change jobs, he must be able to adapt to all the industrial processes so that he can contribute something each time" (manager in the human resources service). Mobility can be used in order to combine populations originating from the various firms that make up FC company, or in order to try to create a synergy specific to the firm by blending or breaking down the various cultures.

No systematic policy has been developed in order to organize mobility and put this wish into practice ; engineers are merely encouraged to be mobile if they wish to pursue a successful career. Thus the human resources service puts forward as a model a type of engineer who alternates between various functions, such as production, specialist posts and marketing (product management), and between different geographical locations (Paris-provinces). Such an engineer is destined to occupy jobs at high level.

The firm has not established automatic mobility paths ; it encourages engineers to be mobile and then manages the changes that take place. These can originate in two ways :

- the manager himself may request a move ; his motive may be a desire to develop his career, inability to adapt to his present functions, a geographical problem, etc.

- the service of which he is a part may wish him to move ; it is the operational divisions that are the real motor of mobility within the firm.

All these requests, together with the vacancies they create, are examined by a committee set up by the human resources service. This committee meets once a month, and brings together divisional managers and the general secretariat.

Since vacant posts are not formally advertised, information is not evenly distributed among all the parties : the services that sit on the committee know which engineers are available, whereas the engineers do not know which jobs are vacant. Negotiations between the hierarchies (the one the engineer is leaving and the one seeking to recruit him) and the engineer are thus conducted informally, sometimes through the human resources service, but usually through the various relational networks. This period of negotiation is very drawn out for the engineer : "it takes time, your own hierarchy says yes, we agree, no, we don't agree ... then you have to know when..." IIP. At that point, only the committee and the human resources service record the engineer as available and the post as vacant, but the bargaining between the engineer and the service seeking to recruit him may already have started. The more efficient the engineer's relational network is, the more rapid his mobility will be and the more effectively he will be able to negotiate. These networks may bring together people who attended the same college or worked for the same firm ("I had already worked with X" IIP) or at the same site : "funnily enough, there are a lot of people who used to work at G here...' IIP. Once the parties concerned have reached agreement in the informal market, the committee ratifies the move.

These long and costly processes apply only to changes of unit or career path ; engineers may, for example, change jobs within the same factory without investing as much time and energy, although this type of change does depend on the size of the unit.

b. Geographical mobility

Mobility usually represents a sudden and clear-cut divide in an individual's professional life ; when it also involves a change of location, it affects his life outside work.

• Production engineers have an impressive record of geographical mobility between the various factories in metropolitan France ; this mobility also forces them to change the type of product they are dealing with, as well as the type of industrial process. Thus they move easily from a petrochemical installation to a fine chemicals plant. This mobility is essential to an engineer's socialization ; what he is being taught is not the various technologies involved, but rather the "social dimension", or man management : "You can easily change job or factory and adapt to different technologies, once you begin to have the knack, as they say ; you learn a bit more about the technical side each day, but you can't learn about the human aspect if you don't mix with different people, if you don't have a wide range of experience ". This mobility leads to a division of labor on the shop floor, as we saw in the factory we investigated. Either the engineer concentrates on management and leads the technical side to the foreman, or he takes responsibility for production and leaves man management to his foreman. In the first case, it is easy for the engineer to be mobile since the foreman is the guarantor, in the short term, of the firm's know-how ; in the second case, mobility is more difficult but the foreman provides greater continuity of management for the shop floor. It should be noted that engineers do not receive any additional technical training to help them adapt to this new function, even though there is a considerable gap between the two types of competence ; at best, if he so wishes, he will be sent "some brochures, so he can put himself in the picture". This confirms our hypothesis that an engineer's training is considered to have finished when he joins the firm ; if he continues to learn, it is only to "refresh" his knowledge and is a private decision taken voluntarily by the individual.

Once they have reached the age of about 40, a considerable number of these engineers who have had varied careers no longer wish to continue living with the "constant upheaval of relocation" : they mention first of all the difficulty of their life outside work and of their family life, but they also dispute the learning value of constant mobility and would like to see it become more organized : there should be time for two engineers to overlap in the same job, time for learning, time to have an effect on the shop floor, etc. "The problem is having the time to do it" IIP.

• The research engineers we interviewed were unenthusiastic about geographical mobility ; most of them hail from the Lyons region, studied there and have no wish to leave ; they accept temporary posts elsewhere, but retain a desire to go back - often their families do not move. This tendency is more marked among engineers whose spouses do not work. They do not see how geographical mobility within the firm could be of any benefit to them.

• Some engineers in the technical center have patterns of geographical mobility that take them on temporary attachments to the process departments of production units. They often return to the center in order to "refresh their skills", and may subsequently leave again.

c. Mobility by technical discipline

If the four main technical discipline are considered, corresponding in FC company to the production, technical, marketing and research services, certain movements between them will be possible, while others will not be. Thus mobility between production and marketing, and vice versa, is the ideal type of mobility for an engineer seeking to develop his career ; it is also the most common.

On the other hand, mobility affects only a small proportion of research engineers, among them specialists in chemical processes working in the pilot service who continue their careers in the process department at the TC or in a production unit, and those engineers who have decided that the time they have devoted to research has given them a depth of scientific and technical knowledge that would be useful in production. This latter group is often disappointed by the moves they make : "it was a positive step, but I would say I' ve suffered a great deal : I became a production engineer at the age of 34, but I've suffered from the radical change in work, in the way of thinking and acting. There were moments during my first year when I almost gave in my notice - it was a completely different world. It's a good idea to get into production when you're young ; I felt I'd taken a step backwards in my career..." IIP. Production engineers "do not go into research", except for a few cases that are cited as diversions ; "it's not the same profession" IIP, but if they are interested in technology they can go to the TC via the process department.

Mobility is possible between certain career paths as well as within the same one. The mobility that takes place depends on the type of engineers in the career path, and it also constructs different types of engineers, as well as different careers for engineers.

d. The construction of the type of engineer

In this second part we have begun to sketch a typology for engineers, which will be confirmed by an analysis of mobility. This typology, in which a distinction is made between engineer-managers, engineer-experts and engineers specializing in a particular technical procedure, is perpendicular to the main career paths.

Engineer-managers : these engineers represent both the firm's model and the classic model of the French engineer. They are mobile within the firm and wish to make a career for themselves, which their mobility enables them to do. In the majority of cases they are taken on as production engineers ; they move to and fro between production and marketing before attaining more administrative functions. If they begin their careers in research, they only stay there a short time : "On the other hand, you can start off in production, that depends on people's profiles ; I'm ready to take on anything, but I preferred technical sales, development on the customer's premises, but if someone suggested a job in production, I would take it..." IIR. The variety of professional experience they acquire gives them a better knowledge of the firm's various structures and provides them with additional training that is less technical than human : "Changing jobs teaches you a lot about people" IIP. "If I took on a job in a factory, it would be a learning experience"IIR. This extreme mobility is their means of developing a career ; it is one of the few clear indications that the firm gives its managers. However, the mobility represents a severance, a reduction of the engineer's technical knowledge in favor of the accumulation of human experience and the proliferation of relationships within the firm.

It is intended to help them look afresh at problems and should not hamper their creativity ; on the contrary, "there is a period of adaptation during which one is ill at ease, but you can contribute different ideas" I TP1. Most of them speak in terms of "career plans" : "do some research then go on to production, that's the perfect route ; after that, you'll go to head office" IIR ; when they are young, they regret that the firm does not really assess competence, advertise jobs, organize mobility or indicate career opportunities more clearly. They very soon realize the importance of informal relations within the firm and of attending the courses on "getting to know the firm", where they meet the managing director, in order to create for themselves an "address book" and thus manage their careers more effectively.

Engineer-experts : most of these are researchers who wish to remain in the RC ; they stress the gap between research and the rest of the firm : "when I came back, I was a little out of touch with molecular chemistry" IIR. "When you're 40, if you go into production you start at the beginning again, you have to prove yourself again just like a beginner" IIR, and the opportunities for development within the same area : "Firstly, mass spectrometry has changed a lot, so I don't feel I'm doing the same job as 20 years ago : I've changed as much as if I had gone into production" IIR They even believe that changing areas of research within the center is difficult, that it is not profitable for the firm and that it leads them, as specialists, to doubt their competence : "people don't like changing topics ; if someone suggested an interesting topic in organic chemistry, maybe, but there are certainly areas in which I am not competent, for example electrochemistry, I'd have to start right back at the beginning ; from a little way off it may seem feasible, but it may not be worthwhile" IIR. "It's difficult to be mobile in research because you very quickly specialize, the gaps between the various areas grow very quickly, and I would feel I was going back to the beginning again, and I would also have lost the theoretical baggage I picked up at college : I would retain my knowledge of the firm, my contacts, but as far as the technical side is concerned, my work, although I've always been in chemistry, it would still be a massive change" IIR.

They favor the accumulation of experience in one field : "What practice means is that by looking at samples you create your own personal memory, you make empirical rules for identification because at a certain point you saw that spectrum appear ..."IIR ; they are concerned at the loss of knowledge that mobility would entail for them, and stress the transmission of knowledge : "Of course there are records, but if everybody were to leave..." "Of course, now they'll benefit from the laboratory's collective memory, all the records - with computerization, for example, we can make esquires in the library. We have our spectrum on the machine, and when we've identified it we store it in memory ; in that way we build up our own library, in addition to that of the manufacturer" IIR. "The role of senior engineers is important to the TC ; when we're working on a project, we rely on the knowledge of the process department ..." IIR. If we want to keep the skill, and if J. leaves, we'll have to take on a doctoral student who can learn it, because it's not enough to have a single engineer who knows everything. J. has gradually passed his knowledge on to me in the course of time..." IIR. They sometimes express an interest in carefully organized changes of research topic, which would enable them to remain specialists in a related discipline in the same center.

They are less concerned with their careers : "You can have a good career in the center : head of department, head of center..." IIR. Yes, people who remain in the same place are penalised"IIR. "In my opinion, it's difficult to make a career in research .. the only hope is to become a project manager, which is not a promotion grade" IIR. They concern themselves little with the firm's human resources policy. Their legitimacy comes from their status as experts, and its recognition, to a greater or lesser extent, in the scientific and technical space.

Single technical engineers : These engineers move between the pilot department, project study and production, but they work only on one technical process (e.g. one engineer has worked on the same process in the TC, in the factory and again in the TC, while another has worked in the pilot departments of various firms...). More than any other category, they describe the difficulty of moving between jobs, since they are both thematic generalists and specialists in one technical procedure, but they are in fact mobile in an organized fashion along a single technical line : "I was told there was a great deal of reluctance to take people from research" IIPi. "In the pilot department, you're involved in everything, so when the engineers in research talk to me about specialty you can't get out of, I'm surprised, there's a period of adaptation, of course, in analysis where the type of technology is very sophisticated you have to become a specialist, and that can be very difficult to get out of, but a chap who does organic synthesis and has a bit of common sense can also do mineral synthesis... IIPi. They value a wide variety of experience in their own field and accumulate a range of technical knowledge. Their careers are not their prime objective ; on the other hand, they value communication within the firm and the circulation of information. "I want to go into production, the ideal thing would be to follow my project on fluorenes when they go into production" IIIR.

FC company's mobility policy is based on encouragement but is effective in terms of volume of moves, since it is initiated by the technical departments and managed by the firm's multiplicity of informal networks.

This raises the question of its exact role within the firm :

• It is claimed that it fosters unity and cohesion, but it separates mobile managers from non-managerial staff who do not move : the fact that technicians and foreman, the repositories of the firm's technical know-how, stay put at one site allows engineers to be mobile. It also exacerbates the fragmentation of the engineering profession : the mobility of engineer-managers enables them to identify with the firm, whereas the reference point for engineer-technicians is their technical skill and engineer-experts continue to look to the scientific and technical space of their own disciplines.

• Only engineer-managers consider that this rapid mobility has positive aspects : it is not only the means whereby they forge their careers, but it also teaches them what they never learnt in college, namely the management of what is intangible, of human resources, etc. As far as technical matters are concerned, the baggage they acquired in their initial training seems to them to be adequate ; from their point of view, as from the firm's, they are "finished products" in technical terms when they leave college, and their mobility serves to mould them as managers within the organization.

• Engineer-experts and engineers specializing in one technical procedure see rapid mobility as a breach, and in particular as a failure to recognize the different functions that engineers can fulfill within the firm, in production, as an expert on processes, in research, and so on. They see the opportunities for and hope to achieve movement within the same function or within the same specialty, which would enable knowledge to be handed on without earlier know-how being lost.

1-2-4 ASSESSMENT AND THE ENGINEER'S CAREER

The development of an engineer's career is determined by the institutional framework provided by the collective agreement for the chemical industry, by the decentralized, secretive assessment, relational in character, carried out by the firm hierarchy and the ambitions of the individual engineer.

a. The collective agreement for the chemical industry

Firstly, the agreement defines what "a novice engineer and manager" ([8]) is by making a distinction between engineers "under the terms of the law of 10 July 1934 or the decree of 10 October 1937, hired to carry out the functions of engineer" and individuals hired "to exercise managerial functions" ; it lays down the educational establishments and university qualifications that confer eligibility for recruitment to this latter category ; moreover, it should be noted that, while it is strictly necessary to have a

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[8] *Le collective agreament for the chemical industry.*

bona fide engineer's qualification in order to enter the technical function, it is possible to recruit a manager with a university degree.

This same agreement lays down "reference positions" in an engineer's career, depending on the type of function, career path, hierarchical level and seniority ; these positions define hierarchical coefficients and thus minimum salary levels. The agreement provides a framework for an engineer's career by laying down "a guaranteed coefficient on being hired and in mid-career" (9).

It abandons the traditional reference to occupations in the chemical industry, but defines a particular position, and the spacing of the corresponding coefficients, for "research engineers" and a "supplementary position". A research engineer is defined as "an engineer whose role is to carry out research on new products, develop original production methods, research the unknown or little known causes of existing phenomena, new manufacturing processes for existing products or new methods of control, analysis and testing". The scope of their activity is not limited to research centers, and may be located in production departments ; moreover, it is stated that their activity does not necessarily lead to "an immediate effect on procedures or production". The supplementary position is reserved for engineers and managers who are no longer novices but who cannot gain access to the category of "established engineers and managers" since they have not assumed "complete and permanent responsibility" ; this position seem to be used for technicians who have been promoted to the status of engineer without there being any real change of function, and for administrative engineers who make up the large majority of these promotions, particularly in FC company.

It is remarkable to note that the collective agreement specifies different types of careers for engineers : these last two types of engineer are to advance by seniority along their own scale, while the typical established engineer changes grade and category in accordance with the "position" he occupies. In terms of differentiation between coefficients, which determine the minimum salary, the research engineer is not disadvantaged at the beginning of his career, but he may be if he remains on the same scale ; the "supplementary position" is clearly disadvantageous. It should be noted that particular coefficients are provided for young engineers who hold a doctorate in order to compensate them, and them only, for their late entry into the firm.

b. Individual assessment

• It has already been noted above that FC company takes over the various classifications to which engineers have been allocated within the educational system : the ranking of the "grandes écoles" themselves, and then classification by "grande école" ; it gives up its own power of assessment at the moment of hiring and adopts the external classifications in order to guide engineers towards a highly diversified range of

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9 *Les classifications dans l'entreprise*, Eyraud-Rozenblatt-Tallard, Documentation Française.

professional trajectories. Thus students graduating from the most prestigious schools benefit "from an accelerated, signposted route through the firm" intended to get young people into management jobs ; engineers with doctorates and future experts are guided towards a certain type of career...

Starting salaries are also determined on the basis of the hierarchies in the education system ; sometimes the school is even involved to a greater or lesser extent in salary negotiations, in the belief that it is one of the actors : "When I was a student, I was told not to accept less than a particular grading, because I would not only be belittling myself, but I would also be belittling the school..." IIP. The collective agreement serves only to lay down a minimum level, and the human resources department determines each coefficient for each individual engineer when he is hired.

Engineers are oriented towards a variety of professional trajectories on recruitment, but they are not given precise career profiles. This orientation and these careers are not formalized by the firm, and as a result they are both transparent to the actors and yet not explicitly documented.

• It is obvious that the greater the influence of the educational system on engineers' careers, the less the significance attached to internal assessment. This is indeed the case with FC company. Five or six years ago, the human resources department initiated the development of the annual assessment interview. This procedure, which involves the hierarchical levels n + 1 and n + 2, entails the joint definition of objectives for each engineer, the monitoring of results, assessment of the individual and overseeing of his career.

The impetus provided by the human resources department was taken up in various ways from center to center, depending on the type of hierarchical relationship already in existence ; thus in those units, such as the RC, where level n + 1, the head of department, takes little or no part in the assessment of researchers, there is no interview at all ; in units in which the internal organization is defined and accepted, it is used. In general, engineers and heads of department complain about the opacity of the assessment system which does not allow them "to manage their careers individually".

Salary increases are decided at unit level by the head of center, with or without an annual interview ; they vary much more in the production units than in the research center, where salaries are differentiated above all on the basis of seniority : "Careers progress more rapidly and are better in the factories, but are more certain and more even in the research center" IIR. This salary scale is completely opaque, but this is considered desirable by the actors within the firm.

c. Career and mobility

An engineer's career is not really the result of the official assessment system. It depends rather on his initial training, and also on the position the individual holds, and is recognized as holding, in the hierarchy of competencies. This situation is not explicit, but it is known and understood by the various actors involved. This reputation circulates within the firm and allows the individual's career to unfold, without any logic -whether career plan or whatever - being pre-established.

It is engineer managers who are subjected more than all the others to this system, which is linked in two ways to mobility. Firstly, the firm restricts access to certain jobs to those who have a certain pattern of mobility ; secondly, the individual who changes jobs forges an increasing number of relationships, thereby increasing the number of opinions at hierarchical level n + 1. However, if this type of engineer has greater opportunities for promotion than his expert colleagues, he also incurs greater risks. Thus after five to ten years, the steepness of his career gradient is established and can only go down after that point ; a refusal to move signifies that his career will advance no further and that he will be excluded from competing for other jobs.

Research engineers are, in part, assessed by their peers, that is by the scientific and technical space, a process that involves agents outside the firm. Their mobility is not highly valued, but their agility within their discipline may make them a reputation. FC company does not have a formal twin-scale payment system that would provide consolation for experts ; and yet individually, they seem to "do well in the system" and do not abandon their careers in research.

Similarly, the engineers specializing in one technical procedure rarely reach the highest positions in the firm, but their mobility within a technical career structure means that they can apply for important technical jobs (functional departments) or switch to careers as engineer managers.

1-2-5 CREATIVITY AND EFFICIENCY

Accumulated knowledge is exploited in different ways by different types of engineers :

Thus **engineer managers** base their reasoning within the space represented by FC company on a logic of immediate efficiency, which has its origins in the market ; they belong to the industrial world and favor on-the-job learning by a process of osmosis based on relationships forged within the firm, as well as training in human resources. Their efficiency lies in their ability to make an organization or a shop floor function and to extract the maximum profitability from the resources at their disposal. Their responsibility is hierarchical and is defined in space (a workshop, a department) but not in time. Their motivation is derived from the section that gives them a function and objectives ; they expect a great deal from collective creativity, from the dynamic of the organization and from the interaction between their theoretical knowledge and the pressure exerted by the market in order to ensure that the unit for which they are responsible is efficient. They are sensitive to the reputation they enjoy among the engineers within the firm. The further they advance in their careers, the more they are managers in FC company rather than engineers.

The reference point for **engineer expert**s is the scientific and technical space, and it is among their peers in the scientific community that they seek recognition. They compare their expertise with the other laboratories in the firm, or in universities and the CNRS. They have the feeling of belonging to the research profession and to the RC. Their motivation is individualist, based on "becoming the specialist in a small scientific field". They work on specific "project topics" (cf. Part 3), defined in both time and space ; they are not disappointed when the project comes to an end, but appreciate that it finishes in the acquisition of a patent, the publication of an article in a journal or attendance at a conference. They believe that only the researcher's individual creativity can lead to real innovation, even if it is the result of previously accumulated collective knowledge, if it subsequently benefits from contributions from the rest of the team and if it is subject, a posteriori, to collective organization : "It (real innovation) originates with one person ; afterwards there has to be a collective effort, but if it is unexpected, and in chemistry the more innovative it is the less it is expected, because it is the result of observation of the abnormal and exploitation of that observation" IRR. Innovation that has its origins in collective creativity is arithmetic "innovation, that is it amounts to nothing more than the adding up of chemical formulae in order, inevitably, to find another one : "it's useful, we pool different ideas, but it's not real innovation" IRR. Industrial innovation is more usually of this type, originating from an industrial objective, but with no real opportunities for normalization within a proper project with a timetable, meeting etc. The research engineer is at the center of the tension that exists, within the industry and among the actors, between these two types of innovation.

Those engineers specializing in a single technical procedure are more closely integrated than the other two categories into the product innovation cycle ; they can follow a technical progression from research to production without changing "specialism". Thus process engineers are found in the pilot department, the technical center and in factories. The appreciate the efficiency of a flexible, well-organized transition from one phase of the process to another, and find their motivation in the successful transfer of knowledge or products between the various units. They work on formalized industrial projects, with precise timetables, scheduling etc., and they operate in small, collaborative and tightly knit teams of "technicians" (2 or 3) that are highly specialized in one particular field.

To conclude this second part, we would like to highlight two characteristics of FC company :

• the importance of the interpenetrating of the educational, industrial and scientific and technical spaces in the social formation of engineers ;

• the uniqueness of the management of engineers in FC company. This management style seemed to us to be "soft", not highly organized, not voluntarist and yet linked to relational practices and networks. In this way, it succeeds to create an identity for the various actors, by using the various influence groups, the micro-solidarity of the profession etc., to mix the various populations without too many clashes or conflicts and to organize the efficiency and creativity of the engineers in a smooth and flexible way.

1-3 WORK SPACE AND INNOVATION

FC company, like many other enterprises, distinguishes between the organization of production and of work once the product is stabilized and whenever it undergoes or generates innovation. Thus the originality of management in the Chemical Industry will make way for the organization of a project to enable an efficient mobilization of the available competencies. But will this motivation provided by Senior Management be enough to create a dynamic force which will modify the working relationships, which will replace the division of work with real cooperation among the actors throughout the product cycle? What form will the product cycle take after the organization of the planned innovation?

1-3-1 THE PRODUCT INNOVATION CYCLE

The specificity of "chemistry" described in the first part influences the production process of the sector and thus the product innovation cycle :

a. The Production Process in Chemistry

Chemistry is the "science of the composition of various bodies, their transformation and their projects, etc.." ([10]). It creates its own objective which consists in identifying, then characterizing products, which are chemical edifices, so as to understand them and with the aim of creating new edifices. If physical chemistry seeks to understand the cyclical laws, the reasons for reactions, to identify them to be able to prescribe laws governing the constitution of these edifices, organic chemistry (like bio-chemistry or organo-metallic chemistry) is concerned with the construction of these edifices, the molecular syntheses.

The various fields of chemistry may be described differently, according to the criteria of scientific disciplines : organic chemistry, mineral chemistry, etc., according to the product studied or researched : fluorine chemistry, superconductors,etc. according to economic and production criteria : industrial chemistry, fine chemistry. This last distinction is of special interest to us, for it contrasts a manufacturing chemistry, a chemistry of commodity, where products are manufactured in great quantity, where the products are "finished", the standard example of the "process"([11]) industry of continuous flow-lines, with fine chemistry, with its high added-value, where production is reduced, the product sophisticated, the channel of synthesis complex and where production is most often carried out, certainly along flow-lines, but "by campaigns", rather than in a continuous fashion.

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[10] *Petit Robert*

[11] P.F. DRUCKER *"The Practice of Management"* 1955

Independently of these distinctions, chemical production will be considered as a "process" as far as production is concerned, "where the product and the process are fused into one and the same entity". Furthermore, throughout the whole production cycle, from research to the production area, the notion of specificity of the "principle of chemical production" compared with other types of production (the contrast of a transformation industry with a construction industry) will be defended by the actors. This specificity will explain the overlapping of the different professional spaces and the different roles of the actors.

Historically, and in its objective, it is difficult to distinguish the field of academic chemical research from the field of industrial chemical research. The state of fundamental research has always directly conditioned industry. Fundamental research laboratories "pass" on to industrial laboratories a chemical edifice to be followed up. The manufacturers interrogate the public research laboratories and relationships, in both directions, are active and interactive. However, stemming from this cooperation, each manufacturer in the chemical industry will define his own research strategy, and orient his own investments and choices. He will build up his own very specific "research" capital depending on his environment and the competition (petroleum industry : operations and distribution). Even if the chemists no longer "bring out" new molecules or new products, as was the case thirty years ago, the competition between companies is based on a more rapid, a more economical procedure, hence this situation where the manufacturer cooperates with the scientific and technical space of his discipline, before subsequently going off to do his research alone.

Unlike what can be observed in the mechanical type industries, (construction), the logic of chemical production (transformation) marginalises human effort. "*Chemical production results essentially from the reactions of forms of matter between themselves. Human effort is therefore by definition peripheral to this production*" (12). added to which, the production by flow-line, either continuous or by campaign, accentuates the disinvolvement of man in the production process. This feature may explain the desire of the Management of the Production Unit to return to lines of homogeneous and pure products under the responsibility of engineer-managers, and to gather the intervention functions (innovation, etc) into specialist units peripheral to the workshop. It is after all impossible to "tinker" with the product in the production area, any intervention is prepared according to the follow up of the reaction, once production is halted. The functions of the engineer are distinct : the engineer-manager is responsible for supplying the installations in material for use in the reaction, for monitoring the reaction, for the control of the quantities of the products requested, the evacuation of the waste materials, etc. and the specialist is responsible for preparing production, controlling quality, innovation. The tasks of these two types of actor on the product in the same production area are also differentiated in time.

b. The Innovation Cycle

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12 *F. VATIN, op.cit.*

It is carried out according to data characteristic of the sector. Furthermore, the fact that the field of study in the "fine chemistry" field and on a industrial site where the Research Center and production unit are one and the same, will strengthen the links between the different institutional actors in the cycle. Whereas in the petro-chemical field, the transfer of products from the laboratory, to the pilot (which is important), then to production, is statutory and uniform, the upstream return circuits of the product are rare, in fine chemistry the differentiation is, however, less institutionalized : thus a manipulation made on the workbench will be made on the pilot and improved and sometimes the production area is nothing but a large pilot where it is always possible to make an innovation.

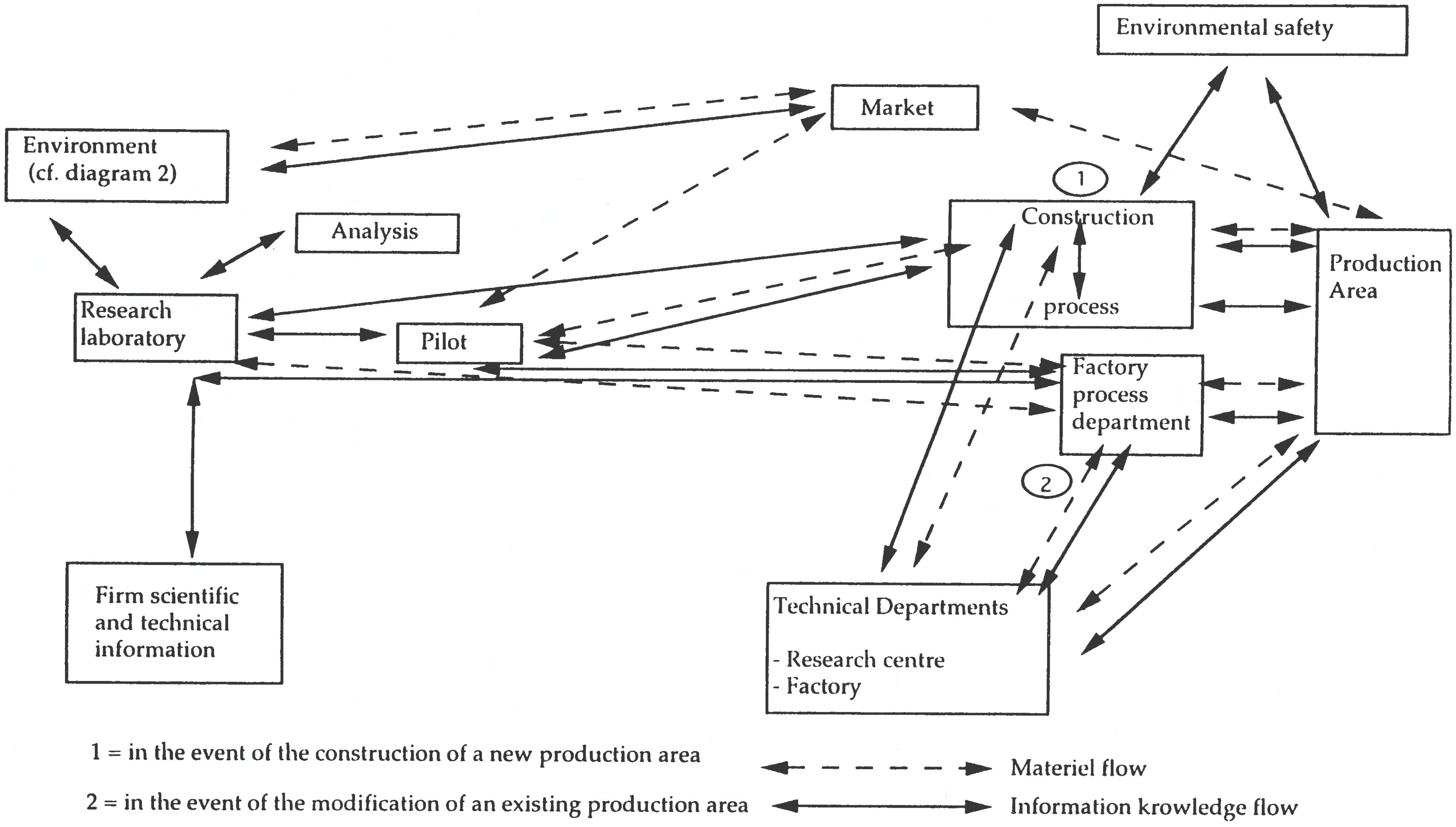
The "research and innovation" feature of our space will also explain its actors and inversely : thus the educational system of the engineers will remain present in the on-site environment : the role of such a school in such a technical discipline; the preference or not for a doctorate. Therefore, FC company, a firm of "engineers", has theoretically centralized recruitment and management of its executives: however, it can be noticed that for research, the choices are specifically made by the centers, that the RDID only becomes involved rarely and that the backgrounds sought differ from those of the manufacturing centers but, that the number of future PhDs in the factories is, however, not inconsiderable.

In the Figure 1-7 we have tried to distinguish the flows of knowledge, information, the material flows of the products, the services materialized which are realized in the innovation cycle.

Thus, the exchanges of the Information Department is in "production of knowledge" as with the analysis laboratory or the research laboratory. The pilot produces some knowledge but also products (to "test" the market, in particular), it takes advantage of the knowledge but does not receive products. The Procedure Departments receive and give information but also interchange products; the Technical Departments, depending on demand, supply a materialized service. The knowledge chain may be resumed thus: based on an accumulation of information included in the environment, in the Information Department, in the accumulated experience of the actors, thanks to the capacity of identification of the analysis laboratory, the laboratory produces "a recipe" which is verified, which is checked for industrial feasibility on the pilot. This recipe may lead to the creation of a new product, but it is more often, either a new procedure, or the improvement of an old process, that is to say a new recipe leading to an already known product. The result of the innovation process is, either the product, or the recipe, or the process. If the product, in the case of an improvement, is already being manufactured, the pilot "will pass" on, will transmit knowledge to the Process Department of the production unit. If the production set-up involves heavy material investments (construction of a new production area or the complete remodeling of the production area concerned), the project will be managed by the Technical Center for the procedure part and in liaison with the manufacturer for the construction part. We have to insist here on the interchanges between the various departments, within the research function, but also between. the process function and the research function. Thus the requests for

FIGURE 1-7

DIAGRAMMATIC VISUALISATION OF THE PRODUCT INNOVATION CYCLE



explanation go via to the Procedure Department of the factory directly to research. this return to the lab seems to be less current than in the past but its frequency is linked, without doubt, to the life-span of a product in production. Perhaps during the first years of the operation of the "substitutes", these long loops will be customary

1-3-2 THE ORGANIZATION OF A PROJECT

a. Varied project types

We are going to describe different types of project and more especially one of them, which is particularly strategic at the moment, the "substitutes" project.

The firm distinguishes clearly between the routine production process and an innovating cycle, since it modifies its traditional type of hierarchical organization for this latter case. The organization of an innovating process into a project should enable the firm to "mobilize all necessary competencies" throughout the product cycle. Thus the director of fine chemistry stressed, during our meeting, the importance of team-work for the engineers, and on the image that the Japanese convey : "*of an efficient organization without there necessarily being a leader*". The organization of an innovating process into a project should enable, throughout the product cycle, the "*mobilization of competencies*" on an objective. A research member of the same management team stressed the "transversality" of the projects within the firm and the link provided by the "product men" between the different moments of the process. The idea being to reunite the various actors in the process, within a well-defined time space, as on a film set, and to make them "function together" in unison like a task force with one aim, efficiency. Our contacts with the Research Center with the Technical Center, with the factory have enabled us to measure the differences between types of project and even, in time, between the moment of research of a project and that of the engineering, even if the symbolic discourse of the Heads of Department is identical "*a project is based on industrialization, a market, patents... its objectives are precise*"

The firm has given the name "project" to different realities :

- Thus at the Research Center, it would appear that there is a tendency for projects to be smaller and smaller : "*currently I have several projects but when I arrived, I had only one project. It happened that at times I shared several projects if they were large. At that time they were more important that today*" **I.I.R.**: even if they only involve one engineer and 2 or 3 technicians, the engineer can manage several projects : " *we only build a team for a special project when we are talking about a large project; with the projects that I have currently : 3 projects with one technician on each and me one third of the time*" **I.I.R.** The objectives of these projects necessarily involve rapid industrialization, and their end result is not always obvious for the engineer or for the technician. We consider them more like "research subjects" than projects (type A).

- On the other hand, the center carries out several large projects, which bring together several engineers and technicians, whose industrial objectives are precise, the intentions of senior management obvious, and the motivation strong : "*they are a great* *number of people who are working on this subject*" **I.I.R.** The strategic importance of a project will also influence the way it is conducted(type C).

- Other projects linked to precise industrial objectives may not pass through the Research Center, nor through the Technical Center and may have very varied methods of management (type B). They are characterized by a strong link with the market of a product and with its actors who are often single technique engineers.

In the interests of clarity, we have characterized three types of project onto which may be hooked more or less the real projects described by our interlocutors :

TABLE 1-14 Diagrammatic representation of projects

A: Subjects rather than projects	**B: "Research and Development" projects**	**C: Large projects**
Project listed on a precise technical discipline within the group	Project listed in a product rang e in which the firm is already involved	Strategic project for the firm
Objective more thematic than industrial	Precise objective : modification or improvement of a product or a process	Précis objective : result forecast from the beginning of the project
Light team around one engineer ; no real project team, no real project manager	Thematic team within a department gathered as project team	Mobilization of competencies around the project ; internal mobility to strengthen the team, if necessary recruitment
Does not necessarily pass to pilot stage. May result by increasing the store of know-how, or be sold as a patent, in fact a C pre-project	Does not necessarily pass to the RC or the TC : - either the development of the product is made by the research team which provides the link with the market - or the production unit operates directly with the Factory Process Department	Passes to pilot in engineering with a view to construction of an industrial site for the firm the development aspect is handled by Head Office
Installment of the research program	Planning for the development	Very precise planning from research to operations

This classification is only a diagrammatical representation of the variety of projects encountered. If the firm's Head Office sees in a project a unity in the innovation process, it seemed to us that on a same project, there were, depending on the moments in the cycle, different sequences : research - pilot - development - engineering - factory;

these different periods, each distinct the one from the other are not organized in the same way. When we speak of a project, we should also specify the moment at which it is occurs. In the same way, the achievement of a project will have an influence on its development, with its position, in both space and time, of great importance.

b. The development of projects

The RC and TC only function according to project structures, unlike the factory which substitutes this type of organization for the traditional forms, only in the event of innovation.

Thus, the life of the laboratories is punctuated by the choice of projects. The calendar starts in September when the operational management teams, the RDID and the Research Center propose themes for research : the operational management teams define the subjects in relation to the evolution of the market, the state of the competition, the industrial strategy of the firm, the needs or the industrial problems of the units (modernization, etc.); the RDID will propose themes linked to the scientific and technical space (advances in this or that field, etc.) from the firms own scientific viewpoint. The proposals of the RC and the researchers will take account of the knowledge acquired earlier, of the vision of the laboratory, of the supposed interests of the firm : "*the proposal of a project made by the researcher is not really the result of an individual process, it is obscure, firstly we discuss with the Head of Department*" **I.I.R.**; in the B-type projects, the proposal is linked to a precise awareness of the market of products : "*I had an idea for a long time, my boss was against it at the beginning, we made several manipulations which worked, so we proposed a research project. We undertook an economic study, we questioned the manufacturers, gave technical results, etc.*" **I.I.R.** Based on these different requests, and the programmed schedules describing the real projects, an annual research program is drawn up with objectives, human means and costs. During the meetings between the different operational management teams and the RDID, a program is finally agreed as well as the financing;

The project will be supervised throughout its development by a research delegate and by a representative of the operational management department concerned. This latter will sometimes be nominated "Project Manager" by the management to follow the process of innovation throughout the cycle.

In the case of A- and B-type projects, the project will always be assigned to the competent department at the Research Center without the project organization modifying the traditional hierarchy : for A, the subject is given to a " Project Manager-Research" who works with the technicians who are assigned to him, for B, the department is more mobilized by the theme, and the Head of Department will become the Project Manager-Research with an engineer and his technicians for C (cf. "substitutes" project) there is a real constitution of a team which cuts across to the traditional hierarchy like a cinema set by project sequence and a wide mobilization of competencies.

The Project Managers have a hierarchical importance which varies according to the type of project. Although this title is, for the management, a means of motivating the engineers, their is a gap between the image that management wishes to give of this role and the vision that the latter have of the task : in FC company, it is an honorary title which does not necessarily correspond to a plus vis à vis someone who is not a Project Manager... **I. I. R.** "The first day I arrived, I had a Project Manager office **I. I. R.** The Head of Department in any event remains the privileged interlocutor of the senior management of the center. The project organization for projects A and B in any event, seems to be the result simply of a discourse and does not call the traditional organization nor hierarchy into question : "*it merely is a question of choosing one or another organization, they can co-exist*" Head of CR Personnel.

The experimental nature of chemistry does not allow a precise normalization of the project planning. The engineers only seem to be aware of rather imprecise and non-motivating deadlines : "*as there are no structures for negotiation in the project, there is no timing... there will only be timing when we have decided upon the construction of the unit*" **I. I. R.** We shall see, in the example of the substitutes, that in C-type projects, the calendar is precise and the deadlines strategic.

The engineer in charge of the project (Project Manager-Research) will firstly devote himself to the bibliographical part of the study, then he will propose an experimental plan, investigations, theoretical knowledge - traditionally justified by his "scientific" competence, this task is reserved exclusively for him. During this phase, he will use the Documentation Department. After the agreement and the detailed "review" of his proposals, he directs the plan of the manipulations to be carried out by the technicians. Throughout the research phase, he orders analyses from the analytical laboratory.

If and when the project "passes" to the pilot, the timing will be specified : the subject of research becomes increasingly a project; a new Project Manager is named, the transfer of the acquisitions made in research is very formalized : a document on paper of the state of the study approved during a meeting with the decision makers. The work organization will start to resemble that of the production area : the new Project Manager carries out these functions under the orders of the Head of Department, with a technician and three operatives; he has to implement : "*the identification and the qualification of these physical processes (transfer of matter, of heat, of fluid mechanics, etc.) which constitute the bridge which enables the cross-over from the laboratory to the industrial scale in the best possible technical and economic conditions*" **I.I.Pi.**

The future of the project is governed, throughout the various stages, by the units of decision-makers : after the research phase or after the pilot stage, the project may be abandoned or shelved to be brought out later, it may be extended by one year, be patented or sold under license, or passed to the pilot : "*We stop the projects slowly most of the time, it can happen that we stop because we have achieved the desired results and then when we build a unit, either we retain the results or we pass to the patent phase*" **I. I. R.** "*It is very rare to find a project that goes right to the very end*" **I. I. R.** The halting of a project in the same way as the abandoning of a scientific procedure may be taken as a stalemate or be seen as the proof of industrial efficiency : "*we have stopped like everyone else, we are not the CNRS*" **I. I. R.** *It happens that we stop a project, that* *may be frustrating, it depends on the circumstances; the responsibility of saying "**we must stop the project**" falls to the Project Manager, the decision is taken in conjunction with the divisions, there is a consensus, but if the Project Manager proposes it, it means he has a good reason" "..."* **I.I.R.** According to the type of project, the halt will be seen differently : project A which is a subject of research belongs to the scientific domain, stopping it is only an industrial episode and does not damage the actors. Project B has a strong development end result which implies that it cannot be stopped or even put off without calling into question the links between the different actors and the market or potential customers; *"Initially, we undertake studies here, we do not have enough customers yet, we consider it to be a good pole of research thanks to our knowledge of the market, then we go to see a manufacturer of equipment and we propose him our product and thanks to a contract of collaboration, we finish our research on this product with them in such a way as to arrive at a formula... and then after we propose it to others : they ask for samples make some tests, they obtain these or those results. In general, at the beginning, it is never good, so we return to the drawing board"* **I.I.R.**; the stopping of a C-type project is taken as the result of a change in strategy of the FC company, but is just as badly accepted by the actors.

The project is only transferred to the Technical Center if it modifies fundamentally the industrial installation or if it necessitates the construction of a new production area or a new plant. It most often of C-type. In general, the decision to transfer to the TC is taken by the operational management in liaison with the senior technical management, it is financed by the former.

From that moment, a short pre-study - three months - is embarked upon, it will be carried out by one or two engineers often new engineers, under the responsibility of a "senior" and with the support of the Costing Office, the Estimates Office and the Documentation Department. It will essentially consist of an economic study of the project after a rapid material summary has been made together with a preliminary plan of the procedure.

This first rough outline will enable the "decision-makers" to confirm their choice of construction for the industrial site, and only the Technical Project Manager will be appointed. The latter is chosen from among the engineers from the Procedures Department or Construction Department; his responsibility and his quality are well known in the center and within the firm. He has the responsibility before drawing up his project team to make a "request for means" in finance and men and to propose a plan; once these are accepted, the project starts as well as the stop-watch : *"it's a project : fine chemistry division, there is Product Manager who is present at each meeting, who follows the variables and the investments. He is not the Project Manager, that is someone from the TC who is responsible to him for the costs, who has to control the requests for loans, asks for endorsements, if there is not enough money. He controls the planning, the costs, the feasibility : he is a superior and an organizer"* **I.I.T.**

The engineer or the "procedure" team must as quickly as possible (3 months) take stock of the material situation and the procedure plan made during the pilot stage by detailing them in order that in the following three months the different machine schedules may be drawn up. These different elements are gradually transmitted to the Construction Engineer who will have the Drawing Office prepare, under the direction of one or several engineers, the PID (Process Instrumentation Diagram). *"We prepare the material schedules which will be transmitted by the Procedure Department to the Drawing Office, we specify the type of equipment, the most important values of the equipment : size, power, etc. from there and once it has been signed by the Construction Department, the Drawing Office based on these schedules, draws up PIDs which are procedure-type diagrams but more precise, and to scale : they are the basis for all projects, they will be updated throughout the duration of the project. They have to be approved. There are constant deals between us and the Drawing Office, we have not given all the specifications, etc."* **I.T.T.**

Parallel to that, the Procedure Engineer will deal with the problems of safety and danger, whereas the Construction Engineer will follow up on site. They will meet up at the end of the project to take part in the commissioning process. These two competencies will be assisted throughout the process by a "network of competencies" the representative of which, within the projects is the Engineer-Technologist. He will provide, according to needs, the specialists in metalwork, instrumentation, electricity, mechanics, roofing, chemical engineering, etc.

Once the project has started, the future operator becomes an associate of the firm. He will henceforth participate in the monthly project meetings which bring together the operational chemistry senior management and senior technical management, the RDID as well as the manager of the CRD representing research (lab and pilot) and the Project Manager from the TC (a meeting by type of product and one for the whole of the project). Within the project engineering team, there is certainly a splitting up of competencies, procedures, construction, technology, but there is also a real finalized common effort, there are technical discussions, negotiations between the specialties, something we did not encounter within the research field.

If within research, the type of hierarchy which dominates were the traditional hierarchy, at the Technical Center the real project organization gives value to the responsibility of the project : the hierarchy of the projects is recognized and esteemed by the engineers even if the department remains a place of identification: *"For each new project there is a new organization, but an organization chart is published each time, for it is the organization which works best : I have the impression rather of belonging to a project than a department, the aim of the Procedure Department is the project"* **I.I.T.** This changing organization compared with that seen in research, is confirmed by a former member of the TC who has moved to the RC. *"In the department, we were at least three engineers, Contract Managers of sorts, and there were technicians grouped in the Drawing Office; we were assigned one or several technicians for a precise project : it was an ever changing organization".* **I.I.R.** *"I had no hierarchical responsibility over the technicians, during the projects we worked on together. There was a project and a Project Manager, it was the real structure of the project that we followed from end to end. There was a well defined schedule for the project with dates marked in time as you will find in all industries".* **I.I.R.**

The project will remain under the responsibility of the TC until its launch even if the operator is associated with the elaboration of the new production area or unit. Sometimes a special structure is implemented at the factory as we shall see for the substitutes project.

Between the different projects analyzed, only the C-type projects modify slightly the traditional hierarchical organization of the Research Center, only these pass through the TC, even if the B-type projects may arrive in the production unit. The A- and B-type projects, either only concern research, or have limited and ad hoc objectives and are only projects for us in name, even if they create innovation and renewal. It seemed to us necessary to come back to the organization of a project which has a strategic value for the firm.

1-3-3 THE CFC "SUBSTITUTES" PROJECT

a. The origins of the project

CFCs (also called Foranes) are products created within the last 30 years and used in the "cold chain" (freezers, refrigerated transport, etc.), in aerosols (30% of CFCs), in the foam sector (flexible or rigid), in the solvent sector. These products are manufactured, for the most part at the FC company in the factory studied.

Starting around 1974, the scientific community and certain politicians became concerned by the effect of the use of aerosols on the ozone layer. Certain of our interlocutors put forward the hypothesis to us that the American chemical group Dupont from Nemours was at the origin of this "toxico-commercial" affair, so as to see off the competition on this type of product by eliminating the small and medium businesses who would henceforth be unable to contend with the investments necessary for the substitution. It is still the case that the direct relationship between distribution of Foranes in the atmosphere and the "hole" in the ozone layer has not been established and that doubt continued throughout the project : "*We are aware that there is a potential risk, but we must clearly establish the relationship between the potential risk and what is happening on Earth.*" General manager of A. ([13]).

A protocol was signed in 1987 in Montreal by 31 countries among which France, to control the production, the sale and the interchanges of CFCs and related products, and a later EEC decision proved to be even more restrictive. Faced with the determination of the politicians and the ecology movement, the senior management of A decided upon a policy of substitution for the CFC products by the HFA products (hydrofluoroalcanes). Research into this substitution started at the RC some ten years ago (A-type), furthermore the industrial site (RC + Factory) already has a real knowledge of this type of product since certain HFAs are already produced in the production areas of the "fluorinated resins" Department, as intermediaries of other products. The senior

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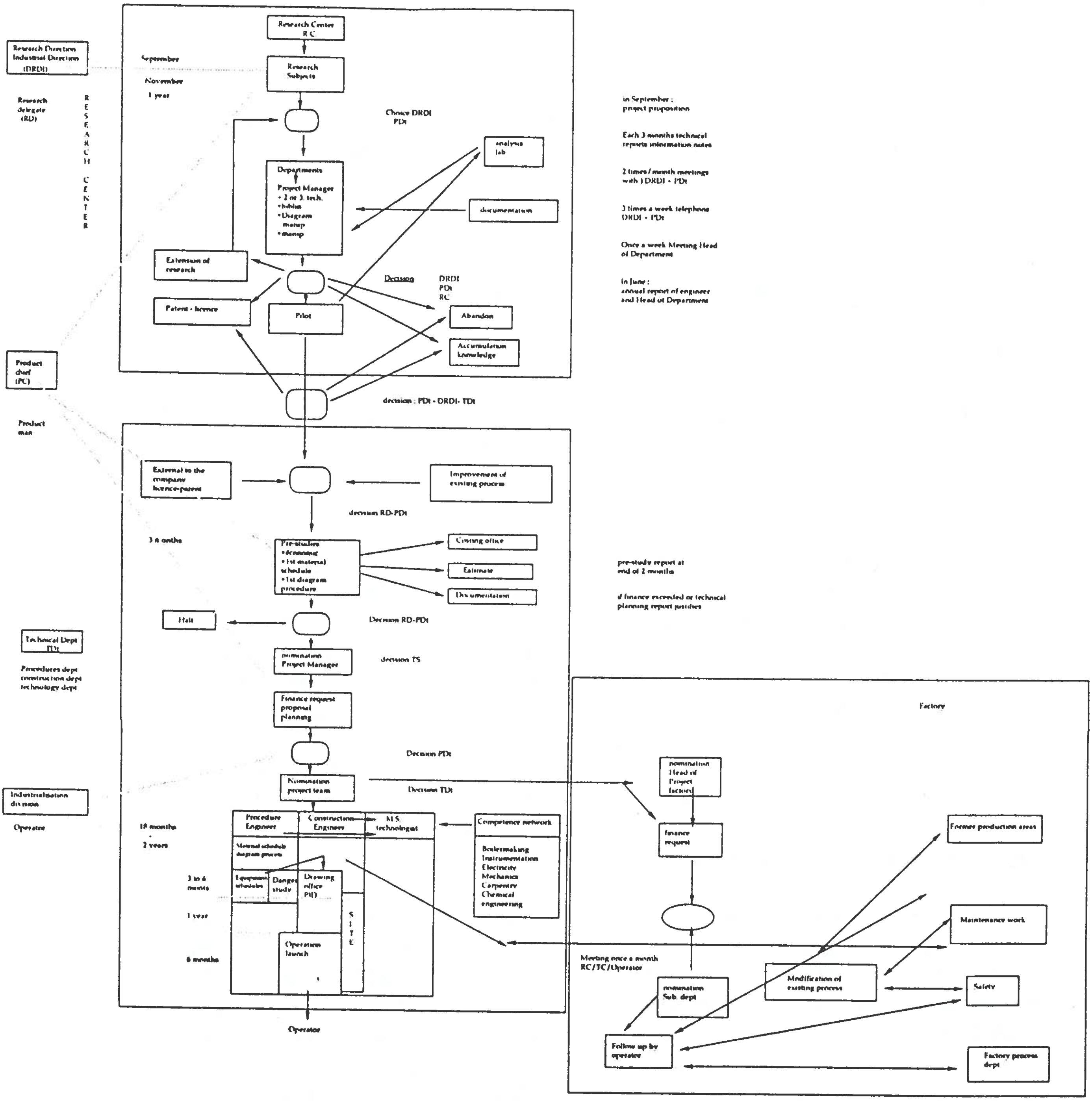
[13] *March 6th 1989 Usine Nouvelle*

FIGURE 1-9 DIAGRAM OF A PROJECT LEADING TO NEW PRODUCTION AREA



management therefore decided that the industrial site studied would substitute the former CFC workshops to the new (HFA).

The investments planned by the firm were to be heavy : "*in 1988 we shall probably have invested around 1.5 billion francs in research and development and production areas*" Deputy Director of A ([14]). From 1988, the FC company moreover signed an agreement with another large producer of CFCs (outside France) for research focusing on the production technology as well as pilot production areas.In June 1988, the two companies increased from 30 to 50 the number of researchers involved. The whole of the cost of the joint effort realized can perhaps be assessed at 50 MF per year, moreover, 800 MF of construction work for new production areas were decided in 1990, workshops which will replace other CFC production units which are to close.

The majority of the HFA are well known products. Therefore environmental and toxicological studies undertaken at international level by the main producers are already underway, but innovation for each of the companies takes the form of either an improvement in the procedure (HFA already produced at the factory) or in the procedure itself.

The production of these first generation substitutes has been increased at the factory studied so as to enable the sales staff in liaison with the product men to test a range on the market. In fact, the HFA will not recover all the current commercial outlets : *certain sectors still prefer products which do not belong to the same chemical family or which involve different technologies*". ([15]). Thus in the aerosol domain, the CFCs have henceforth been replaced by mixtures based on Butane, Propane or Dimethylether. Furthermore, the HFA are more expensive since they are difficult to produce, they must therefore be saved and "recycled". There is therefore a part substitution "that which takes the place of something else, that which replaces, plays the same role" ([16]) of a product, but not the recovery of markets.

b. The operation of the "substitutes" project

It is similar to that of the C-type project with a reinforcement of the strategic characteristics of the latter : we have seen that, before being priority, this project had been developed in research according to a path A, but upon seeing the size of the stakes, senior management quickly decide upon the programming, the budget, etc. There are not as with an ordinary product intense discussions, negotiations between the different actors of the process. Everything, in our example, is discussed and negotiated at Head Office

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[14] *Presse de l'Entreprise 1984*

[15] Presse de l'Entreprise 89

[16] *Petit Robert*

and applied locally, even if formally, there will be as always, the drawing up of a program schedule, establishing annually the objectives and the means.

The Project Manager covering the whole operation, because of the high stakes involved, is a member of the senior management team of the FC company. The result is, in practice, a Project Manager by function type with an obligation for intense coordination.

What will characterize the project, will be the importance taken by the calendar and the time scale : these are determined a priori, according to the date programmed for the opening of the production areas, it fixes impressively the start of the different phases, independently of the evaluation of the results of each of them. These different movements of the process (research, pilot, CT, etc.) are less broken up in time than during other projects. Thus, the project passes to pilot, whilst work in the laboratory continues, in the same way, when the new production area starts to function, the substitutes will continue to be analyzed and experimented in research or in pilot. The toing and froing of information between the different moments of the development are current and do not represent the character of a stalemate or lack of success for the actors that we have seen elsewhere.

At the Research Centre, the project is assigned to the department thematically competent, that is to say the fluorine derivatives, and will constitute within it the research team for the project. This latter brings together engineers and technicians, with the Project Manager being one of the engineers. On this occasion, the department is actually redeployed, contrary to usual practice, to bring together the competencies necessary for the stakes involved; the role of Head of Department, the hierarchical head taking cardinal role in this action. On the other hand, it seemed to us that a certain type of habitual organization had been reconstituted in the center : 1 engineer coupled with "his" technicians and his "manips"; we in fact noticed that the engineers had "split up" the work by type of technique. "*The engineers on the project split up the work, there is a part in the gas phase and a part in the liquid phase*" **I.I.R.** and have redivided each task between the technicians (a fluorination line), no meeting was organized to enable the team to have an overall view of the project.

The follow up of the different stages will be placed under the control of the new hierarchies at the highest level in the firm, and resources, both technical and human will be mobilized in both number and quality.

Thus at the TC, the Project Manager appointed is from a important hierarchical level and he has the power to intervene in the structure of the center to concentrate the means he needs, when he wants them during the project. He also supervises as much the procedural aspect as the construction aspect; he is the pivot for the transfers of knowledge or resources between the RC and the future production unit, and to achieve this, it was he who initiated the creation or a "substitutes coordination" Department in the factory; the role of this unit being twofold :

* "*Provide an interface between the factory with its personnel and its engineering staff... It is quite simply that when we graft manufacturing or new structures onto an existing unit, it is the existing social and technical...* " **I.I.P.**

* The representation of the operator : *engineering has a tendency to provide a"turnkey "operation, but we, our part of the work consists of saying to them, we want this for this purpose... to optimize the manufacturing tool that we are going to need to use later on...*" **I.I.P.**

To do this, the department is organized according to the following Figure :

FIGURE 1-8 Organization of the "Substitutes" Department

CDS

Product 141/142 1 Engineer + 1 Supervisory staff	Product 134 a 1Engineer + 1 Supervisory staff	Representatives of Technical Departments 2 technicians	Common supervisory staff	Supervisory procedural training

The two units, bringing together an engineer and a member of the supervisory staff, make the daily liaison with the Construction Department (report schedule followed every day) have relationships a little less frequently with the Procedure Department; the Procedure Department of the factory has moreover an engineer who concentrates on the project. The technicians made available by the Technical Departments provide all the mechanical parts, regulation, electricity, and "*provide the interface between the factory and what we are going to construct*". **I.I.P.** The entity "common" (cf. Figure 1-8) considers all the common needs that the two production going to be built will have (steam, etc.). One supervisor is responsible for planning and organizing the training necessary for the operatives (around one hundred) who will pass from the closed production areas to those about to be created. It also brings together what the Head of Department refers to as "procedure" : *it is a fact that from the moment that you create something new within the existing that you need to graft it, therefore, we call this procedure, which is everything that we can inject in order that the graft is not rejected*" **I.I.P.**

The Head of Department and his team are responsible for the organization of the future production areas, as well as the closing of the old ones, taking into account the objectives of production. They have to forecast the new labor needs and the level of qualification of the future employees. The new structures will be implanted in the "Foranes" Department, the two head of product "coordination" engineers will become respectively the two operations engineers "*it really is something to ..., it's exceptional to* *live through that; not everyone has this opportunity..."* **I.I.P.** At this moment the atypical existing organization which favors the role of the supervisor as opposed to that of the engineer will probably be called into question (cf. IIIrd part 3), which was one of the future operators wishes.

The closer the project deadlines, the more uncertain they become, thus the closure of all the Forane production areas should have taken effect, but it is not the case; all the actors concerned avoid specifying to start-up date for the new production areas. On the other hand, there are many people who, stress on the double gamble made by the firm, both economic *"they are products that we are not familiar with"* **I.I.P.** and technical *"you have to realize that it is a mad gamble..."* **I.I.P.** The approaching realization of the project does not lessen the uncertainty for the majority of the actors, and if in any event it has been lessened, it is in a different way depending on the position held in the organization : thus researchers who have worked on first generation substitutes are probably reassured, despite the imminent operation, but the manufacturer is not; on the contrary : *the worst will be a revision of the specifications"* **I.I.P.**

The project should enable the firm to mobilize, for a determined period of time, all the competencies around a particular objective. It should enable the various actors to work together even if they are not used to it; to do this, it creates procedures of communication, of concentration and approval (reviews, etc.) between them and between the sequences (phases) of the innovation process.

The type of organization is more or less formalized depending on the type of project. Thus, in an A-type project, it would seem that the substitution of such a management by that provided by the traditional hierarchy serves as a smoke-screen and that the scientific work continues to be performed within small teams directed by a researcher. The B-type project whose objectives are, in the short term, precise and finalized, brings together competencies that are not dissimilar one to another : same department, same specialty, familiarity with working together. The efficient mobilization of all the firm's resources was only realized in front of us in the HFA project which succeeded in organizing the cooperation of the different actors of the cycle as a task force, even if the sequences of the project were maintained and that the image of a film set was not realized.

1-3-4 THE DIVISION OF WORK AND COOPERATION

The division of work as well as the division of labor are expressed differently according to moments of the cycle of innovation and according to the type of actors who participate. It may also give precedence to a cooperation and a mobilization on a project.

a. The division of work and cooperation throughout the cycle

The product cycle is divided into successive phases both outside and within the firm. Thus in the description of the scientific space and innovating space given in the first part of this monograph, we noticed that there exist specific places to produce basic knowledge and that the firm was specialized in a finalized and applied research. These professional spaces each have their own specialty, they keep up contacts, even if they are not working on the same moment, the same sequence of the process; the information flows from one side and the other are under tight supervision due to the fact that one part of the research is being conducted outside the firm. *"we must be careful for by asking questions, we give information"* **I.I.R.**

Within FC company, the different moments of the cycle are differentiated in the organization chart. The RC belongs to the RDID, the TC to the TD, the production unit to product management, as far as research is concerned, the applications (CA) are separated from finalized research. The formalized relationships between these units stem most often from Head Office. On the occasion of the strategic project on substitutes, senior management tried to initiate cooperation between the different centers which are, as it happens, on the same geographical site. This was attempted by formalizing the structures of dialogues and the information networks (meeting, commission,etc.) and we are led to wonder if this rather forced collaboration will last after the project. In the second part, we saw the difficulties of mobility for the engineers from one of the phases of the process to another. The division of work might, in fact, correspond for the actors, to professions, to different specialties *"it is not the same profession (research)"* **I.I.P.** depending upon whether you are in research, process or production area, for example. This type of argument presents problems : indeed, we have seen the importance of the initial training in the assessment of an engineer and in his career path, and in the same way, the weak recognition of his acquisition of technical skills within the firm. However, the engineers in FC company do possess, with the exception, of certain "single technique engineers", an identical type of training (the schools of chemistry), which may lead to a feeling of belonging to a common profession, that of the chemist. Chemistry as a scientific field, as a sector of activity is a referent, within which there are several functions : that of researcher, producer, etc., and several specialties; thus engineers in chemical engineering (single technique engineers) constitute a community amongst themselves and apart, they may be mobile between research (the pilot), the TC (procedure) and the factory (Procedure Department), they often act as intermediaries between the different functions of the firm and are at the origin of the cooperation between the different actors. The applications engineers also have, this type of role within the firm, between research and the market (the customer).

If the work process is split up into different stages, into sequences which are often impermeable to one another, within one of these phases, we see the same type of division.

In Research, first of all, the Documentation and the Analysis Department offer the research laboratories assistance by providing services and only rarely become involved in the project : " *we have constant relations with the analysis lab, it is a service lab, we turn up with a product and ask them what it is, we explain what we have done, they enter straight into the subject in certain cases"* **I.I.R.** these are relationships of a subcontractor type which exist between the different units, with very different professional recognition between the actors, with the researcher being considered more valuable than say the analyst or the documentalist. The research moment is just as distinct from that of the pilot, the interchanges of information only taking place in a formalized way and in front of third parties. We did not meet engineers or technicians following a project to the pilot stage to be able to continue to see the evolution of the experiment "*the engineers rarely come to see the pilot, a technician comes more frequently*" **I.I.Pi**. Between these two structures, the tasks are described as being very distinct : *in order to implement a procedure, research undertakes basic experiments to know what may be applicable on the industrial level and we make the industrial procedure*" **I.I.Pi.**

Here again, the professions are described as different "*the pilot is already industry...*" **I.I.R.**; the type of work is very specific.

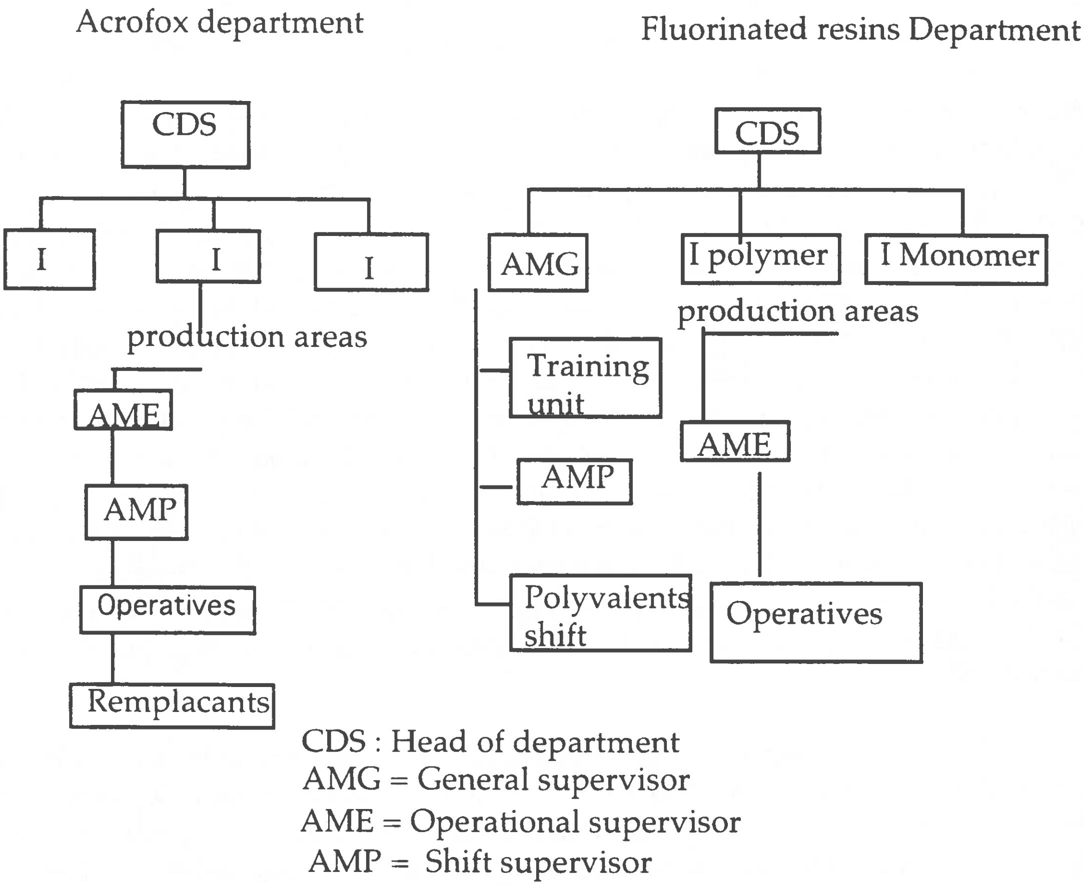
At the Technical Centre, the division of work is carried out according to the different disciplines necessary for the realization of the project by units of competence : procedures, costing, construction, etc... each being called when necessary by the consulting engineer. We have observed, moreover, that this type of organization also enables the sub-contracting of part of the tasks outside the firm. "*A did not want, for reasons of workload, the engineering to be undertaken at the TCL : senior technological management decided to call upon an external engineering firm abroad (within the EEC) which had already worked on this product, on the procedure...*" **I.I.T.** This practice of collaboration with the exterior does not seem to be more difficult than if it were internal and there the technical competence is still preferred.

At the factory, we have noticed two types of logic leading to distinct work divisions :

1) Firstly that which consists of making the product line "pure", by undertaking properly technical functions, where the work of man gives "added value" to the process of chemical production, that is in the areas of maintenance, safety, quality, innovation, services independent of production; there remains in the production area solely the management of the continuity of the chemical process.

This type of division of work as well as the professional skills of the actors leads to an organization of work between Engineers and Supervisory Staff which current on the site, but not obligatory : thus, at the Acrofox, we find a traditional hierarchical line : CDS, Engineer, Operational Supervisor... (cf Figure 1-10), whereas at fluorinated resins, the Head of Department has under his orders two engineers, one of them responsible for the monomer workshops, the other the polymer workshops and a general Supervisor (AMG) responsible for training, shift supervisors and some polyvalent available to both departments, since the engineer (monomer or polymer) only has under his direct orders the operational Supervisors and the operatives.

FIGURE 1-10 Organization of two production areas



Without thinking too deeply about the trends which appear in the factory organization, it would appear that there is a desire to homogenize the different forms of technical management, to rationalize them. The chemical products from the factory are intermediate products, products in small quantity (fine chemistry), very specific even if they are catalogued, stabilized and commercialized to a known clientele. They induced a type of organization of multiple small production areas coordinated with each other, flexible, and providing the manufacturing and also safeguarding the reproduction, the durability of the product (maintenance, innovation in the safety process, etc.). The autonomy of the Operations Supervisor responsible for a workshop was then large and the roles of the Production Engineer and Study Engineer well determined. The automation of the production areas has enabled the Shift Supervisors and the Operatives to ensure the control of several production areas at the same time, it has then, made possible economies in the position of General Supervisor (who covers the whole department) necessary at this time (chemical industry crisis) and has enabled a reduction in the hierarchical line, whilst retaining flexibility thanks to the introduction of polyvalent staff. In this type of organization (fluorinated resins types), the production engineers seem restricted to a technical function (management of the workshops and heads of production) in the medium term, the AMP being responsible for the very short term organization and for man management. We observe that this AMP (they are three in number) has a full range of department know-how, since as a former AM Operations who has risen in status, he is a former member of the department and has a good knowledge of the environment thanks to a mobility within the factory. His weight in the organization, compared with an engineer who spends a little time in each function and from whom they have removed the long term tasks to be replaced by procedures is therefore very important. This role is also going to minimize the importance of the AME of each production area, the latter younger and better qualified, finds himself in fact cut off from part of the tasks, and operatives (an AMP who has a problem with the production area of an AME will talk about it firstly to his hierarchical superior (AMG). Faced with this situation, it seemed to us that the senior management wanted to come back to a pure hierarchical line, certainly costly in labor but identical for all the departments and, where the engineer covers all the tasks which are normally entrusted to him, that is the "*technical management, the organization and man management*" **I.I.P.** This will lead along with a tendency to strengthen the procedures, to an investment in the work of transcription of bibles "*indicating what should be done, by whom at which moment...*" **I.I.P.** with the avowed aim of stabilizing the production process but also formalizing the existing knowledge to be able to transmit it more effectively. This type of rationalization should also help strengthen the powers of the engineer (written knowledge) faced with a technical competence, dominating the non formalized savor faire (oral knowledge), and also centralize control and thus reduce the autonomy of the production areas.

2) We must come back to the organization by product line or by process that we observed in the factory : we noticed that in the Fluorinated Resins Department, the current trend was to return to process lines; this type of production organization can be justified by a superior efficiency of the actors in their own profession : monomer or polymer, etc. this reassures the engineer in a precise technical function as a specialist as well as the importance and the potential of his knowledge compared with his savor faire of the product. The engineers from this department are also former chemical technicians who have in large measure been trained on the job. This type of workshop management coupled to the importance granted to the role of the AMP marks without doubt the desire to separate from production engineer-mangers who are too mobile, to reconstitute within the production area the set of tasks of the technical function, to incorporate and ensure the reproduction of the savor faire. All this seems possible in the type of production department where the process is fluid but not totally continuous (campaign);

This type of division of work or of cooperation will therefore induce certain types of divisions between actors.

b. The division of labor and cooperation between actors

1) Individual work and collective work cooperation between engineers

In the project of research into substitutes, we have noticed that the research engineers had broken down the set of tasks into two very distinct subjects in order that each remained master of his team : *the project engineers shared the work, there is the gas phase part and a liquid phase part"* **I.T.R.** *"We each have our Fluoridation lines, as for me, I am responsible for three technicians and I have three lines, he has three technicians and two lines"* **I.I.R.** In the same way, it would seem that senior management prefers to multiply the small projects on which one engineer intervenes, prepared to coordinate the different tasks itself, rather than initiate larger projects where cooperation between engineer is hit and miss : *"Currently, I have several projects, I have rather several jobs on the go which depend on several projects"* **I.I.R.**

At the Technical Centre, the engineers are not placed in competition, even if they intervene on the same project. They are, in this case, the representatives of the different disciplines working towards a common goal.

Throughout the production process, the tendency of the firm is to create for each engineer a space of autonomy compared with the other engineers and to lessen the hierarchical relationships between them. Thus, the role of Head of Department at the factory is administrative, management, he is more the interface between the senior management team and the production than hierarchical head.

It seems to us that, given the valorization attributed to external training and given the solidarity of the corps of the schools, the firm avoids producing and classifying the individuals itself, and then hierarchising them on a production site. We can also be led to think that the scientific dimension of the sector integrates into this reasoning which means that a young engineer is considered just as competent, if not more so, than an older colleague because he is closer to the scientific and technical space. But we should also ask ourselves about the wide and frequent use of the proximity of this space with that of the firm. Is it not also used as an alibi?

For these reasons, the cooperation between engineers is difficult and only imposed when absolutely necessary : e.g. substitutes project.

2) the division of labor between engineers and technicians or supervisory staff

As in any research Centre, the division of labor between the engineers and technicians is clear-cut. Engineers justify it firstly by the difference in knowledge between the two categories more than the level of studies (which effectively poses a problem when an engineer is a BAC + 5 years study and the technician a BAC + 4 years study (Master of Science) : engineers are holders of theoretical knowledge, scientific knowledge as opposed to the practical knowledge of the technicians : *"the only authority is an authority of competence, those people have a technician's training, they can only solve problems at a technical level, as soon as a scientific reflection is required on the bibliography, patents, no!... Me, I bring new ideas, based on scientific fact"* **I.I.R.** *"But their knowledge is different, there's information that they do not have..."* **I.I.R.**

If the engineers are the only ones to possess scientific knowledge, they may, according to them, share in technical knowledge : *"I have the scientific knowledge but I master the practical, I could carry out some manipulations ..."* **I.I.R.** *" When I arrived here, I abandoned the practical part carried out by the technicians, I only attached myself to the theoretical part, I divided the competencies, the theory is my domain, the practical, they are better, I leave it to them..."* **I.I.R.** The superior technicians who possess a BTS or an IUT understand this weakness in engineers; *"If there are some technical problems not justified by the bibliography, they are more embarrassed than L"* **I.T.R.** and they often remark that information and certain types of information do not reach them : *"the objectives... the engineers knew but did not talk about them"* **I.T.R.**

This distribution between the two types of knowledge is accompanied by a complete division of the tasks. For certain engineers, their responsibility is the bibliography, the drawing up of the plan for experimentation, whereas the work of the technician is the implementation of these experiments, that is to say the manipulations : *"I do not carry out manipulations for it is not necessary..."* **I.I.R.** *"in the spirit of an engineer, a technician should not manipulate"* **I.T.R.** *"The library to a technician? No, they do not like it..."* **I.T.R.** This is accentuated by the desired dispersion between the places for the different practices (the office and the laboratory) which widens further still the division of labor and the separation between the categories : *"the engineer in his office, the technician on his workbench"* **I.T.R.** *"they used to give us an experimentation plan, but never worked in the lab, there were in there offices on the first floor..."* **I.T.R.** Certain engineers aware of the importance of experimentation desire a close collaboration with the technician and do not abandon the manipulation work of the research chemist : *"This little I don't know what, it's the technician who will find it, because he is the one who manipulates, if the engineer is always in his office and does not have a good relationship with his technician, he will not understand..."* **I.I.R.** *"engineers do not much like to see their technicians spending time in the library, but L told me last week that it would be a good idea if I were to go and look up some references on different subjects in the library"* **I.T.R.** *"if I leave the workbench, I would have to leave the Research Centre for I should no longer be at home here"* **I.I.R.**

At the <u>Technical Centre</u>, the division between engineers and technicians is ratified by the organization itself; the engineers participate as such in the different projects whereas the technicians are grouped together in the different offices - costing office, drawing office, etc. - directed by an engineer. These offices, like the technicians provide services for the projects and for the engineers. The hierarchical relationships do not therefore exist between the majority of the engineers and technicians. *"I have had few contacts with them (the technicians), because they are all part of autonomous offices"* **I.I.T**. It would seem that within the costing office, where we met a woman engineer, the high degree of specialization of everyone *"makes the distinction between engineers and technicians very difficult to perceive"*.

It seemed to us that the division of work between the engineers and technicians was less when the engineer had a doctorate. In fact, it would seem that although a doctorate may be an individual exercise which does not encourage team-work, a doctorate obliges an engineer to acquire a practical knowledge that is to say "to manipulate in the laboratory"; he backs off less on his technical knowledge confronted with a competent technician, no longer takes refuge in his office: "*furthermore, when they (the engineers) have a doctorate, they have manipulated therefore they are happier to spend some time in the laboratory. Those who have just left chemistry school have therefore never manipulated like us, they are worried and hide in their offices*" **I.T.R.** At ease as much in the laboratory as in the library, the holder of a doctorate makes the different tasks less rigid and less compartmentalized. "*I used to work in the library, I got fed up and as I really wanted to manipulate...However, at A tradition has it that engineers do not manipulate.*" **I.I.R.** This division seems also to be aggravated depending on the scientific disciplines, the more important the "chemical recipe", the more necessary it is to appreciate, to see a synthesis take place, and the more the division of the workplaces of the engineer and the technician are harmful : on the other hand, in those fields close to physics where the experimentation is more easily measured, we observe this separation much more clearly. "*I don't go to the laboratory, chemists tend more than us to go and see the manipulations, but I am on the physics side of things*" **I.I.Pi.**

In the factory, the competence of the supervisory staff in the production process obliges the engineers to restrict themselves to "management" tasks, unless they reserve for themselves technical functions outside the workshop : Procedure Department, Environmental Safety, etc. The division takes place then between a qualification and a savoir faire acquired over a long period on the site and an external training backed by an overall awareness of the firm obtained thanks to mobility. The management of the "Fluorinated Resins" Department is attempting to create a collaboration between the different parties, by maintaining engineers in a technical function where "*they have a long term vision*" **I.T.P.**, and by trying to incorporate the savoir faire of the supervisory staff.

3) written rules and informal knowledge

From the Research Centre to the production area, we have observed that the technicians and supervisory staff do not formalize their know-how before transmitting it, they do not regulate their relationships : thus, it is they who accompany the project from the lab to the pilot, it is they who organize and initiate, on the job, the reproduction of the qualifications of the workforce in the firm. On the other hand, the engineers manage their function based on procedure: transmissions of draft projects under review, edition of instructions "Bibles", etc. These two "ways of doing things" strengthen the contacts between the actors : for some the "do it yourself", training on the job, for others external training and the procedural know-how. Each category hopes to maintain the status quo, autonomy for the technicians, power for the engineers, by excluding the other party from the realm of his competence: the refusal or work-to-rule by the supervisory staff on initiatives of the engineers who tend to make them draw up procedures for the functioning of the production areas, the exclusion of technicians from the library. This opposition sometimes leads to silent struggles, and in any event rules out all direct cooperation; the single technique engineers, certain experts may attempt to carry out mediation, or imagine more coordinated types of management (the engineer doctors; the Fluorine Derivatives Department).

CONCLUSION

FC company, which is as we have seen, in the first part, at the crossroads of varied professional spaces, is seeking to transform itself into an "corporate unit" bearing in mind the potential of the sector, the "chemical" branch, but also bearing in mind group E, dominated by the petroleum companies. This cohesion seemed necessary to enable it to absorb and digest the different restructuring operations which have been imposed upon it, whilst serenely awaiting the next. It would appear to give rise to the question of which type of logic of production is necessary for a collective identity to form within the firm : should they reunite the different actors of the firm around the product (plastic materials) and give preference to the links with the market, or should they seek to build the necessary technical skills within the firm based on production sequences, professions (polymerists, process engineers, applications engineers,...) ? For the actors to identify themselves with the firm, do they need, as the firm seems to believe strictly to choose between these two logics?

Currently, the organization by product goes hand in hand with a Human Resources Management Department that we have described, in the second part, as "soft". This policy, initiated by operational management, is incitative, flexible, the result of multiple informal negotiations at different levels within the firm. It relies on an assessment of the engineers based on their external training : the classification of their schools and those produced by these same schools permits the organization of engineers amongst themselves. The experts are themselves judged by the scientific and technical community of their discipline (on the external part).

We have seen that this type of assessment, which ensures the continuity of the *esprit de corps* in the firm, makes a hierarchy amongst engineers difficult and reduces the qualities accumulated by the older ones compared with their younger colleagues. This type of judgment also accentuates the individual nature of the training received and makes even more difficult collective work between engineers : collective creativity seems difficult to organize faced with praiseworthy individual creativity. It opposes engineers whose training is external to that of the technicians and supervisory staff who acquire their qualifications over a long period within the firm, further strengthening the social division of the work. The types of knowledge are different, as is their distribution; technicians and supervisory staff will concern themselves with the reproduction of their own workforce within the firm whilst the engineers seek to formalize the assets of their category (procedure, etc.). On this occasion we shall perhaps see emerging a certain solidarity in the category of engineers against the non-executives.

The "single technique engineers" are distinct from the run of the mill engineers, in that they are mobile throughout the production process, they acquire professional skills themselves within the firm starting with on a different "profession"; any evaluation of them cannot exclusively be made on the basis of their external training (schools not necessarily concentrating on chemistry, vocational training, etc.). They have an intermediate role between the professional categories and the trades and between the product sequences, perhaps they will provide the springboard for a link between the logic of products and the logic of professions?

FC company, with its gray areas into which certain actors creep (single technique engineers), has an organization which enables it to manage the exceptional. In fact, the firm only succeeds in mobilizing its competencies, its resources, in initiating a dynamic and innovative tension between the actors and the product sequences, when the stakes are strategic, and linked to the very existence of a unit, fundamental for the company, for a market, etc. Then and only then, does the cooperation between actors become a structured and efficient force in the dynamics of the firm. Without the involvement of senior management, without the priority, even vital nature of the project, the innovation process is managed traditionally by the hierarchical organization, and then, given the extreme divisions of work and labor, at half speed, remaining, however, routine and non-effective. The company only manages to mobilize its human and technical potential in a limited space (time and place) and without continuity.

2. A CASE OF THE JAPANESE COMPANY

Foreword

This report comprehensively examines the issues which involve technical workers in Japan, especially those in the chemical field. Topics include labor markets for technical workers within enterprises, career formation of these workers, and their roles and cooperative relationships with other functional groups in the research/development/production process.

Toward this end we focus on the Japanese petrochemical industry and compare it with the case of the French petrochemical industry.

Japan's petrochemical industry started in 1957 with Maruzen Petrochemical Company making second-class butanol out of waster gases created as a result of refining, but this production was on a very small scale. A genuine petrochemical industry centering on naphtha cracking was launched in 1958 and 1959, under the government's strong guidance, by three former *zaibatsu* companies (Mitsui, Mitsubishi and Sumitomo) and the Nippon Oil Company Ltd. group[1].

The Japanese petrochemical industry, which has since experienced remarkable growth, has been subject to the government's strong guidance and protection. The government has fostered this industry by disposing of the site of the former army's fuel factory, permitting the introduction of foreign technology, providing funds through loans from the development bank, providing tax exemptions, and lowering the cost of raw materials.

It is said, however, that, compared with firms in Germany and the United States,petrochemical companies in Japan are small and less competitive in international markets. According to Itami and others ,the Japanese petrochemical industry is not as competitive as the advanced steel, electric, automobile and semiconductor industries because of a lack of dynamism in industrial accumulation. They explain this in detail, referring to environmental and external factors as well as internal factors such as corporate action and management methods[2].

The petrochemical industry's accumulation of technology has the following characteristics. First, technology for this industry is more often accumulated in laboratories than at factories, and fundamental research is more important for this industry than other sectors. Second, the discovery of one chemical reaction tends to cause a drastic conversion from existing technology. Third, the chemical industry has

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1: Suzuki, Haruo. Kagaku Sangyo-ron (Theory of the chemical industry), Toyo Keizai Shimpo-sha, 1986

2: For details see Nihon no Kagaku Sangyo-Naze Sekai ni Tachi-Okuretanoka (The chemical industry in Japan; why it is behind world standards for the industry), by Hiroyuki Itami and Itami research office, NTT publishing, 1991.

the characteristic of making a wide variety of products so when formulating the concept of a new product a strategy which incorporates a broad perspective is required. Finally, the petrochemical industry does not have enough human resources compared with the machine and electric engineering sectors. Although the chemical industry depends heavily on fundamental research, which requires expertise, the number of employees with doctorates is far smaller in Japan than in the United States and Germany.

Product innovation rather than process innovation determines competitiveness in this industry. It is true that the efficiency of Japanese ethylene equipment operation and the sophisticated Japanese production system for derivatives are above the world average. Regarding new products, however, the Japanese petrochemical industry is heavily dependent on technology introduced from abroad.

In fields such as films and tires, where process innovation is more important, many Japanese companies are competitive in world markets. On the other hand, Japanese firms remain uncompetitive in some fields where product innovation is more important.

According to a survey of the 35 largest Japanese chemical companies the number of patents these firms applied for was increasing steadily year by year–10,885 in 1983, 11,710 in 1984, 12,274 in 1985, 14,326 in 1986 and 14,665 in 1987. Foreign chemical industries are shifting to stress functional products, while Japanese chemical companies have emphasized research and development. This seems to be steadily producing good results[3].

Japan Chemical, a general chemical company which is examined here, was established as a manufacturer of coal derivatives including coke, ammonia and dyes. The firm entered the petrochemical industry comparatively recently, in 1964, and its petrochemicals such as olefin derivatives account for only 40% of sales. Inorganic carbon products including coke account for 30% of sales, as do functional products including materials for the electronics industry and drugs. In recent years, however, the company has rapidly increased its production of functional products as a proportion of overall production.

A survey was conducted at various levels including Japan Chemical's head office, the Research Center, development centers and factories. The Research Center, which concerns itself with the wide range of Japan Chemical's businesses, has sixteen laboratories. From among these the Chemical Laboratory, which deals with catalysts and fundamental processing, was selected as a target of the survey. Among development centers, the one located in the site of the "Mi" factory which focuses on petrochemical process was selected to be surveyed. Engineers at the Mi factory were also surveyed.

3: Kagaku sangyo no Doko to Senryaku 5 (Trends and strategy of chemical industry No. 5) Chemical technology patent research committee, PMC publishing 1989, p.13.

At the head office we asked personnel managers about the current personnel and labor management system and future trends. At the Research Center we interviewed officials in the management division, the director general of the Chemical Laboratory, and researchers. At the development institute the director general, officials of the management division, and research staff were interviewed. At the factory level we interviewed personnel and labor officials, managers and technical staff.

2-1 Overview of JC COMPANY

2-1-1 Company Characteristics

a. Management system

JC company is a firm which is representative of the Japanese chemical industry. It was established in 1950 and is currently capitalized at ¥68.97 billion. It employs 8,970 and sales were ¥785.5 billion for the period from February 1988 to the end of March 1989.

As shown in Figure 1-15, JC company has adopted a business group organizational structure and each JC company division is a profit center. In the head office of the firm, each division chief has about fifteen workers: two staff officers who supervise a planning group of three, a sales group of five to ten, and a technical group of five to ten.

The basic research divisions are collectively accommodated in the Research Center located near Tokyo. Development Centers are affiliated with JC company's five major plants which are scattered all over Japan. The Research Center has 1,172 employees, of whom 1,076 are engaged in R&D. The Chemical Laboratory selected for the survey is dedicated to basic petrochemistry research and has 94 employees including nineteen women.

The Mi Plant, which is a major petrochemical production site producing about ¥150 billion worth of products annually, has work force of 1,839, of whom 438 including 243 operators are assigned to the plant's Development Center.

b. The corporate group

In the chemical industry it is not unusual for a firm to develop a *keiretsu* (corporate group) by establishing subsidiaries or affiliates (which mainly operate in downstream fields) through joint ventures, by establishing technical tie-ups, and through mergers and acquisitions when entering new fields of business. The JC group comprises a total of 52 firms– thirteen consolidated subsidiaries[4] and 39 subsidiaries. Shares in nine of these are listed on stock exchanges. The group also has 21 overseas manufacturing subsidiaries. Annual domestic sales of the entire group except JC company were ¥1,092.6 billion, and the consolidated subsidiaries accounted for 50% of this.

Business fields and numbers of employees for firms within the JC group are shown in Table 1-15 The activities of these firms encompass all areas downstream of

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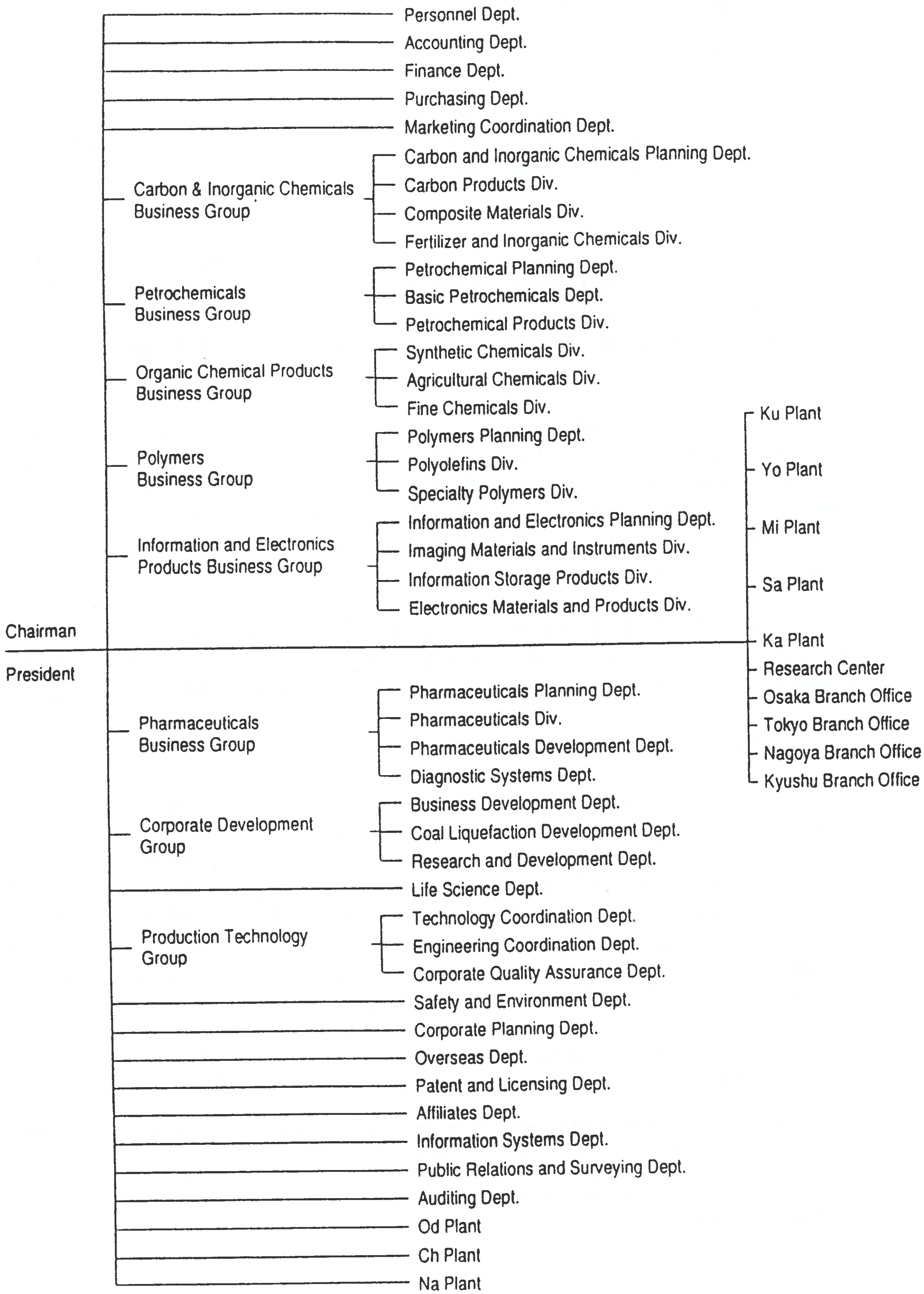
4: If a subsidiary receives more than 20% of its capital from a parent company it is included in consolidated financial statements made by the parent company. Such a subsidiary is called a "consolidated subsidiary" here; other subsidiaries are referred to simply as "subsidiaries."

FIGURE 1-15 Organization Chart



JC company products and include transportation, engineering and information services. Among the group are large firms which employ over 1,000 workers, and the total number of regular employees of all companies in the group is 13,882[5].

TABLE 1-15 Major Companies in the JC Corporate Group

(as of end of March 1989)

Company	Business Fields	No. of Employees Male	Female	Total
JC		7,681	1,289	8,970
Sa*	Polystyrene, ABS synthetic resin	1,114	155	1,269
Sb*	Polyvinyl chloride, plasticizer	684	117	801
Sc	Aluminum fabricating	349	49	398
Sd	Fluorescent products	332	46	378
Se	Engineering, facilities	299	9	308
Sf	Polyester resin, polyester film	136	8	144
Sg	Soy milk, sugar ester	43	9	52
Sh	Survey, analysis and retrieval of information	52	31	83
Si	Information processing consulting	66	19	85
Sj*	Isocyanate derivatives	36	3	39
Sk	Floppy disk	35	1	36
Sl	Transportation	92	2	94
Sm	Marine transportation	53	0	53
Sn	High-purity terephthalic acid	72	9	81
other		1,021	70	1,091
Total		12,065	1,817	13,882

*: affiliated companies in petrochemicals

Almost all employees of the companies from Sa to Sf in Table 1 have been temporarily or permanently transferred from JC company but, as a rule, among the companies from Sg to Sn and those in the "other" category only their executives have been (temporarily) transferred from JC company.

The work forces of companies Sa to Sf, which are closely related with each other, are substantially employed by the group as a whole because all their enterprise-based labor unions are affiliated with the JC Federation of Labor Unions. Federation negotiations with JC company proper result in virtually identical working conditions among these companies.

5: On Table 1-15, the number of regular employees of JC company proper includes regular employees temporarily transferred to other group firms.

Subsidiaries and affiliated companies are established only for purposes of business management, such as the need to form joint ventures upon the introduction of new technology, to secure top-quality human resources and achieve advantages in business by accumulating special know-how, or to facilitate decision-making on investment in physical plant.

c. Breakdown of recent sales amounts

The breakdown of sales amounts for the period from February to September 1988 is as follows: carbon products and inorganic chemicals such as coke and carbon black, 31.0%; petrochemicals such as olefin and its derivatives and raw materials for synthetic fiber, 38.2%; and functional products such as imaging materials, information storage products, electronics materials, pharmaceuticals/biochemicals and engineering plastics, 30.8%. Exports accounted for 12.6% of total sales, which is considerably low compared with JC company's counterparts in fabricating and assembly industries such as electronics and automobiles. The firm's business is largely based on domestic demand. It can be pointed out that recent trends are toward an emphasis on functional products. Sales of these products accounted for merely 17% of the 1985 total, but this figure increased to 30.8% three years later (in 1988) and then to 33.3% during the period from April to September of 1990. In contrast, the proportion of carbon products and inorganic chemicals is rapidly falling–the percentage of sales decreased from 35.4% in 1986 to 29.0% from April to September of 1990. Also, JC company previously had an aluminum smelting division which employed 1,700 at its peak. Drastic loss of competitiveness as a consequence of the two oil crises forced the closure of this division in 1981.

As described above,JC company has been shifting from mass production to producing products which are more highly refined. Investment in the R&D which has made this move possible has risen year by year, from ¥33 billion in 1988 (about 6% of sales) to ¥40 billion in 1989 and to ¥42 billion in 1990.

2-1-2 Business Management and Human Resources

a. Characteristics of the labor force: job assignment, educational background, position and age

(1) Number of employees

JC company had 7,681 male and 1,289 female employees for a total of 8,970 as of the end of March, 1989 (see Table 1-16). While the average age of male employees was 41.5 and their average length of service 18.6 years, those of female employees were 26.9 and 6.0 respectively. The reason for the comparatively high average age is that JC company tightly restricted hiring for a long period following the oil crises because of the lack of activity in the petrochemical and aluminum smelting industries.

Average monthly salaries for JC company's male and female employees are ¥352,907 and ¥183,639, respectively.

The figures in Table1-16 exclude regular JC company employees who have been transferred to other firms. If these workers are included, the total number of employees comes to 8,970 as shown in Table 1-15.

TABLE 1-16 Characteristics of the JC Work Force

(as of March 1989)

	Number of Employees	Average Age	Average Length of Service	Average Monthly Salary
Male	7,553	41.5	18.6 years	¥352,907
Female	1,289	26.9	6.0	183,639
All	8,842	39.3	16.8	328,231

Note: Average monthly salary includes basic gross salary and payments other than standard payments for all employees except those transferred to subsidiaries, excluding bonus payments. Age of retirement is sixty.

(2) Educational background and job assignment

A breakdown of the labor force by job assignment is shown in Table 1-17. Employees assigned to "staff" work account for 44.8% of the entire work force, and 27.5% are "university graduates" (according to in-house standards), 3.6% are technical college graduates, and 13.7% are high school graduates. The percentage of factory workers who were employed regardless of their educational background is 43.1%, while those allocated miscellaneous clerical work (females) account for 11.3%.

In JC company, members of a function group which consists of managers, research and development engineers, field engineers, senior clerks, and the like are called "staff workers." JC company manages its human resources by sorting personnel into four categories: "staff," "factory workers" such as operators, "office workers," and "other" such as drivers and nurses[6].

TABLE 1-17 Employee Assignment

(as of August 1989)

	JC only		Including loaned employees	
Staff				
University graduates or above	2,477	(27.5)	3,756	(26.9)
Technical college graduates	324	(3.6)	411	(2.9)
High school graduates	1,237	(13.7)	2,285	(16.0)
Factory workers (operators, etc.)	3,887	(43.1)	5,923	(42.3)
Office workers (female)	1,019	(11.3)	1,538	(11.0)
Other (drivers, medical care)	73	(0.8)	74	(0.5)
All	9,017	(100.0)	13,987	(100.0)

(Figures in parentheses are percentages.)

The educational backgrounds of employees correspond to the above categories. For instance, the qualification required of staff workers is a high school diploma or post-secondary education and this has been shifting to a technical college degree or better. Until 1976 some of the more competent high school graduates assigned to factory work were often chosen for staff work. However, partly due to the increase in the percentage of the general population which has received higher education, the minimum qualification is now graduation from a technical college.

As for technical positions, people who were approved by the company as being "university graduates" were previously acceptable but over the past ten years the trend has been toward hiring those who have completed Masters programs. Females, though not many, have been employed in technical positions and almost all of these women have been assigned to laboratories.

Many of JC company's factory workers were hired just after finishing middle school since no educational qualifications were required for these positions. Recently the percentage of factory workers who are high school graduates has risen because the qualification of a high school diploma was established in 1971. Middle school graduates are still occasionally hired for factory work, but candidates are limited to those in mid-career. JC company does not distinguish between graduates of ordinary and technical high schools regarding assignment or treatment. As will be described below in the case of the Mi Plant, there is a trend toward hiring mid-career university graduates for factory work. Through office clerks are generally high school graduates, the number of technical college graduates assigned to this work has been increasing recently.

A breakdown by educational background of the whole labor force actually present at JC company is shown in Table 4. There are no significant differences between JC company proper and the JC group as a whole regarding these percentages. According to in-house standards, 27.5% have a background of "university education," but 29.6% actually have "Bachelor's or higher degrees" and 13.8% have "Master's or higher degrees." Further, 33.4% of employees are high school graduates and 27.5% are middle school graduates;??most of these are operators??. The average age of middle school graduates is 48.3 and their average length of service is 25.2 years. On the other hand, average age and average length of service for high school graduates are 37.1 and 16.2 years, respectively. Both these figures are lower than those for middle school graduates by about ten years. The majority of younger operators are high school graduates.

6: Managing human resources by distinguishing "staff workers" from "factory workers" is common among firms in Japanese industries which have relatively long histories such as steel, heavy electrical machinery, and shipbuilding.

TABLE 1-18 work Force Breakdown by Academic Career

(as of August 1989)

	JC only (%)	Average age, length of service	Including loaned employees (%)	Average age, length of service
Doctors	1.5		1.1	
Masters	12.3		10.4	
Bachelors	15.8		17.2	
Bachelors or higher	29.6	34.7, 9.9	28.7	36.9, 12.0
Technical/junior college graduates	8.1	26.3, 5.6	7.4	26.2, 5.4
High school/middle school (under old system)	33.4	37.1, 16.2	34.7	37.6, 16.3
Middle school/higher primary school	27.5	48.3, 25.2	28.1	48.8, 25.6
Professional college and other	1.4	33.6, 8.2	1.1	33.1, 8.0
All	9,017 employees	38.5, 15.9	13,987 employees	39.6, 16.8

b. Overview of personnel management system

(1) Recruiting

Hiring since 1982 is shown in Table 1-19. No "regular" hiring (of newly-graduated young people) for production divisions had been done for roughly the ten years preceding 1987 because of weak demand accompanying the oil crises, but such hiring was resumed in 1988. Mid-career employment for these divisions, which had also been suspended for a long period, was reopened in 1987.

TABLE 1-19 JC Recruitment

		1982	1983	1984	1985	1986	1987	1988	1989
Staff	New graduates								
	University—male	93	105	88	136	124	128	144	155
	University—female	23	28	29	43	57	31	30	38
	Technical college	65	35	7	14	37	24	19	19
	Subtotal	181	168	124	193	218	183	193	212
	Mid-career workers	0	0	0	0	0	8	2	0
Production Division	New graduates	0	0	0	0	0	0	0	38
	Mid-career workers	0	0	0	0	0	0	37	50
Women	New graduates	197	167	104	125	197	151	119	143
Total		378	335	228	339	443	342	351	443

On the other hand, "regular" annual recruitment of about 200 staff workers continued during that era in order to push forward new business activities and research and development in the severe business climate. "Regular" hiring of about 150 females for office work was also maintained, though the number varied somewhat year by year. New female workers in large part filled the vacancies created by the resignations of women following marriage, pregnancy, and so forth.

Table1-20 shows the number of "regularly hired" staff workers, which includes those who were assigned to subsidiaries (some staff workers recruited by JC company proper are sent to its subsidiaries). In 1989, 90.2% of new employees were assigned to JC company proper but there were years such as 1986 when as many as 30% were assigned to subsidiaries. This means that staff workers are substantially recruited by the group as a whole.

TABLE 1-20 New Graduates Employed as Staff (including affiliated companies)

	1982	1983	1984	1985	1986	1987	1988	1989
University—male	117	144	97	179	204	171	168	173
%	79.5	72.9	90.7	76.0	60.8	74.9	85.7	89.6
University—female	28	42	36	56	67	32	34	40
%	82.1	66.7	80.6	76.8	85.1	96.9	88.2	95.0
Technical college	84	37	7	15	45	30	23	22
%	77.4	94.6	100.0	93.3	82.2	80.0	82.6	86.4
Total	229	223	140	250	316	233	225	235
%	79.0	75.3	88.6	77.2	69.0	78.5	85.8	90.2

Note: Percentage figures indicate the proportion of such employees hired by JC.

> "We employ new recruits after informing them as to what assignment, including assignment to the subsidiaries, they are going to have. There are cases in which recruits are assigned from the start to group subsidiaries. Through our subsidiaries recruit employees by themselves, they almost never discriminate between the employees assigned to them by JC company and those they hired themselves after these people enter the firm"

Each subsidiaries has its own enterprise-based labor union, and these unions have formed a Federation and JC company Unions. Working conditions and so forth are negotiated between the Federation and JC company and very similar agreements are reached at every subsidiary. Therefore working conditions are practically identical among these firms.

Table 1-21 has been prepared to show the breakdown by major field of study for recruits with Bachelor's or higher degrees. Recently the employment of people who majored in fields other than chemistry–particularly pharmacy, veterinary studies, physics, electrical engineering, and electronics–has increased. This is because the group has been building its research and development capabilities in the fields of medicine and functional materials.

A breakdown by sex and academic background for new staff workers hired in 1989 shows 104 male Masters, the largest group for that year, and a considerably smaller number of 20 male Bachelors of Science (Table 1-22). Only nine male Ph.D.'s were hired in that year. Recruiting Master's degree holders is favored because such people can be assigned among a variety of specific tasks. As for females in technical fields, 17 Masters and 23 Bachelors were employed–more Bachelors than Masters.

TABLE 1-21 Majors of University-Graduate Recruits (including affiliated companies)

	1982	1983	1984	1985	1986	1987	1988	1989
Non-engineering majors	34	22	22	36	45	35	35	40
Engineering majors								
Chemistry	67	86	40	77	119	98	73	89
Biotechnology	4	12	9	14	14	2	13	8
Pharmacology/Veterinary	11	16	23	39	25	9	26	25
Agriculture/Biology	6	11	8	13	14	6	2	12
Physics	3	8	10	20	12	15	8	8
Electrical/Electronic	1	3	6	9	9	13	12	6
Mathematics/Industrial	9	14	6	10	12	10	14	9
Mechanical/Architecture	10	14	9	17	21	15	19	16
Sub-total	111	164	111	199	226	168	167	173
Total	145	186	133	235	271	203	202	213

TABLE 1-22 Sex and Academic Achievement of 1989 Recruit

		Male	Female
Engineers	Doctors	9	0
	Masters	104	17
	Bachelors	20	23
Non-engineers	Bachelors	40	0

(2) Promotion policies: position and qualification

Position titles vary with the nature of the work (see Table 1-23). Positions are in descending order: in the business field–division manager, chief secretary; in R&D–center director, group leader (GL); and in production–department manager, section manager, deputy section manager.

JC company uses *shokuno-shikaku seido.*, a ranking system which includes job groups categorized by degree of competence. This personnel system has been adopted by many firms in Japan. The system has been in use at JC company since around 1952 and has undergone some modifications since its introduction. The current system is shown in Table1-24. Employee treatment is determined by these qualifications. For example an employee qualified as *shuji* (supervisor), engineer, or *fuku-sanji* (vice-secretary) may be appointed deputy section manager. However, there are very few who actually hold managerial responsibilities. Employees with *shuji*, engineer or higher qualifications receive salaries and benefits equivalent to those of managers; 43% of all employees hold such qualifications but only 6.3% actually have managerial responsibilities. The chain of command is straightforward. Because no special allowance is paid to those in managerial positions, whether or not one is assigned to a managerial position does not make any difference in one's employee treatment. The qualification system was last revised in 1982, and upon revision a new qualification of *sanyo* (councilor) was added to the system while the position of department manager directly under divisional manager was eliminated. The revision was aimed at facilitating decision-making and improving the flexibility of employee assignment by deleting a layer from the hierarchical command pyramid.

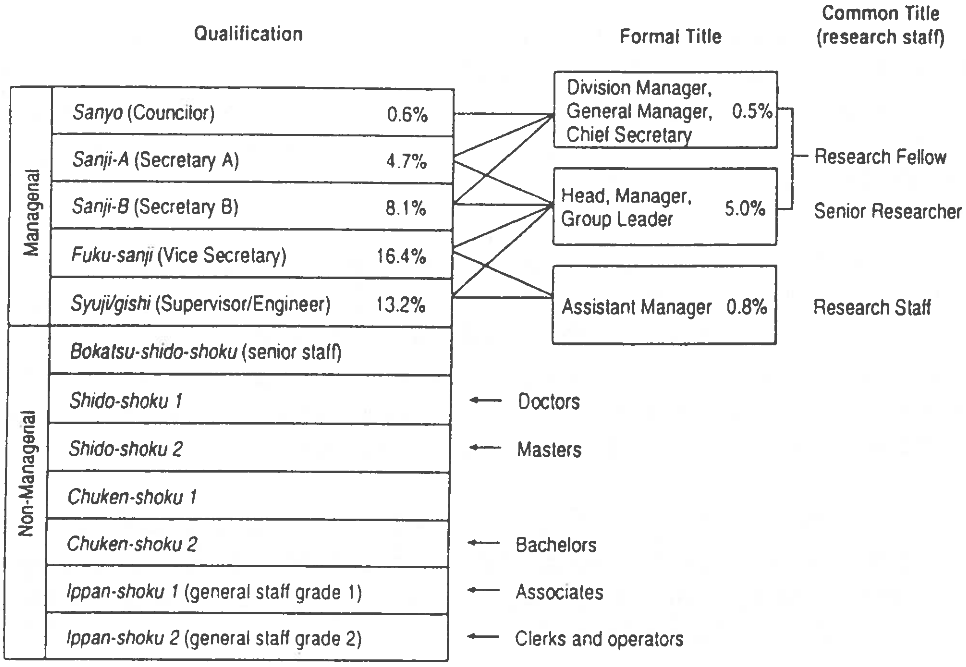
At the start of employment, a high school graduate is rated as *ippan-shoku-2*, a technical college graduate *ippan-shoku-1*, a "university graduate" (Bachelor) *chuken-shoku-2*, a Master *shido-shoku-2*, and a Ph.D. *shido-shoku-1*.

A new factory worker is rated as *ippan-shoku-2* and it would be fortunate for such an employee to be rated *tokatsu-shido-shoku* (senior staff) by the age of mandatory retirement. A new technical college graduate's rating of *ippan-shoku-1* is raised to engineer at the age of 35 or 36 on average. A holder of Bachelor's or higher degree is generally rated an engineer at about the age of 30.

TABLE 1-23 Management Structure

Business	Chief Secretary → Manager
General Affairs	Chief Secretary → Manager
Sales and Marketing	Chief Secretary → (Division Manager) → Branch Manager
R&D	Group Leader → Manager
Production	Deputy Section Manager → Section Manager → Manager

TABLE 1-24 Relationships between Qualifications and Job Titles



(3) Performance ratings

JC company performs three sorts of performance rating: for salaries, for bonuses, and for promotions.

The performance evaluation for salaries is conducted annually in February. An employee is rated relative to other employees who were recruited in the same year and have the same educational background, on the basis of overall merit as determined by ability in fulfilling duties, achievements accomplished and so on. Two types of forms are used for these ratings, one for rating researchers (the researcher form) and another for rating employees other than researchers (the general form).

In the general form, ratings fall under the following four broad categories:

i) Personality and manner (sense of mission and responsibility, cooperativeness and harmony, vitality and aggressiveness, self-development, popularity and confidence inspired among other, prudence and steadiness)

ii) Business management ability (management and business sense, leadership and organizational ability, decisiveness, cost consciousness, education and training of subordinates)

iii) Basic ability (ability to understand, analytical ability, expertise, insight and judgment, expression)

iv) Business execution ability (originality, agility, negotiation and persuasion, planning ability, dependability, business specialty)

The researcher form is similar to the general form, but business execution ability and business management ability are replaced with research :bility and management ability. Also, the researcher form has sub-items, such as organizing experiments and establishing research policy, which are a little different in nature from items found in the general form.

Both forms also have an overall rating section with ten grades from outstanding to unsatisfactory, an aptitude and development section, and a comment section where the duties of the employee, the bases of the overall rating, the achievements of the employee, and general remarks on topics other than those covered elsewhere can been entered. Those who rate employees fill in the overall rating section while keeping in mind the results of other sections.

> "The major purpose of rating by specific item is to express the aptitude and personality of the employee so that this can be applied to his or her education and training. Thus these ratings are not directly connected with the overall evaluation of the employee."

The ratings by item are used merely for basic data to be loosely referred to in the overall rating. It seems that the weight of the factors in evaluating employee ability should vary with the position of the employee, but JC company uses the same forms for all staff workers and none of the factors are weighted. The same rating forms are used for performance ratings for bonuses. For the summer bonus the February pay raise forms are used, and for the winter bonus a new rating is performed using the same forms during October and November.

The primary evaluators of the employees are their immediate superiors, thus section managers are evaluated by their division managers. The completed forms are sent to the personnel division and from there to the head office where the evaluations are standardized. The primary evaluators of deputy section managers are section managers. Rating are performed on an annual basis, and the results of ratings conducted in previous years are not considered.

Promotion ratings are done once a year from May to July. The ability of an employee to complete his or her duties and the general question of whether he or she is capable of fulfilling greater responsibilities are evaluated. This rating is also relative to other employees with the same educational background and having been employed in the same year, and is standardized. There is a special form for promotion rating which is used for rating both researchers and other employees. The evaluators enter promotion rating remarks (overall ratings), achievement evaluations, and ability and manners ratings (expertise and knowledge, ability to perform duties, and attitude toward work).

As shown in Table 1-25 there are standards which tie eligibility for promotion to year of graduation. For instance, in 1988 the 1980 university graduates became qualified for promotion to *shuji* or engineers, at the age of around 30. The candidate's research paper is used for reference in the rating and an interview is held. The rating by superiors made with the rating form is also considered. As the themes of research papers tend to be abstract, it is changing the themes to more technical subjects is now under consideration. The interview is attended by the factory director (or department manager in the case of head office personnel) and managers from the relevant organization and the labor management department.

TABLE 1-25 Standards and Methods of Evaluating Candidates for Promotion (1988)

Promotion to:	Standard Year of Employment	Merit Rating	Thesis	Interview
Council	(individual basis)	×		
Secretary A	1963 university graduates	×		
Secretary B	1968 university graduates	×		
Vice Secretary	1975 university graduates	×	×	×
Supervisor/Engineer	1980 university graduates	×	×	×

JC company's personnel rating system is not analytical or precise. Rather, it employs a loose, general rating concept. In its actual operation the year the employee joined the company tends to be significant.

This system of rating employees working in technical fields is standard throughout JC company. The fortunes of an employee's division have no bearing on the treatment of the employee, nor are bonus amounts linked to the performance of their particular department. When superior people are intensively deployed in strategic division there is a possibility that applying a strict rating distribution curve will result in frustration. For this reason, some firms allocate more funds to laboratory budgets to allow for higher salaries there than elsewhere in the company. JC company, however, has taken no such special measure. The wage system is company-wide and there are no employees with an annual salary contract.

(4) Employee education and training

i) Company-wide education systems

JC company's company-wide education systems consist of training for specific positions, skills training, education to meet the trend of globalization in business, and self-development. The main training method is OJT (on-the-job training). To supplement OJT, various horizontal education and training programs and measures which support self-development have been established (referred to collectively as off-JT).

Training for positions is broadly divided into qualification/position training and new employee training. The former is provided separately for the department manager, *shunin*, and unit chief levels. Employees receive this training when they are appointed to these positions. Skills training in marketing, general operating techniques, and so on are provided to the relevant employees. For education to meet the trend toward globalization there are various programs such as overseas study and field trips, foreign language courses, and courses at special organizations (such as the Trade Training Center, short-term studies at overseas business schools, etc.). To promote self-development there are support programs for correspondence courses and job-related basic knowledge courses, and for obtaining public licenses.

TABLE 1-26 Education Programs

	Total Man-Days	Location	Starting Date
By Position/Qualification			
Councilors			May 1984
Division/Department Managers and Chief Secretaries	1,600	company-wide	Latter half 1985
New management employees			From hiring
By Job Class			
Operation Chiefs	2,100	each establishment	From hiring
Group Leaders			
AIA training	300		February 1989
Refreshment training	300		
Subtotal	4,300		
Vocational Education			
Marketing	150	head office	September 1986
Divisional training	600	head office	From hiring
Patents	250	company-wide	From hiring
Technology course	2,000	each establishment	From hiring
Subtotal	3,000		
Globalization education (foreign language training, etc.)	900	each establishment	From hiring
Correspondence courses	400	each establishment	July 1984
Special license acquisition	100		August 1985
Basic vocational knowledge course	300	company-wide	February 1977
Total	9,000		

During the six months from October 1988 to March 1989 JC company carried out 4300 man-days of position training, 3000 man-days of skills training, and other training totaling 9000 man-days (see Table 1-26 for details). In-house training was propelled by 23 staff workers (six full-timers) assigned to in-house education. Three full-timers and two part-timers in the human resources development group within the personnel department at the head office are in charge of almost all planning for position training. Also, for this purpose there are six staff workers in the human resources development office at the Ku Plant, another six at the Mi plant, and six other workers at other establishments.

Until around 1975, in-house education and training at JC company focused on union members. It tended to emphasize aspects of employee consciousness such as work motivation and was linked to labor management and labor-management relations. From about 1975, after the first oil crisis, the scope of training for managers was expanded while training for rank-and file workers continued. At the same time, skills training began to be highlighted. (Incidentally, the human resources development office of the personnel department was opened in November of 1976.)

Recently, as JC company attempts to make itself a group of professionals who are rigorously profit-conscious in response to the business environment of technological progress and global business relations, the firm has also moved to establish stronger policies for education and training. The company has set the following seven goals regarding education and training: ability improvement for those in managerial positions; planned and systematic acquisition of expertise and technology; improved peripheral knowledge and technology; job adaptation training for transferred or loaned workers; acquisition of management techniques; cultivation of internationally-minded personnel; and planned cultivation of superior personnel.

JC company established human resources committees in all its establishments in March of 1986, to push forward the restructuring of its human resources development system. It built the Training Center in Tsukuba in October, 1986. Training in general operating techniques was reinforced by construction of the Operating Technique Training Center at the Mi Plant. Also, in October of 1988 Sm company was established to run the training establishments and to assist JC-group firms in educating and training their employees.

ii) Recruit training

The recruit training system for newly graduated employees recruited from university by the head office consists mainly of induction, cultivation, position training, and foreign language education.

During the induction process all new recruits first have about two weeks of training at the head office beginning in early April. Next they experience three-shift duty on plant production lines for about six weeks, regardless of their eventual assignment being technical or clerical. Though this takes place at the plants, they do not actually engage directly in the production process and the operators responsible for production never entrust them with major responsibilities. They just assist the factory workers with indirect work such as doing odd jobs and collecting data for the operations record. JC company has continued this practice for a long time based on the idea that understanding operation sites by experiencing production work is an important key to subsequent development. After experiencing the production environment the new recruits are assigned to positions at the end of May.

The establishments to which they are assigned hold OJT, interviews, and other training programs for them. The contents of OJT are left to the discretion of the division. Though there are establishments which emphasize on OJT and those which do not, the head office's personnel department requires all establishment supervisors to submit three-year cultivation programs for new staff workers and follows up on them.

As for technical college and high school graduates recruited by the establishments, each establishment trains these employees in groups separated by academic background according to the needs of the establishment.

New (male) operators have a three-year cultivation period. They go through recruit training in the same manner as other recruits do, but during the following three years they receive training in general operating techniques nine times (for ten days at a time) as is the case at the Mi plant (see Table 1-27), experiencing actual work at plants. The reason operators are required to receive such extensive training is that it has become indispensable for even operators to understand digitally-controlled systems since the number of processes controlled by computers has been increasing at production sites.

TABLE 1-27 Education in General Operating Technology (Freshman Course)

	Schedule	Contents
1	At hiring	Basic operator knowledge; security and safety education; basic mathematics, physics and chemistry
2	Six months later	Human relations at the work site; supplementary education for basic scholastic ability; basic theories of chemical engineering and thermodynamics
3	One year later	Basic theories of chemical engineering, reaction engineering; simulation training (at plant where trainee is working)
4	16 months later	Basic theories of chemical engineering, thermodynamics, reaction engineering, etc.; practical training for rotary machinery, security and safety education
5	20 months later	Supplementary practical training for rotary machinery; practical training for electric machinery; simulation training (unit processing)
6	Two years later	Supplementary practical training for electric machinery; practical training; basics of instrumentation; simulation training (unit processing)
7	26 months later	Supplementary practical training in instrumentation and metals; simulation training (unit processing)
8	32 months later	Supplementary practical training in metal materials; simulation training (unit processing and adaptation training for diversified plants)
9	Three years	Practical training for facility security; simulation training (adaptation training for different plants); summary

iii) Training for transferred workers

Job adaptation training is held when JC company transfers workers from other divisions to, for instance, the pharmaceutical division. The training is conducted extensively by divisions which receive transferred workers. As described below, JC company has begun producing disk storage materials as a new business at the Mi plant. Before the start of this new area of production a considerable number of workers were transferred among the Research Center, the Development Centers, and the plants as a consequence of beginning this new activity. Operators were also transferred to Mi from other production lines and are expected to support the job adaptation training of employees who transfer in afterwards, as well as to contribute to the new production process as the core of the disk material work force.

As might be guessed the training received by technical line employees is provided largely in the form of OJT and is conducted at the division or shop level. This training is followed up by the personnel department, which requests reports on employee cultivation programs from supervisors after the employees have been assigned in order to verify that OJT is developed according to the OJT plan.

(5) Personnel transfers

Personnel transfers in JC company are shown in Table 1-28. In 1988, for instance, a total of 431 employees were transferred within the firm. Thirty-eight were transferred from the head office to regional establishments, 69 from regional establishments to the head office (the number of employees at the head office increased by 31), 111 from one regional establishment to another, and 213 within establishments. Furthermore, 134 JC company employees were transferred to subsidiaries and 54 returned to JC company from subsidiaries, the number of outgoing employees exceeding that of incoming employees by 80. The number of employees who were transferred between subsidiaries reached 75 and there were 263 employee transfers involving subsidiaries. In addition, 22 employees were transferred abroad and seven returned form abroad. This adds up to 723 transfers.

As the number of staff workers within the group managed by JC company's head office was 6,452 (as of August 1988, we see that more than 10% were transferred during that year. Among the 94 managers and staff workers who left the company that year were those who retired upon reaching the age limit.

c. Labor unions

Each plant has its own union and all of these belong to the JC company Federation of Labor Unions. Laboratory unions belong to the JC Research Center Labor Union. Each plant and laboratory, and the Osaka Branch, have their own unions. Tokyo, Nagoya and Kyushu Branches belong to the head office union. In addition to the unions mentioned above, the enterprise unions of subsidiaries such as Sa also belong to the federation. This has resulted in all enterprises within the group having practically identical working conditions.

While labor issues have been negotiated by the union federation, problems peculiar to an establishment such as work content are discussed at each establishment at joint labor-management conferences. Such problems may be discussed by the labor commission at each establishment, but almost all problems peculiar to an establishment are negotiated in a joint labor-management conference.

TABLE 1-28 Personnel Transfers

	1986	1987	1988
In-company			
H.O.-establishments	52	35	38
Establishments-H.O.	77	58	69
Between establishments	69	146	111
Within establishments	50	102	213
Subtotal	248	341	431
Related companies			
To related companies	138	115	134
From related companies	48	60	54
Between related companies	61	53	75
Subtotal	247	228	263
Overseas			
Outbound	12	25	22
Inbound	21	19	7
Subtotal	33	44	29
Total	528	613	723

Note: Excludes clerical and production workers; also excludes transfer as a result of promotion.

2-2 A labor system Centered on Engineer

2-2-1 Outline of the Research Center and Development and Production Divisions

a. The Research Center

The JC Research Center conducts studies for JC company which range from basic research to application studies. The Center is divided into three sectors in line with the company's business activities. The first sector is the Chemical Science Research Sector, which specializes in chemistry and related fields and comprises the Analysis Laboratory, the Chemicals Laboratory, the Specialty Chemicals Laboratory, the Computational Science Laboratory, and the Industrial Engineering Laboratory. The second sector is the Life Sciences Research Sector, which comprises the Toxicology Laboratory, the Pharmaceuticals Laboratory, the Bioscience Laboratory, and the Agricultural Chemicals Laboratory. The third sector is the Materials Science Research Sector, which is dedicated to studying functional materials and is made up of the Carbon and Inorganic Materials Laboratory, the Thin Films Laboratory, the Photoelectricity Laboratory, the Polymer Laboratory, the Advanced Composite Materials Laboratory, the Magnetic Media Laboratory,, and the Semiconductor Laboratory.

The Research Center had a total of 1,076 research and development personnel as of July, 1989: 281 in the first sector, 432 in the second sector, and 363 in the third sector. It also had 96 other workers, such as clerks, who were not assigned to particular sectors. There were also about 143 permanently-assigned personnel from subsidiaries who were responsible for medical safety evaluations and botanical engineering.

TABLE 1-29 Academic Careers of Research Center Employees

	Men (age, length of service)	Women (age, length of service)
University	615 (34, 9)	184 (27, 3)
Technical College	46 (30, 10)	0
High School	125 (40, 20)	0
other	37 (49, 23)	87 (25, 5)
Total	823	271

Note: "Other" comprises men transferred from plants (middle school and high school graduates) and female junior college and high school graduates, who act as assistants at the Research Center.

Almost all Center employees, both male and female, had Bachelor's or higher degrees and many of them had Master's degrees (see Table 1-29). Among employees with university educations the average age of male employees was 34 and their average length of service nine years. Though these figures are high compared with the average age of 27 and average length of service of three years for female Center employees in the same category, the numbers are not surprising when viewed in the light of the fact that the average age of all JC company employees who have Bachelor's or higher degrees is 34.7.

The JC Research Center was established in the 1940s and was originally located about ten kilometers from the current site. Construction of the present facility started in 1968 as part of a plan to bring all research sectors together in one place, and the last sector moved into the new Center in 1976. The second sector, the Life Sciences Research Sector, was organized after 1975 and was augmented at the time it moved to the Center. JC company had originally concentrated its efforts mostly on producing coke, fertilizers, agricultural chemicals and the like, but it adopted a new policy of advancing into functional material fields and areas downstream of its major products since raw-material industries are vulnerable under contemporary market conditions. The company has been devoting a fair share of its effort to these new fields, and therefore systems and topics of investigation in the Research Center are shifting toward functional products.

> "Research and development into petrochemicals, coke, and the like is being performed by the Development Centers at the establishments where these materials are produced"

For this reason, the number of employees researching the mature sectors of petrochemicals and coke has been decreasing. The Biosciences Laboratory, the Thin Films Laboratory, the Photoelectricity Laboratory and other laboratories responsible for research in biotechnology and new raw materials have been established. In the Polymers Laboratory, which has a long history, research topics have been shifting from polyolefins to functional materials such as engineering plastics. In the Carbon and Inorganic Materials Laboratory also, research into carbon fiber and other materials has been replacing research on coke. Such changes in research fields involve changes in the research support sectors. For instance, changes in analytical techniques have expanded the territory of the Analysis Laboratory. Newly-introduced advanced computing technology, which has become more frequently used due to its improvement, has triggered the augmentation of information processing sector.

b. The chemicals Laboratory

The chemicals Laboratory handles the basic fields of catalysts and processes and has eleven research groups: catalyst groups A to E, the polymerism group, organic groups A to D, and the coal liquefaction group. There are a total of 94 workers in the Chemicals Laboratory (see Table 1-30). A group is formed for each field of technology, such as complex catalysts or vapor-phase oxidation catalysts, consisting of five to a dozen people and led by a group leader (GL).

The breakdown of Chemicals Laboratory researchers by educational background, as shown in Table 1-31, reveals considerable similarity to that of all Research Center employees. The average age and average length of service of workers with Bachelor's or higher degrees are a little higher than those of similar employees of the Research Center as a whole. The age distribution of these workers shows that the number of those who are 33 years old or younger, who joined the firm since JC company started actively advancing into new fields, is greater than that of older workers and accounts for 55% of all workers. On the other hand, 15% are 45 or older.

"I think relations between people in the development divisions at factories and researchers at the Research Center are lateral and equal in terms of academic background and research capability, and I am not aware that one is above the other. I myself am interested in technology for practical application. So if I am requested to work on practical application by a factory, I am willing to carry out such work." (Master, Chemicals Laboratory, 29 years old)

TABLE 1-30 Organization and Staff of Chemical Laboratory

TABLE 1-31 Academic Careers of Chemical Laboratory Employees

	Men (age, length of service)	Women (age, length of service)
Doctors	8	0
Masters	38	10
Bachelors	3	5
Subtotal	49 (35, 10)	15 (26, 3)
Technical College	11 (30, 10)	0
High School	12 (40, 21)	0
Other	3 (42, 21)	4 (27, 8)
Total	75	19

Note: "Other" comprises men transferred from plants (middle school and high school graduates) and female junior college and high school graduates, who act as assistants at the Research Center.

About 18 people have degrees.

The breakdown of researchers by common academic majors is organic chemistry 63%, catalysts 11%, inorganic chemistry 8%, physical chemistry 7%, chemical engineering 4%, pharmacy 4%, and polymer chemistry 3%.

Because many areas of research pursued by the Chemicals Laboratory are those such as catalysts, for which accumulated experience is important, there are comparatively many researchers who work there for extended periods.

"As there have been cases of researchers being transferred from the Chemicals Laboratory to other laboratories because groups were reorganized during the recent system innovation, there is no reason that such people cannot move to other areas of research."

c. The Mi Development Center

The major site of JC company's petrochemical production is the Mi Plant, and a Development Center is located at the same site. The Mi Plant has been changing its production from petrochemical materials to functional materials, and with the change the research territory of its Development Center has been expanding.

The Mi Development Center has a section responsible for analyses, which includes the Quality Test Unit and the Analytical Physical Properties Research Unit, a section in charge of research and development such as for improving and rationalizing manufacturing processes which includes the Process Research Unit, the High Polymer Unit, and the Functional Materials Research Unit, and a Research Coordination Group which oversees the researches performed at the Center. (See Table 1-32)

TABLE 1-32 Structure and Operations of the Development Center

(July, 1989)

Division	Operations	No. of Employees (group leaders)
Coordination	Patents, library, reference materials, coordination and general administration	18 (1)
Quality Inspection	Process analysis, product analysis, verification (including high polymers), environmental analysis, soy milk analysis	91 (2)
Analytical Physical Property Research	Analysis verification (including high polymers)	49 (3)
Process Research	Petrochemical process research, rationalization	92 (5)
High Polymer Research	High polymer process research, development of polyolefin property processing, technical services, PVC development, analysis, and technical services	114 (6)
Functional Materials Research	Disks, TP, new films, food wrapping materials	67 (3)
All		431 (20)

The Analytical Physical Properties Research Unit is responsible for developing analytical methods to be applied to new products before production of these products is begun, and for solving technical problems which arise suddenly, by utilizing maximum analytical power. The Unit performs a broad range of analyses including surface analyses of information storage materials. The Process Research Unit is in charge of studying production processes for products other than polymers which are produced by the petrochemical plant, and the High Polymer Research Unit studies polymer production processes. Polymer products do not sell well without close and meticulous technical support for customers, so within this Unit are personnel who deal with the manufacture of small amounts of special products. The Functional Materials Unit is responsible for new disk storage materials, TP (thermal printing films), and new functional films. The Development Center has a total of 431 workers, of whom 114 belong to the High Polymer Unit which is the largest unit.

The breakdown of Center employees by educational background and the distribution of their ages and years of service are shown in Tables 1-33 and1-34. About 80% of employees who received university education have Master's degrees. The nature of the work allocated to a particular employee does not depend on educational background; the work assigned to a university graduate and a high school graduate differs to some extent when both are young, because of the difference in their ages, but after they acquire some experience each will be charged with similar tasks. Incidentally, three graduates of technical high schools who earned Doctorate degrees after starting their careers work in the Center.

TABLE 1-33 Development Center Staff by academic careers

(as of September, 1989)

	University Graduates	Technical College Graduates	High School Graduates	Women	Other	Total
Management	35	2	31	—	1	69
Staff	48	16	9	—	—	73
General Workers	—	—	234	46	11	291
Total	83	18	274	46	12	433

TABLE 1-34 Development Center Staff by Age and Length of Service

Age	
less than 20	7
from 21	106
from 31	105
from 41	160
over 51	55

Length of Service	
less than 5 years	93
over 6 years	34
over 11 years	46
over 16 years	109
over 21 years	109
over 26 years	28
over 31 years	7
over 36 years	5
over 41 years	2

The Center has many high school graduate *ippan-shoku* employees because it needs operators of bench test equipment and pilot plants, who work in three shifts. The Center now has 243 operators, all of whom were transferred from production lines.

Each GL is responsible for two or three topics of investigation and five or six staff workers. Below the GLs are some (manager-equivalent) researchers who act as something like topic leaders.

d. The Mi Plant

The Mi facility is JC company's main petrochemical plant and started operations in July 1964. Today it is one of the nation's leading factories with an ethylene production capacity of 400,000 tons per year and a derivative plant consisting of more than 20 units. Together with nearby plants owned by other chemical companies it is part of a large petrochemical industrial complex. The factory's site occupies about 2.1 million square meters. In 1987 the Mi plant produced about ¥150 billion worth of ethylene, propylene, acetaldehyde, polyethylene, alpha olefin, acetone, 2 ethyl hexanol, polypropylene and other chemicals.

As shown in Figure 1-16 the Mi plant is organized into four production departments, a power supply department, an engineering department, an administrative department, a security and environment department, and a planning and coordination department. Among staff workers the number of university graduates is almost the same as the number of technical college and high school graduates combined (see Table1-35).

TABLE 1-35 Composition of Mi Plant Work Force

	Management and Administrative Employees				Operators	Clerks	Total
	University graduates	Jr. college graduates	High school graduates	Subtotal			
Administration Dept.	43	1	31	75	47	37	159
Production Dept. 1	21	8	18	47	239	7	293
Production Dept. 2	26	7	14	47	268	7	322
Production Dept. 3	20	3	7	30	169	5	204
Information Materials Dept.	20	2	11	33	62	18	113
Power Supply Dept.	7	3	9	19	73	3	95
Engineering Dept.	48	32	73	153	10	18	181
Production Control Dept.	7	0	5	12	0	3	15
Security and Environment Dept.	5	0	7	12	4	3	19
Development Center	85	18	44	147	243	48	438
Total	282	74	219	575	1,115	148	1,839

FIGURE 1-16 Organization Chart of Mi Plant

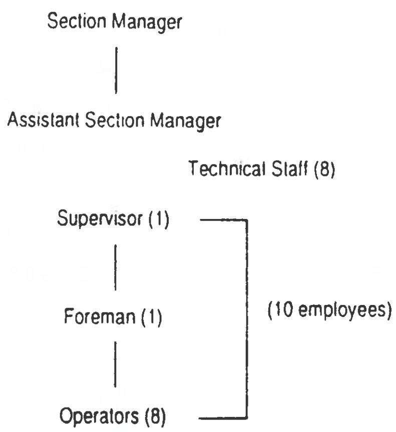
- Factory Manager
  - Administrative Department
  - Production Department I
    - Ethylene Section
    - Gas Section
    - Octanol Section
    - Alpha Olefin Section
    - Nonanol Section
    - Tank Yard Section
    - Coordination and Technical Section
  - Production Department II
    - Aldehyde Section
    - Nitrile Section
    - Aromatics Section
    - Organic Acid Section
    - Chlor Alkali Section
    - VCM Section
    - Coordination and Technical Section
  - Production Department III
    - Polyethylene Production Section I
    - Polyethylene Production Section II
    - PVC Section
    - Plastic Products Section
    - Soy Milk Section
    - Coordination and Technical Section
  - Information Media Products Dept.
    - Hard Disk Section
    - Technical Evaluation Section
    - Coordination and Technical Section
  - Power Department
    - Power Section I
    - Power Section II
    - Coordination and Technical Section
  - Engineering Department.
  - Planning and Coordination Department
  - Security and Environment Department
  - Development Center

There are 147 engineers at the Development Center, while the largest number of engineers, 153, is found at the engineering department. The main jobs at the engineering department are design, construction, and facility maintenance. The department is responsible for the plant as a whole regarding these concerns, which is the reason it has such a large number of engineers.

As for the production departments, relatively large numbers of engineers work in the coordination and technical sections of each department. Their main responsibilities are to evaluate and improve the production lines of their departments, and they also serve as coordinators for department projects. Their status is "technical staff workers" of the department. Engineers are also deployed at each departmental production group, being in charge of everyday production management including practical improvement, solving minor problems, and small-scale production line refinements. In addition, the workshop chief deals with projects which directly relate to operations such as revising and reorganization equipment operation manuals.

As a representative petrochemical production system, the organization of an Ethylene Center production line is shown in Figure 1-17. It consists of four teams in a three-shift system, each team having ten operators, and eleven technical staff workers including the section manager (six Masters, two technical college graduates, and three high school graduates).

FIGURE 1-17 Ethylene Section Organization



Ethylene is the basic raw material for petrochemical production. When naphtha is heated and mixed with steam, ethylene (C_2), propylene (C_3), butane-butylene (C_4) and cracked gasoline (C_5 to C_9) are produced through thermal cracking. The yield ratios for ethylene, propylene and other materials produced from naphtha cannot be changed much, i.e. the ratio of propylene to ethylene can vary only between 0.7:1 and 0.8:1. Thus downstream production plants for each type of derivative must be well organized, and this makes the comprehensive production management of a petrochemical plant as whole very important for achieving a satisfactory operation rate.

> "According to market conditions we sometimes change our operations structure. Normally we produce 220,000 to 260,000 tons of propylene against ethylene production of 400,000 tons. However, if sales of one item out of our product line decline the overall balance is lost. Another important issue is how to utilize the gas component of the fraction most efficiently. The administrative department coordinates this sort of company-wide production management."

Ordinary ethylene centers mainly handle polyethylene and polypropylene. However, the Mi plant is characterized by its comparatively small-scale production of these two items. To offset this situation, and to maintain a better balance, relatively large portions of ethylene-base alpha olefin and vinyl chloride monomer as well as propylene-based 2 ethyl hexanol have been produced.

The average age of the Mi plant work force is 40 years, while for operators and high-school graduate staff workers the average ages are 44 and 36, respectively. The company does not make any strict distinction among occupation categories according to employee educational background. Within a production department, however, the period of working continuously for a particular division is generally longer among technical college and high school graduates compared to university graduates.

Furthermore, 90% of all operators come from towns which are located in the same prefecture as is the plant. Before 1970 the majority of new employees were middle school graduates, but this has shifted to high school graduates since 1971. The Mi plant stopped hiring new operators for ten years due to the oil crises. When operator hiring resumed in 1988 (operators were hired without consideration for their academic backgrounds), even university graduates applied for the jobs saying that they preferred to work near their home towns and did not mind working as operators, and some were actually employed. In 1988 there were thirteen university graduates among the mid-career workers who joined the company that year[7].

This was not because operator job content was upgraded to the extent that university graduates alone were suitable. During the ten years operator recruitment was suspended, operators who continued working were trained with in-house education and acquired higher skill levels. On the other hand, it is true that the technical demands on operators have become greater than before, meaning that operators must be highly capable people. When the company lifted its academic requirements for operators, not a few university graduates applied for jobs. At the time the factory was established the company could to secure quality recruits from technical high schools.

7: About 70% of these university graduates had done non-technical majors. After attending university in the Kansai area or Tokyo they returned to their home towns to find no suitable employment, and applied to JC company.

JC company used to weigh an operator's practical capability more heavily than his or her academic background. As university graduates become operators, it is likely that labor management will become more complicated than ever and that a thoroughly merit-based system will have to be introduced in the future.

Years ago, operators were middle school graduates and staff workers were high school graduates. Later the company started to employ high school graduates as operators. Accordingly, there were different employment opportunities provided for high school graduates: as operators and as staff workers. However, that system was abandoned in 1977 partly due to the poorer quality of high school graduates, and the recruiting of staff workers shifted to technical college and university graduates.

2-2-2 Connections between Research, Development and Production

a. R&D theme management

The research themes of the Research Center's Chemicals Laboratory have mainly centered on petrochemicals. At present, however, they extend beyond traditional concerns to cover a wider range of topics. Catalyst technology is at the core, and themes include organic fine chemicals, inorganic fine chemicals, and organic synthesis technologies. Thus, researches are being conducted on a wider range of subjects and the precise connection between a particular research project, development, and production is not readily apparent.

At the Chemicals Laboratory, research on petrochemicals is regarded as a quite mature field. However, JC company's manufacture of pharmaceutical bulks and synthesizing of functional resins such as engineering plastics have been growing based on the firm's catalyst and organic synthesis technology. For example, the Pharmaceutical Research Center is in charge of synthesizing pharmaceuticals but the Chemicals Laboratory handles the commercialization of these items as well developing efficient production processes for them.

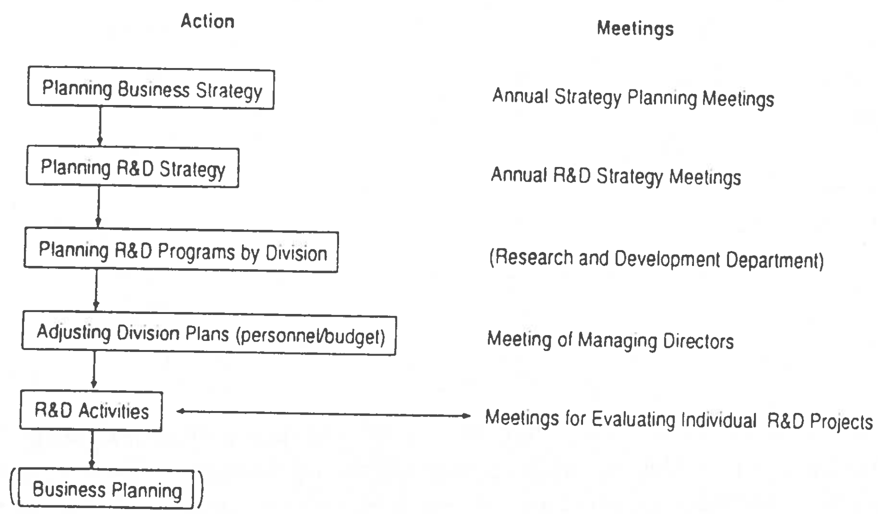
> "I have had to make more than a little effort to follow up the technology which I have dealt with, in relation to the factory or the sales division. At the same time I am charged with developing new technology, which requires originality and creativity, and I personally want to emphasize such work. I am doing two different categories of work roughly half-and-half at the moment. Compared with some years ago, the general focus of our activities has shifted to the search for new business opportunities including new ideas or technology, and our work is not as closely linked with factory activities as it used to be. With the exception of very serious complaints from customers, problems are normally handled at the factory." (Master, Chemicals Laboratory, 31 years old)

> "I specialize in surface chemistry, which involves the interface between different substances such as liquid and liquid, solid and liquid, and gas and solid. I am studying technology to control the interface. Through it is a

very broad field, we cannot use this technology alone. We are cooperating with people in other fields to develop new products." (Master, Chemicals Laboratory, 31 years old)

R&D themes are managed according to the flow chart shown in Figure1-18. First, a theme-search conference for R&D is held to discuss research themes at the corporate level, based on decisions reached at management strategy conferences. At the division level, R&D conferences are held to discuss research projects requested from within the division, and new research themes and the general direction for R&D activities are thus determined. The actual plans for staffing, budgets, and schedules are formulated at the Chemicals Laboratory according to the results of the above discussions, after which the actual studies begin. Monthly report meetings, progress meetings for individual projects, and other meetings concerning research are held from time to time.

FIGURE 1-18 R&D Process



"The R&D strategy committee decides to what extent to emphasize what area. For example, if importance is attached to a certain area, many staffers are placed at a laboratory directly committed to that area. The R&D strategy committee consists primarily of members of the head office's R&D Department and is joined by the director general of the Research Center. Prior to committee meetings, the directors of the laboratories (and, in some cases, GLs) and the head office staff of the related division meet to coordinate views within the Research Center.

"In entering a new field, research themes are always solicited and the R&D strategy committee also considers them. In expanding to an entirely different field, however, prior to a meeting of the R&D strategy committee a group such as a management strategy committee makes a decision on the scale of R&D. "

Research projects are handed to the division concerned immediately before commercialization, and meetings on the progress of the individual R&D theme are held jointly by the division, the factory and the laboratory. The project is later transferred to a development team. After all procedures shown on the flow chart have been completed, a discussion meeting on the theme is held again at the company level.

The progress of an R&D project is evaluated using a check sheet formatted as shown in Table 1-36 Then the deployment of personnel is determined for a particular theme, and the schedule is managed according to detailed plans for preliminary studies, basic studies, development, bench testing, and pilot plant operation.

TABLE 1-36 R&D Progress Check Sheet

Theme	Group	No. of Personnel	Progress							Important Theme	Evaluation
			Start	Detection	Search	Basic	Development	Bench Test	Pilot Plant		
New	Carbon	1	89.4			×	×				Faster establishment of catalyst-separating method
Current	Petro-Chemical	1				×					
New	Petro-Chemical	2.5	88.7		×				×	×	
New	Fine Chemical	1.5			×	×					
Detection	R&D	1	88.4	×						×	
Current	Synthetic Chemical	0.5				×	×				
Current	Composite Materials	1.5			×			×		×	
Common	Project Planning	4.0			×						

There are some cases in which problems at the manufacturing stage cannot be solved by a plant's development center alone and further support by the Chemicals Laboratory is requested depending on the project. In other cases, research activities are requested by a certain division: on a basic research field, a search for a new catalyst to increase production quantity, the development of a new catalyst, or a new process to synthesize a functional material for a new business division. Other types of projects, such as those to determine the properties of catalysts, are financed by the head office budget. Thus, the extent of cooperation with other divisions varies depending on the nature of the project.

b. Management of research and development

Next the Research Center is described in more detail to show how research and development is managed.

(1) Placement of research staff

Within the Center there are many groups for different purposes such as organic analysis, inorganic analysis and drug analysis. Each group, which is led by a

GL, consists of some researchers and assistants. The size of a group is not fixed, though the analysis group has more than 70 members.

A group operating pilot-scale equipment is composed of 12 members, the largest in the Chemical Laboratory. However, under a theme related to basic research into catalysts, a lone researcher experiments with a small cylinder as a reactor.

Group W, which consists of 12 members, works on several themes. The number of necessary staff differs from theme to theme. In this case one GL is responsible for all the group's themes.

Although each group is given themes, group members are assigned to particular themes at the discretion of the group. The group leader, who knows the team members best, takes their careers into account and judges who is qualified for what subject. Individual researchers are committed to single themes.

This is not true of research assistants. For example, Group Y is working on five themes and has five researchers and an assistant, who is involved in only one theme, while Group X's assistant is engaged in measuring physical properties not only for Group X but also for Group Z.

A veteran researcher, a new researcher and an assistant are counted equally in terms of workload adjustment, which is done by each group's GL and reported through the director general to the R&D management division.

(2) Research theme proposals and the R&D budget

New research themes are solicited by the R&D management division by distributing suggestion sheets, usually twice a year, or are proposed irregularly through GLs. Anyone can propose a research theme at any time. Therefore assistants can in principle propose research themes, but actually they rarely do so. In most cases, theme proposals are presented by researchers and forwarded through GLs to the R&D management division.

There are no particular rules for voluntary research designed to probe a new theme. Research on new subjects, the expenses for which are budgeted separately by company, is conducted by each of the laboratories. An opportunity is also offered to present the results of the research within the laboratory.

No voluntary research is done informally. Voluntary research is conducted as a part of regular research activity because budgets are appropriated by theme. Some department managers and director generals actively encourage voluntary research, and some staff also hope to do such work. They feel that they should follow their interests even if there is, strictly speaking, no formal support for such work.

Proposed themes are forwarded through the institute's management department to the head office's R&D management division, which makes final decisions on adopting new proposals, assigning personnel to the themes, and budgets.

Research and development expenses are appropriated as a part of the head office's budget. About 20% of R&D expenses are spent for basic research. The ratio of R&D expenditures to sales is over 6%.

Eighty percent of research themes are addressed by specific divisions. In these cases it is thought that research expenses should be included in the budget of the division concerned. Therefore the division in charge of a particular theme is identified and then expenses for the theme are estimated and incorporated into the accounting for the relevant division.

It is unclear which division should be responsible for basic research, and in this case the R&D department bears the expense. Some analysis expenses are assigned to relevant divisions and the balance of expenses, such as those for research and development of analytical techniques, is shouldered by the R&D department.

The medium- and long-term objective is to improve functional product areas. In line with this, emphasis has been placed on photoelectricity, pharmaceuticals, and new materials for disk-based information storage rather than on division-based research.

There is a rising tendency, however, to quicken the pace of research and development due to the severe economic situation. This means accelerating the R&D process for themes which appear likely to bear fruit in the near future.

The more emphasis is put on functional products, the heavier becomes the weight of the R&D budget because priority investment is important for improving the efficiency of investment in research and development. At the same time, what approaches can be taken to improve individual researchers' skills, to raise awareness and to establish better research organizations and systems are of tactical importance.

> "We set up the Twenty-First Century Committee to consider future trends in technology and expected changes in the market and the social environment. The committee's membership was drawn from among researchers, and the members discussed what to do in response to such changes and what research is necessary. I do not know whether their recommendations are being adopted in their entirety, but I believe such an effort will help the staff and raise their awareness."

(3) Managing the research schedule

Decisions are made on whether to continue R&D on specific themes at meetings of the theme review committee, which are attended by the vice president (top technical executive) and representatives of the R&D management division. These meetings are held once a year.

The general basis for making such a decision is whether or not a market exists. Research is launched on the assumption that investment will lead to effective results in the market. If conditions change, the research may be stopped. Long-range research is continued as long as market prospects are encouraging.

> "The research method is, however, largely at the discretion of the researcher in charge. Therefore we see to it that a change in theme will not discourage the researcher and take a flexible attitude. For example, even if it was decided that research should end in June the term may be extended to September because prolonging the activity lead to an accumulation of technology."

After R&D has advanced to a particular phase, whether to move to production or to continue R&D is considered. R&D is controlled according to the schedule authorized by the company's division and the laboratory.

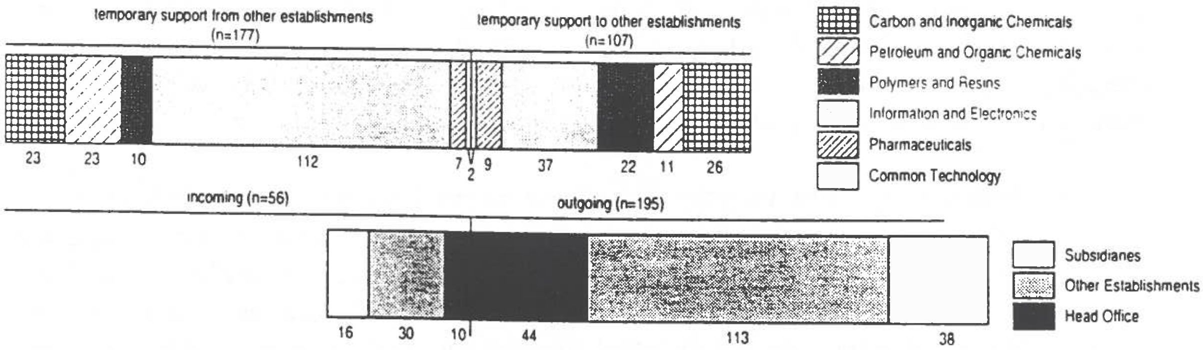
> "The average period of research is three to five years but some themes, including pharmaceutical projects, take ten years. The schedule is determined according to the individual theme."

c. Personnel exchange between the Research Center and other divisions

Movement of personnel in and out of the Research Center may be illustrated by the following statistics: during one year, from August 1988 to July 1989, 87 people joined and 39 people left the Center, resulting in an increase of 48 people.

Movements of personnel over the four-year period from August 1985 to July 1989 between the Center and other divisions are given in Figure1-19 (these exclude new recruits and retirees). Incoming personnel totaled 56 (an annual average of 14, this being 1.3% of the Center's total work force of about 1,100). On the other hand, 195 people moved out of the Center (an annual average of 49, or 4.5% of the Center's work force). This resulted in a net outward movement of 139 (or 35 annually).

FIGURE 1-19 Transters between Research Center and Other Divisions (August 1985~July 1988: 4 years)



The main destinations of outward transfers were other JC company establishments, and in about 60% of cases these workers were to take with them some know-how from the Center. Transfers to JC company subsidiaries accounted for 20% and aimed at transferring Center know-how to a subsidiary's production division. Transfers from the Center to the R&D management division of the head office accounted for about 20%.

Transfers for assistance purposes were seen quite frequently. Incomers moved from other JC company establishments for this purpose amounted to 177 over the four years (an annual average of 44 or 4.0% of the Center's personnel), while those leaving the Center for other establishments for the same purpose to amounted to 107 (an annual average of 27 or 2.5% of the total). The reasons behind transfers for assistance purposes were various.

> "We often have researchers from other establishments come to the Center, sometimes for long-term assistance or other purposes. The period of stay is usually from one or two months to two years. In some cases they join a research group for a particular research project. Other cases include the Center needing personnel who can operate equipment which is at the final stage before completion. Also, the Center provides for joint research on developing new catalysts using personnel from other establishments. Research for this type of movement vary case by case."

However, there has been a shortage of workers at the Center recently and transfers to fill the gap have become the main reason for movement into the facility.

> "Previously the Research Center was staffed by experienced high school graduates or college graduate researchers. These workers were responsible for conducting tests and providing test results, and at the same time they supported us technically. But now we cannot expect to recruit high school or college graduates here, and those who have Masters degrees must perform do every test procedure by themselves from planning to actual testing. In this regard, we think that the specialization of researchers has been diminishing." (Master, Chemicals Laboratory, 40 years old)

Another reason for personnel transfers from the Center to other JC company establishments is to support factory workers for handling specific technology after it is released, because when a development project is completed the technology is transferred to a factory for commercialization.

> "Previously, when the base of a new technology had been established we could just ask the factory to scale up production based on the sample we offered and they could manage the procedure without major difficulties. Recently, however, the production processes for functional and other materials has become new to factories and therefore in an increasing number of cases we must have personnel who can move together with the new technology."

In contrast to transfer from the Research Center to other establishments, personnel who will take responsibility for the commercialization of a particular item at an establishment sometimes join the R&D activity at the Center and later return to their establishment bearing the fruits of the development in order to implement production. Personnel coming to the Center for this purpose include production technology engineers, R&D staff, personnel from Development, and factory production workers.

> "Batch size is becoming smaller, and sometimes the capacity of a trial production factory is satisfactory depending on the item. Though factory technicians and operators are good at stable mass production of the same item, they cannot cope with manufacturing different items which change almost every day. Now there are some fields in which we cannot make a clear distinction between R&D activities and the production stage." (Master, Chemicals Laboratory, 31 years old)

Among those transferred to the Research Center, many are workers from the Development Centers. For the past several years many of those who were engaged in manufacturing information storage media such as hard disks and optical disks came to the Center from factories, because such items were new business fields for JC company. Technology transfers of this sort have been difficult for factories with little experience in processes used for manufacturing such items. Reviewing incoming personnel according to their former jobs, the majority were engineers at manufacturing sites while others were from Development Centers (the latter amounted to slightly less than 40 for the 12 months previous to July 1986).

To prepare for industrial production of hard disk surface materials, a group of people came for reinforcement purposes and stayed at the Center for two years. This preparation included training for core production personnel as well as for those who were to be involved in inspections at the factory. 'Thus, transfers to reinforce the Center's structure also served to train personnel in charge of the production of particular items. Such training also involved engineers from firms outside the JC group when manufacturing was to be outsourced.

Originally the Development Centers handled the transfer of expertise to production lines when a new item was commercialized. In the case of disk material manufacturing, however, there was no store of basic technology accumulated at the Development Centers and therefore the Research Center provided personnel training programs involving production line operators.

Although many workers have come to the Center for assistance concerning carbon and inorganic products, at times a considerable number of Research Center personnel have been dispatched to assist factory operations because of problems in starting production of items which were developed at the Center. In this way, personnel exchanges between the Center and other JC company entities are mostly associated with technology transfers.

"There are some cases in which the researcher who has been involved in a technology is transferred to a factory where the project is scaled up to an industrial business. But, in may case, I don't think I will move to a factory when my project is transferred to the production stage. I feel this way because I know the name of the person and the location of the factory that will be the successor to our research here. He was working with me here at the Research Center as a co-researcher and we are of equal status in the company. So we do not have a relationship where one person gives orders to the other, but we are sure that we can cooperate in a friendly manner. Thus, we have a system to transfer technology very smoothly to the factory." (Master, Chemicals Laboratory, 40 years old)

Data on personnel transfers in and out of the Chemicals Laboratory are given in Table 1-37. During 1988 and 1989 there was not much personnel movement involving the Laboratory, either inbound or outbound, and one reason for this may be the fact that research in the petrochemical field has largely matured. However, there were twelve temporary transfers (six incoming and six outgoing) which were not associated with technology transfer but were done for general assistance or other purposes.

TABLE 1-37 Personnel Movement in Chemical Laboratory (1988~1989)

Hired	Resigned	Transferred/Loaned		Studying Abroad		Assistance/Business Trip	
		In	Out	In	Out	In	Out
10	4	4	3	1	5	12	12

Note: "Assistance" indicates workers moved to other establishments for a few months to help operation or receive OJT.

d. Transferring know-how to Development Center.

Development Centers are recipient organizations which are active in commercializing new items which originate from basic research at the Research Center. Thus their main responsibility is to link technology to production lines. In addition, Development Center engineers the are expected to help improve existing products since they are closely associated with manufacturing divisions. The activities of Development Center engineers include taking responsibility for starting operations at a new plant, performing studies and technical improvements on operation problems in the manufacturing process, conducting various analyses and tests, and exploring new topics. Thus, they provide relevant information from the production site to concerned parties such as the head office divisions, the Research Center, and engineering divisions, and make major contributions to JC company's R&D efforts.

When a new item is very close to commercialization the Chemicals Laboratory at the Research Center will, for example, directly contact potential users to solicit their evaluation of the performance of the item and supply small samples which they can produce with beaker-scale manufacture at the Laboratory.

At a further stage, i.e. pilot production, the Research Center receives evaluations of industrialized products from product uses. At that point the people who will assume responsibility for the project at the Development Center are formally appointed, and they visit the Research Center to establish and maintain close contact concerning the item. They sometimes work at the Center for lengthy periods.

If a project is proposed by a particular division, channels for communicating the relevant information are formed among researchers involved in the project as it advances from development to commercialization. In such cases, since the project is sponsored by a division the official reports on R&D progress are prepared by the division as the project proceeds. These reports cover all stages from proposal to development and research.

Concerning technologies and fields entirely new to JC company, the Development Centers maintain a constant vigil over the contents of researches being carried out at the Research Center. Searching for any promising theme, a Development Center supports such projects so that it can commercialize the item and manufacture it at the factory to which it is attached. There are usually two routes for such information: one carries information on the early stages of basic research through personal contacts within the R&D group, while other consists of formal communication through the division to the Development Center.

While the head office has overall responsibility for selecting a particular division for a particular business, there have been increasing numbers of products which defy the firm's conventional product boundaries. As a result, divisions are now competing for new products. Under these circumstances the decisive factor for success is how early a division can obtain relevant information. Therefore, daily interaction between researchers at the Development Centers and their counterparts at the Research Center is indispensable in order to create and sustain informal personal networks.

The selection and arrangement of research themes at a Development Center is generally decided by its director. As mentioned above in Part 1, Section 1, there are several groups in each research section and each group is simultaneously involved with a few different research themes. When a particular theme is expected to generate intense activity, the research section group can expect the help of other workers who are investigating other themes. Although the normal procedure is for the group leader to request such help, the director of the Development Center may directly approach other groups for help in urgent circumstances.

"When assistance from other groups is required, the request should clearly state: 'We can do this much ourselves, but to reach a certain goal we need this

> number of people.' Each group possesses considerably different specialist knowledge. Even so, assistance from other groups is very useful because the researchers and the group leader of the group concerned precisely determine the direction of the research beforehand and can specify for precisely what data they want helpers. For such activities as data collection, there is no difference between groups."

The budget scale for an R&D activity is roughly determined at the stage when the number of people to be involved in particular theme is reported to accounting at the head office. The total budget is reported to the Development Center as well as to any division which will pay for a particular project. The final decision on the number of people to be assigned to each research theme is approved by the head office, because the head office also pays R&D expenses.

> "Negotiations with the head office start with our proposal, for example 'Let's start this theme with five people.' If it is a project which to some extent builds upon previous work done at the Research Center, the head office definitely participates in the discussion. If there are not enough people available we may compromise by saying, 'We actually need five, but we can at least get started with three."

Thus the Development centers are situated between the Research Center and the production line and deal with issues which overlap basic research and industrial production. For some themes, even though there are no concrete plans for commercialization a Development Center takes a strong interest in applied research by cooperating for information acquisition and exchange between researchers. In such cases, the Development Center tries to support the applied research through the entire process up to commercialization from a medium- or long-term viewpoint.

Concerning themes relating to new business, a team of researchers form a Development Center may move to the Research Center to help shorten the period required for commercialization. In the case of special functional materials for which markets have not yet developed extensively, bench tests and small-scale pilot production are done at the Development Center in tandem with efforts to market the product. For other themes, the staff of the Development Center works together with production engineering staff and production line personnel to test altered operating conditions using an actual plant. Thus, the range of activities of Development Center staff is quite broad and flexible.

e. Production division technical staff

The production sector is responsible for stable and efficient production. Toward that end, the main responsibilities of the production sector's technical staff are examinations and improvements related to production control and quality control. This includes technical work associated with plant operation such as maintenance, operation control, production control, cost reduction, rationalization, energy conservation adn safety, all considered from an operations perspective.

(1) Engineers in production sections

Technical production staff are also deployed at the production section level. They handle minor refinements as well as investigating and improving unsatisfactory production operations. At an ethylene plant, for example, the total production quantity is so large that even a 0.1% improvement could lead to considerable cost savings. Therefore a large number of technical staff are deployed at production sites such as ethylene plants where maximum effect can be expected of improvements despite the technological maturity of the field. The exact number of workers differs from section to section, since department managers evaluate the importance of each section and determine the necessary size of its technical staff according to their priorities. Although the number of personnel is generally fixed according to the size of the section, some special considerations is awarded when a section is regarded as being particularly important.

The technical staff at an ethylene production site usually concentrate on work at the plant, and if they participate in a different project they are shifted to another organization. Many of the technical staff at the Mi ethylene plant have been working at the site for a relatively long period as specialists in ethylene production; this is similar to the circumstances of some researchers at the Chemicals Laboratory who for years have been involved only with catalysts.

The technical staff are assigned job areas such as maintenance or operation control and are rotated between different job areas once every several years. As they are assigned to a particular section in the event of problems or urgent need in the section, they cope with such matters quite flexibly.

Most technical staff in the production division majored in chemical engineering, applied chemistry, mechanical engineering, electrical engineering, or measurement engineering. The engineers in charge of the production process are involved in operations control, while those in charge of facilities are assigned to the engineering department. Many of the latter are specialists in instrumentation or electricity. Thus there is a rather well-defined border between production and engineering. There is relatively little movement of personnel between the two areas. Even so, these workers are not assigned to any particular area of work for an extended period though they may remain within one section, because JC company's philosophy holds that they would be unable to think with an overall perspective if their work were limited to one particular area. This philosophy is also reflected in the treatment of engineers in the engineering division, who are shifted systematically among many plants to develop perspective from a variety of experiences.

Engineers who are university graduates and posted to production sections as technical staff are expected to become section managers in the future, so the focus of their training is on helping them to acquire the experience which is required of a generalist. Similarly, JC company aims to train its operators so that they can cope with a wide range of duties. In summary, the goal of basic rotation policy at chemical plants is allow workers to experience a variety of situations.

(2) Engineers in the Coordination and Technical Section

Technical staff in charge of activities which are common throughout a division serve in the Coordination and Technical Section (CTS). The nature of their jobs is quite different from that of staff workers in other sections whose duties are extremely broad and are associated with everyday plant operation. Other engineers, for example, deal with improvement proposals submitted by employees, attend morning meetings, and evaluate current operations. These engineers work under the pressure of events and therefore cannot concentrate on a single issue. But CTS staff can distance themselves from everyday plant operation and involve themselves extensively in a particular question.

Although both CTS and non-CTS engineers are basically similar in their focus on production, non-CTS staff must react immediately to events while CTS staff are in position to cope with improvement from a longer-term viewpoint. Under these circumstances, it is critical that CTS staff workers obtain information from operators concerning problems during operations, because this information is used to begin their approach to an improvement topic.

> "One of the most important things is that the CTS staff have production experience and can maintain effective communication with operators through friendly relationships, so the engineers can absorb information which is useful for their own tasks. CTS staff must be open to useful information provided by operators. Sometimes a very serious problem is identified by an operator who points it out as a minor difficulty."

The CTS staff plays an important role in large projects such as the opening of a new plant. Depending on the project, some researchers form the Research Center may lend their assistance. In other cases a research group from the Development Center participates. CTS staff often coordinate all such projects, and these personnel often work together with Development Center engineers on improvement projects through a close contact who is performing the bench tests.

(3) Rotation of production department engineers and other workers

Engineers cannot remain level-headed if they work in one section for a long time, so these people are rotated from time to time and can themselves apply for such a move. In addition to minor rotations between sections, there are larger-scale transfers such as between departments or factories.

The scale of movement is larger for university graduates than for graduates of technical colleges or high schools, whose mobility is somewhat limited.

Operators, however, rarely experience transfers with the exception of extraordinary events such as the opening of a new plant or a shift to new business due to withdrawal from a previous business. Recently, operators from the Mi Plant were transferred to the Od Plant and the Ch Plant, which are undertaking trial production, because the Mi Plant did not possess any technological base for its new business field of information-related materials. The operators from the Mi Plant stayed at the Od or Ch Plants for one or two years and returned to Mi after acquiring the relevant skills. Technical staff workers form the Mi Plant were also transferred at that time for the purpose of assistance.

2-3 Formation of Engineer Groups and Their Social Characteristics

2-3-1 Personnel Management Policies for Engineers

a. Hiring technical personnel

Since JC company's overall employment policies are explained elsewhere (see Section 2 (2) (a) of Chapter 1), the discussion here is limited to the employment of research staff and especially the recruiting of researchers necessary for expansion to a new area.

JC company recruiting teams are formed by alma mater to hire chemistry majors. Team members visit their schools and ask professors to recommend candidates, and meet with students to provide information about their research institute. Students who apply for jobs are given an employment test. Those who are hired are usually placed in a laboratory other than that of the recruiter. Almost no students are hired because their presentations at academic meetings were unique and excellent. Most apply because they were recommended to do so by a professor they became acquainted with at an academic meeting.

When recruiting biology majors to expand in this area, the company has professors associated with the JB Scientific Research Institute recommend candidates. This institute was established in 1971 as an affiliate and is engaged in fundamental research on bio-related subjects. To acquire qualified personnel, the company sometimes directly approaches laboratories whose themes are worthy of attention. Through these efforts the company has gradually increased its number of researchers over the past decade.

The Applied Biological Laboratory now has 95 staffers. Research on gene recombination has been conducted since ten years before this laboratory was set up. The staff hired before the laboratory was established now act as group leaders and have become the core of personnel expansion. The laboratory has sharply increased its hiring during the past three years though it stopped hiring from 1975 to 1980 due to a slowdown in the petrochemical industry.

The company hires fresh graduates regularly, though some mid-career workers are also hired. Staff hired in mid-career account for only 5% of the work force at the Applied Biology Laboratory. People who have studied at US universities are also regarded as being mid-career, so actually the proportion of employees with work experience at other companies is much smaller. The company fosters human resources from within.

> "Basically, our company does not hire irregularly nor make public job offers. If there is a person who strongly hopes to work for our institute, or if we desperately need an expert in a certain area, we consider hiring a mid-career person."

Among the research staff the largest group is that of experts in organic chemistry. The film sector is increasing its employment of physics specialists, and the engineering development section hires people in the machine area. Electronics majors are placed in the fields of photoelectricity or control engineering in the engineering development section.

> "We have had relationships with certain chemistry professors for years. We conduct joint studies with them or entrust them with research. But we have no senior staff who majored in physics, mechanical engineering or electronics, so we have difficulty hiring people in such areas."

The fact that JC company is a chemical business causes personnel problems, similar to those experienced by an electronics manufacturer trying to enter the chemical area which has difficulty acquiring chemistry specialists. In this sense, both industries are making inroads into each other's labor market.

b. In-company education for newly-employed engineers

(1) Introductory education and job assignment

As described in Part 1 2 (2) (d), education for newly-employed engineers at JC company is based on OJT and provided at the workshop with the exception of the collective education they experience when entering the company. More precisely, the first three years after an engineer joins the company is regarded as a training period, even for people with Doctor's and Master's degrees, and all are expected to acquire the basic knowledge required of corporate engineers or researchers during this period. Appropriate educational programs are prepared at each establishment for these new employees.

When freshly-graduated personnel are employed in April, in line with company-wide personnel management policy all of them participate together in an introductory seminar lasting a week or ten days. When this introduction is over the new employees, including office workers, are sent in groups to factories for one month as trainees where they work under the three-shift schedule. The new employees are interviewed about posting during this period, and they are sent to their workplaces by the end of May following an announcement. Engineers are then deployed at the Research Center, a Development Center, or a production site. Those assigned to a factory will work in production to learn about the plant for about a year, doing shift work. Those posted to the Development Center will study the production field most closely related to their research specialty.

Assignment interviews are held again at the Research Center because at first the new workers are just assigned to a Laboratory. They are asked which field of study they are interested in, or what they studied at university, and in this way their work places are chosen to satisfy corporate R&D strategy. This process is arranged by the Research Center's personnel management and administrative departments. Although each laboratory requests the type of personnel it wants in advance, priority for assignments depends primarily on the decisions made at corporate management strategy conferences.

At the chemicals division, for example, tens of new engineers who majored in chemistry are inducted and individual workplaces are determined after interviews. These people are not always assigned to exactly the same field as they studied at university though their academic experience is taken into consideration.

> "Even if someone studied organic chemistry at university they may be posted to an inorganic field. Aside from such extreme cases, those who studied organic chemistry may join an organic group in the chemicals Laboratory or may be involved in organic synthesis at the Photoelectric Research Center or at the Pharmaceutical Research Center. However, if the pharmaceutical division deals with a particular animal and takes on a new graduate because he or she can handle this animal then it is quite likely that the newcomer will be involved in a field very close to his or her university specialty."

As is apparent from the foregoing, deployment of scientists and engineers is decided from a corporate perspective.

(2) Education for new Research Center employees

Table1-38 outlines the educational system at the Research Center.

New employees join the company in April every year and, after participating in the company-wide introductory program and factory training, some are posted to a Laboratory. First the general structure of the Laboratory is explained during a three- or four-day orientation session, and the new employees are then assigned to particular positions after being interviewed.

An experienced researcher[8] acts as career counselor (CC) for a newcomer and provides guidance during the first year on an individual basis. A new employee can expect to receive advice on topics such as the details of writing a research paper, everyday clerical routines, research guidelines, and safety procedures.

> "Career counselors are chosen at each workplace and preferably are 'researchers,' with priority given those who are conducting work similar to that assigned to the new staff worker. In a new business area, however, experienced workers who are not yet managers sometimes serve as career counselors for newcomers."

8: Laboratory personnel are referred to as "staff workers" until they are promoted to a managerial post and termed "researchers."

TABLE 1-38 Training at the Research Center (August 1988~July 1989)

Participants	Item	Term	Participants
Three-Years Training after Joining Company			
All employees hired in April, 1989 (new employee training)	Introductory education	Apr.–May 1989	98
	System instruments operation	June–July 1989	344
	Glass handling training (includes some non-newly hired employees)	June 1989	about 100
All employees hired in April 1988 (new employee training)	(new employees board together)	Oct.–Nov. 1988	80
	Briefing meeting one year after joining company	Mar.–May 1989	80
	System instruments operation	Aug.–Sept. 1988	246
	Fire-fighting equipment operation (includes some non-newly hired employees)	Nov. 1988	about 100
	Analysis equipment operation (includes some non-newly hired employees)	Feb. 1989	total 378
All employees hired in April 1987	OJT according to yearly training schedule		83
All employees hired in April 1986 (third year training)	Training at other establishments	Feb.–Mar. 1989	122
	Career planning	Mar. 1989	122
	Interview	Apr.–May 1989	122
	Briefing meeting three years after joining company	Mar.–June 1989	122
Management Training			
Managers (of divisions and sections, and chief secretaries)	First step: Lectures by key officers	Feb. & Apr. 1989	20
	Second step: K&T method	June 1989	20
	Third step: Research and proposals on issues	Dec. 1988	81
New group leaders	Training for new Group Leaders	Aug. 1988	15
New supervisors and engineers in 1988	First step: Collective training	Aug. 1988	50
	Second step: Training camp	Nov.–Dec. 1988	50
	Follow-up training	Mar. 1989	50
Vice secretaries/supervisors/engineers	Marketing training	Occasional	11

Usually a research target is set for three to six months in the future and the new employee's work is evaluated at the end of that period. New workers take an overnight seminar trip four or five months after entering the company, when all new employees gather again for the first time since being posted to different workplaces. The general business circumstances of the company are explained and participants are expected to deepen the mutual friendship which arises among workers who join the company in the same year.

Of course, there are some cases in which a newcomer is not satisfied with the field to which he or she was assigned. Therefore at the end of the first year another interview is held to evaluate the employee's adaptability. People from personnel management at the head office, the personnel manager of the Laboratory, and the employee's career counselor participate in the interview. If the new employee cannot come to terms with the current arrangement, he or she will be assigned to another section.

About one year after they join the company a meeting is held for new employees to report on their individual performance, as well as for the purpose of practicing presentations. The career counselors offer practical advice on topics such as selecting the theme of the presentation and how to prepare visual aids.

The training program for the second year consists mostly of OJT. The company provides as many opportunities as possible for participants to observe other JC company divisions via field trips and other means. About two and a half years after entering the company these employees participate in another overnight trip on which they meet engineers working at plants who joined the company in the same year, and members of each group make presentations on their work and discuss how to maintain connections between laboratories and plants. These meetings are organized because laboratory engineers have little chance to contact their counterparts who work at plants.

> "A total of about 100 men and women participated in the trip this year. Ten groups of ten were divided into two teams to visit factories. While male researchers know the factory environment because they worked on a three-shift basis at a factory for a month, this is the first and a very useful opportunity for the female researchers who are assigned to laboratories without experiencing work at a plant. Also, it is more meaningful to visit a plant after being involved in research for some time."

Third-year employees participate in another presentation gathering, where they are expected to report on their work in greater detail. Although they report about their research in monthly section meetings, this is an opportunity for them to present the contents of their research to a larger audience. At these meetings more than 100 researchers are divided into two groups and each individual gives a 15- to 20-minute presentation, making this a two-day event. In addition to the all third-year researchers the General Manager, Research Directors, group leaders and other researchers in the same research group also attend the meeting. The presenters report on their achievements during their first three years to largely complete the three-year training period.

Lastly, however, they are interviewed for career planning and asked to express what they would like to be doing in five or fifteen years time. In addition to the above, other technical education sessions concerning safety, computers and analytical equipment are held from time to time.

(3) Newcomer education at the Mi Development Center

There is also a three-year education program for those deployed at the Development Centers.

TABLE 1-39 Training for Newly Hired R&D Employees (within 3 years after joining company)

OFF-JT	OJT
First Year—Introduction • Boarding Together (before hiring) • Training after assignment a) Introductory Education Security, making proposals Basic attitude as a staff worker R&D operation b) Graduation thesis presentation	• Thorough understanding of security • Basic experiment technology • Knowledge related to operations • Preparing materials for study meetings • Presentations at study meetings
Second and Third Year—Establishing a Foundation c) Basic education Analysis basics enhanced technology analysis outline Patent education Research project d) Briefing session At R&D Center and other establishments	• Leading subordinates • Surveying literature and announcements of results • Planning experiments • Enhancement of special knowledge • Improving experiment technology • Data analysis technology

The new employee seminar at the Mi Development Center is basically similar to the new employee seminar at the Research Center, and is outlined in Table 1-39. Employees are regarded as being in an introductory period during their first year. After completing the factory training on production they are posted at the Development Center, and OJT continues under the guidance of an engineer one or two years older than the newcomers. Section managers from other sections also assist in OJT as advisors.

Below are remarks of an engineer who is a technical college graduate and was assigned to a 70-member resin development group which handles polyethylene within the polymer research team of the Development Center in April 1984.

> "In my case, I had no particular career counselor–several engineers taught me various things in turn for the first several weeks. Although there was a roughly-outlined training program, I was the only newcomer that year and I received individualized training for about two hours per subject between routine work activities. The contents were not directly related to development, but rather emphasized basic technology. Later I was sent to a plant to work as a trainee, considering improvement proposals. I did three-shift work at a low-density polyethylene plant and was taught various things by the chief of the workshop. I learned that poor facility design jeopardizes stable operation as well as burdens operators, learned out about production processes for the products I would be dealing with, and came to understand what are the most important factors for achieving the target product quality.
>
> "For two years after I joined the company I was learning my job, following the instructions of my seniors. I was never embarrassed, because they helped me when necessary. But from the third year I had to work rather independently on a particular theme and then I started to study myself."

Thus, for some time now new employees have not been regarded as independent engineers for the first few years. Various sorts of in-company training have been provided them, including OJT and Off-JT led by senior engineers and training at a production site by considering improvement proposals.

The Development Center holds a poster session in November every year, as does the Research Center. Display panels are placed in a large room and researchers standing in front of their panels try to explain what they have been doing on a face-to-face basis. In an ordinary discussion or presentation meeting it takes 30 to 40 minutes for one presentation and the number of participants is very limited, so as the Development Center grew this type of presentation method was adopted.

Each research group has a monthly meeting for reporting and discussion, which is also a valuable OJT opportunity for newcomers. Young researchers are encouraged to participate via other opportunities, such as the company-wide joint research presentation meeting and conferences of the analytic physical properties research division which are held regularly at each establishment.

c. Overseas study

JC company has three types of overseas study programs. In one program, individual researchers who want to study abroad submit applications and if they pass the company's written and oral examinations they join the program. About five people go abroad every year under this program. Some are sent from laboratories but others include those who will do business overseas in the future or who will enter a US business school.

Another program features overseas research and is provided to educate personnel who will be engaged in promising fields as key persons. The period of study is two years, and a total of five people are sent every year; recently this has included one or two from Development Centers and production divisions, while formerly most were from the Research Center.

The third program dispatches researchers on business or for short-term overseas study in order to learn about a particular technology for a year or ten months. Four or five people are studying abroad under this program every year.

In addition to these there is a program called "technical attache" for those who have just become chief researchers. These workers have a good deal of research know-how and can interact with foreign researchers on a give-and-take basis. They can directly contact the place they wish to visit and exchange views with their counterparts at an overseas research center or university for about three months. They are require to submit a report after returning to Japan. The arrangements are made by the researchers themselves, but all expenses are paid by the company.

Furthermore, researchers are encouraged to participate in overseas scientific conferences if they can give a presentation. About three people attend such meetings every month. As for domestic scientific conferences, they have considerable freedom to participate.

d. Movement to laboratories and other establishments

Concerning personnel changes at the Research Center, the number of workers moving out to technical divisions at the head office or factories, taking with them research results, is larger than those coming into the Center for assistance or as ordinary transfers. Many moves to the head office are to the R&D management office or to the pharmaceutical development division for clinical development, which requires interaction with medical doctors. Since the pharmaceutical development division of the head office stresses R&D activities, a considerable number of researchers are sent there from the Center.

As for transfers to factories, the most common circumstances involve participation in a new business division such as hard disk surface materials and carbon fiber. These personnel transfers form the Research Center are done mainly to move the fruits of R&D efforts to actual business divisions and mostly involve younger researchers. One example of this would be the transfer of researchers from the analytical physical properties research center to a pharmacy factory which lacked personnel capable of analysis.

Since the disk material factory (which was preparing to start production between 1985 and 1987) has now started full-scale production, the number of personnel transferred from the laboratories has declined. But the company still maintains a basic corporate policy on personnel transfers which holds that the quality of the laboratories is demonstrated only by quick development of high-quality products and transfer of the technology to other establishment.

Incoming personnel transfers to the laboratories are similar to ordinary worker rotation so young people as well as group leaders are involved. Among personnel transferred to subsidiaries, the vast majority are either older workers who become new managers, replacing former managers who have reached the age of mandatory retirement, or younger people whose movement is associated with a technology transfer.

Considerable managerial ability is required of the Research Center's executive managers, so these posts have been staffed by bringing in managers from other establishments or the head office who have extensive business experience rather than by promoting employees who are active in research.

Mobility between laboratories can be regarded as being different for two groups of workers: one consisting of those between 25 and 35 years of age and the other of those between 35 and 45. The purpose of transfers among these two groups is different. Moreover, the destinations of transferred workers are limited to rather specific areas and assignment to another division is quite rare. Basically, those transferred undertake a new project which will benefit from their previous experiences.

Because the Center has expanded quite rapidly there have been sufficient posts available for promotion, such as group leader or manager, including factory manager, and thus the Center has not had to face the issue of an aging work force. However, the length of serving as group leader is becoming longer than it was.

Handling older workers who have been serving as group leaders is more difficult than dealing with those who have continued their research work. Since group leader is a managerial position and these people have been away from active research for some time, it is very difficult for them to return to doing research. For employees who have continuously been doing research, on the other hand, there are some posts in which they can utilize their experience even at age 40 or 50. But since the corporate organization is a pyramidal hierarchy there is a tendency to send former group leaders to subsidiaries or outside companies to make use of their managerial abilities.

2-3-2 Promotions, Turnover, and Working Hours

a. Promotions and salaries

As mentioned in Part 1, corporate-group-wide personnel systems are applied to office workers and technical employees based on job evaluations and individual qualifications. Regardless of the work site– the Research Center, a Development Center, or production line –treatment in terms of salary is basically the same for workers who are ranked in the same job function/qualification category.

Generally speaking, self-motivated development of technical ability has come to be highly regarded in Japan and this requires top-quality scientists. JC company researchers have been paid as technical specialists and this policy will not change in the near future.

Some companies have introduced a special compensation system for engineers who are actively engaged in very advanced and specialized fields, in order to raise the salary ceiling for such researchers who are not always promoted according to a general production line system. Such companies treat researchers in a particular field similarly to directors. In addition, they conclude contracts with outstanding researchers which provide for favorable payment on an annual salary basis in order to secure specialists. But very few companies attempt to drastically reform their existing salary system in favor of R&D engineers. JC company will maintain its present salary system for some time though there will eventually be some changes.

Promotions in JC company are based on evaluation of the individual's performance and capability. A quarter of the Center's work force is promoted from *sanji B* to *sanji A*, for example (refer to Part 11 2 (2) and Table 10), with the number of people being promoted varying from year to year. Promotion to *sanyo* is done on an individual basis. On the other hand, promotion of employees in line divisions does not always correspond to individual qualifications because the proportion of the number of positions for each rank to the size of the entire work force is fixed. In the laboratories there may be group leaders with lower qualifications and group members, subordinate to group leaders, with higher qualifications, and there are also more *sanji B* than *fuku-sanji*.

Salary calculations are based upon factors such as age, ability and qualification. As rank is not a factor, one's salary depends on one's seniority, job evaluation and qualifications. Those with identical job evaluations and qualifications receive the same salary wherever they work, whether at a laboratory or a factory.

b. Turnover among technical personnel

The separation rate is very low among researchers. The few workers who resign from the company most commonly cite reasons which have to do with personal matters such as running the family business. Aside from female workers, many of whom resign upon marriage or childbirth, only four or five out of a total of more than

600 researchers leave the company in any given year. About half do so because of family-related issues and half for a change of employment as they move to a university or a national research institution out of preference for basic research over industrial research.

Almost no one resigns from the Mi Development Center. At factories only one or two university graduate staff workers per year leave the company. Moreover, there are very few cases in which technical staff workers at a factory or a development center are transferred to the Research Center or to the head office, far fewer than office worker transfers.

c. Working hours

There are no time recorders at the laboratories. Since July 1989 a flex-time system has been used and researchers can come and go as they desire outside the core time from 10 A.M. to 3 P.M. Total work hours are calculated monthly.

Overtime allowances are not paid to deputy section managers or higher-ranking workers. Union members record their hours, to be checked by their group leader, and are paid for their overtime hours. They are paid for studying reference materials as overtime when the materials are related to their current activities, but are not paid for time spent on other studies at the library.

2-3-3 Exchange of Technical Information within the Company

R&D engineers can participate in the activities of professional societies, while production engineers can participate in seminars or other meetings sponsored by industrial associations. Thus engineers have opportunities to exchange views with engineers from other companies in the same industry or with university researchers. Although they maintain contacts with their university school-mates, such relationships are limited to the personal realm and usually detailed technical information is not exchanged, for example, for the purpose of solving problems. Instead, the importance of exchanging technical information within the company in order to solve actual technical problems is stressed.

In the laboratories, technical information is exchanged at two types of presentation meetings. One is the quarterly discussion meetings held by each division, at which reports on research in progress are also presented for discussion about important concerns. These meetings are attended by the director of the Research Center, division managers and laboratory managers. Invitations are sent to all relevant establishments though attendance is optional. Presenters are various and might include a young researcher with one year of service and another with ten years of experience. The themes submitted from laboratories for presentation are sorted by a research coordination office and the most desirable are selected, after which the most suitable researchers for particular themes are appointed presenters. There are no participants from outside the company such as university professors.

Two other presentation opportunities are held at the Research Center every year. In addition, each laboratory holds monthly meetings for research progress reports.

At the Development Center, monthly R&D discussion meetings are held to explain to the factory managers what R&D projects are under way. The meetings include extensive discussions and are attended by section managers from the departments concerned, line staff, the Development Center manager, and the relevant group leaders and staff workers of the Development Center.

Different panel presentations are held regularly. Invitations for these are sent to the relevant establishments, partly for the purpose of newcomer education.

2-3-4 Personal Career Views of Engineers

This section describes career formation process of corporate technical personnel centering on the individual views of engineers.

a. On academic and introductory in-company education

Large Japanese manufacturing companies induct all newly-graduated employees every April. This is also true for research divisions. The hiring of mid-career workers is very limited except for special cases such as when moving into a completely new business field.

New employees who have just graduated from a school are not treated as engineers during their training period, and training for basic and specialized education is provided by the establishment while they are on the job. During this period new workers are expected to acquire the basic knowledge they need as corporate engineers, including how to draft reports, prepare references for meetings, organize data, and make presentations.

After this period is over they develop themselves mainly on their own through the process of their work.

> "The first hurdle a new employee freshly graduated from university is to acquire knowledge of technology for laboratory tests in a new field. While learning this, the new-comer usually begins to feel apart from the university and becomes aware of being a businessman." (Master, Research Center, 33 years old)

> "I acquired most of my ability and knowledge within the company, and what I learned at school was almost useless. We cannot work without understanding machinery and electricity. But more than a few people care about what they majored in at school." (graduate of a technical high school machine course, Power Supply Department, 43 years old)

"When we entered the company we could not understand the production process at all. It takes some time, until we get some experience. We cannot be motivated if we do not know how the overall process is operating, how the portion we are engaged in fits with the entire production procedure, and how important it is in the overall process. In my work, however, I can see only a small portion and I feel I have to continuously widen my own vision. If the hypotheses of a study is proved untrue in an R&D program, that is the end of the theme. Thus there is the question of how many hypotheses we can propose. And then scientific knowledge and experience are necessary to focus on an important hypotheses." (graduate of a technical high school chemistry course, Development Center Researcher)

"After experiencing three-shift work for about a year I was engaged in a discussion on improving the plant. May is the time for regular plant repair, and we could actually see various structures of the plant to complete our training. There is no connection between my research at university and the work I am doing at the company. At university, many research themes dealt with a single phenomenon and beaker-scale experiments. I feel a large gap, because I cannot apply what I studies at university to an industrial plant. Though I visited factories on my university field trips, I merely grasped the scale of an actual plant. If I could have stayed at one plant for two weeks, experiencing discussions on improvement proposals, I may have acquired some knowledge to bridge the gap, but the gap was not crossed with one- or two-day tours." (Master of Chemical Engineering, Coordination and Technical Section, Production Department)

b. On the capabilities required of engineers

Different kinds of technical knowledge are required according to the field in which someone works. Moreover, some capabilities cannot be acquired through academic study–they definitely require actual practice.

"Since computers have been introduced on a large scale to production, we cannot improve anything without knowledge of the computer systems. We must master operation skills to some extent in order to accurately interpret indications of trouble. In the past there were panels displaying the overall process in the instrument room, and we could locate where abnormal operation occurred using them. Now we have to summon the instruments we want to read to the monitor's screen. Even within a factory the computer systems differ greatly among different sections." (graduate of technical high school chemistry course, Deputy Section Manager, Production Department)

"Compared with when I joined the laboratory, the range of work has expanded. It is interesting to work at a challenging job, and I think I can manage to fulfill my assignment regardless. When I feel I have come up against a wall I get the most help from suggestions from my colleagues, information from references, or previous reports dealing with the subject. Though I will not find an exact replica of my problem in a previous report, I can learn quite a lot from knowing what approach was taken in similar circumstances. But we have no way of obtaining information on cases from other establishments unless we have had at least five years of contact with them, and know what research they have been doing.

"Now I am in a position to teach young engineers. I think it is important to let them learn in a natural fashion how to work. Since they don't want to fail in a new field, they cannot choose a theme if they lack independence and this is beyond one's specialist knowledge or personality. The most important criteria for a development engineer are ability, preparedness, and motivation. If they can participate in larger projects, according to their ability, they become increasingly involved in preparations including coordination others. Not only technical skills but face-to-face persuasive power is important. Another requirement is creativity, because coordination alone is not enough." (graduate of technical high school chemistry course, Development Center)

"We can accumulate general knowledge, but for my job [functional polymer materials] different knowledge is necessary for different product. As business people we should make a good impression on others. It is an advantage if we can have good enough relations with our customers who are in charge of development that they say to us, 'We want products with this performance.' What is required of corporate engineers is different from what is required of academic researchers. If we do not express ourselves forcefully we will not be heard even by anyone in our own company. So knowledge alone is not sufficient, and the overall character with which one can get along in the company is important.

"I don't think conventional OJT will be sufficient in the future. When it comes to high-performance materials we cannot do business on the basis of salesmanship or personal relations alone. Even with a good human relations, we sometimes cannot deal with new technologies without the help of a researcher from the Research Center who thoroughly understands the product. In the past we could transfer technology only. But today we must transfer personnel as well to diffuse complex knowledge within the company–otherwise we will lose the good timing necessary for business. But these individuals may not be good at relating to people or may not like to interact with production workers." (Master of Science, Development Center)

Under these circumstances, the most important factor for bringing up engineers is to have them challenge the unknown with an independent mind. Skill in negotiating with or coordinating people is not so vital for engineers working in technical fields in which they can operate on their own (such as research on a specific topic or an independent improvement project). But in other cases, persuasion and negotiation are very important. The latter include cooperative tasks involving staff workers at a production line, technical fields which involve joint effort with construction and production division engineers including personnel from outside companies as are seen in the engineering division, and various negotiations including price negotiations with customers accompanied by supplying small samples, as may occur in a development division involved with functional polymer materials

If engineers with strong negotiation skills as well as technical capabilities are brought up while upgrading their sensibility for operations, they will be able to demonstrate their leadership abilities while promoting projects and as a result will rise in the company.

2-3-5 Conclusions

The major characteristic of JC company's personnel management is flexibility. The company particularly tries to foster technical experts in-house: it hires new graduates and provides them with in-house training centered on OJT. This policy applies to all positions and to affiliated firms within the corporate group. One consequence is that a federation of corporate-group labor unions plays a role in standardizing basic working conditions. Given this mechanism, the company has succeeded in moving personnel between divisions in response to sudden changes in the business environment. An example of this would be its withdrawal from aluminum refining and expansion into pharmaceuticals.

This system involves promoting qualifications and as a result more than 40% of all employees are treated as managers. The organizational hierarchy appears to be slim because line managers account for only around 6% of the work force, but in terms of treatment rather large numbers of employees are in managerial positions.

Throughout the process from research to development to production there is a mechanism for maintaining flexibility even in obscure parts of the process. Thus to avoid undermining morale, even when calling on researchers to change a theme the company has them continue the ongoing work until they come to an appropriate conclusion. There are frequent opportunities for informal communication between Research Center staff and Development Center staff. When entering a new area, engineers at a factory often assist the research and development division for a short period and research division staff do likewise.. This flexible practice of short-term assistance is remarkable. It is rarely entered on personnel records, so engineers appear to be rotated less often than clerical employees. But it is certain that challenging the unknown through assisting other business units is more significant for improving employee expertise than career development through personnel rotation. For technical personnel as professionals, a wide range of such assistance experiences would be regarded as more important.

Such a linkage between research, development and production divisions will work effectively in research and development areas directly connected with market needs or seeds. Innovative basic research, however, depends on the long-term accumulation of research results.

In the United States there is a clear division between research and development. Development is managed much more strictly than research, and the development phase is frequently reviewed.

At JC company, however, as demonstrated by the case of the Chemical Laboratory, research themes are considered and reviewed in minute detail and staff are placed with care. But many things, including projects on new themes, are left to the discretion of individual researchers and group leaders.

The industry is now placing more emphasis on product innovation. Even in the area of basic research, will a business strategy which emphasizes flexibility remain effective? How will JC company respond to the new circumstances?

PART II THE ELECTRONICS INDUSTRIES

1. A CASE OF THE FRENCH COMPANY

1-1 PRESENTATION OF THE COMPANY

The first part of this monograph is an attempt to characterize FE Company on the basis of a few fundamental elements. The first of these will be an outline of the company's trajectory over the past decade, the second a description of its organization, particularly the way in which the various levels of activity in the technical functions are articulated, and the third and final one a survey of the human resources it has at its disposal.

1-1-1 TRAJECTORY: Program, Performance and Strategy

a. FE Company in the French industrial context

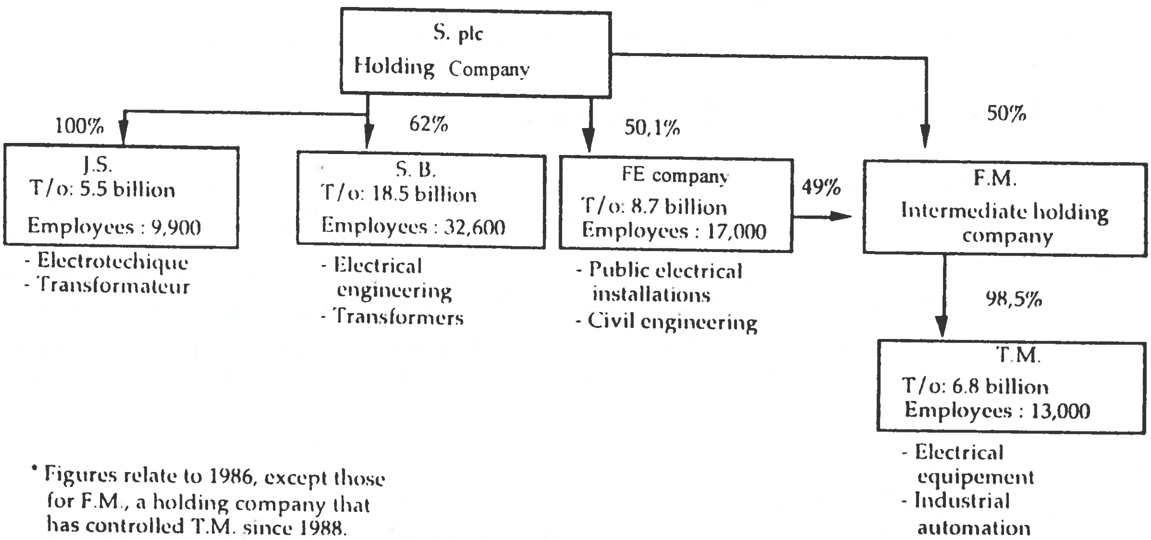
Since its creation in 1920, FE Company has specialized in the manufacture of electrical instruments and equipment for the essential functions of control, protection and automation in all electrical power systems. In short, the business of FE Company revolves around the control of electrical power. As will gradually become clear, its professional identity, its technical skills and its human resources have been conditioned to a large extent by its powerful historical identification with what it regards as its specialty, almost as its vocation.

This attachment to its specialty, which has had a profound effect on the company's personality , has not, however, prevented it from becoming one of the important players in the electrical engineering sector at a time of radical restructuring. Both in France and through the world, the industry is experiencing profound change brought about by the development of powerful new electronic technologies and the growing concentration of companies in the sector.

FE Company's particular specialty is the production of circuit breakers, and in this area it vies for market leadership on both the European and world levels with major groups such as Siemens, GEC-Alsthom and Asea Brown Boveri that are both much more diversified and considerably larger than FE Company. By way of example, let us compare FE Company with GEC-Alsthom, which is its most direct competitor in the French market . The former has a turnover of some 10 billion francs (1987 figures), 80% of which is generated by the circuit breaker market, while the corresponding figure for the latter is 47 billions from a range of activities such as electrical equipment, railways, shipbuilding, the nuclear industry, and so on.

Despite its high degree of specialization and a sometimes uncomfortable financial situation, FE Company has succeeded in becoming a highly competitive player on the international market. Over and above the dynamic this has created, the company's success cannot be dissociated from its increasing integration within the S group of companies. This group, a large industrial conglomerate with interests in the iron and steel, machine tool and nuclear industries, among others, used to be the archetype of the industrial group structured by a logic of legal and financial arrangements. Lacking any great coherence in its industrial policy, the S group faced severe economic difficulties at the beginning of the 1980s and was forced successively to abandon its many interests. Following this reorganization, the group refocused its attention on its activities in the electrical sectors, as Figure 2-1 shows. In doing so, S group madeFE Company the spearhead of its restructuring. It had long been a minority shareholder in FE Company, and its stake increased from 35% in 1981 to 64% in 1990, with successive increases in capital.

FIGURE 2-1 Structure of S Group



* Figures relate to 1986, except those for F.M., a holding company that has controlled T.M. since 1988.

Now that the S Group (holding company) controls four subsidiaries (operational companies) through majority shareholdings,FE Company is considered to be the keystone in the overall strategy, with its manufacturing know-how as the pole of excellence around which the dynamic of the S Group is to be organized. Thus FE Company's actions must be seen within the overall context of the group as a whole, as the chairman and managing director of S Group acknowledges :

"There is often confusion between autonomy and decentralization (with respect to the relationship between parent company and subsidiaries). I am in favor of decentralization, but in a group there cannot be complete autonomy. We all belong to the same organization. Thus strategic and financial decisions are taken at S plc level, but those decisions are implemented at subsidiary level. Power is shared, and as a result FE Company, and the other companies in the group, should be able to play a role in world markets...".

b. Economic trajectory of FE Company in the 1980s

By the widest definition, namely the consolidated balance sheet, FE Company had a turnover of 14,636 million francs in 1989, recorded profits of 690 million francs, invested 1029 million francs and employed 25,021 people throughout the world.

These figures show that, despite successive drastic restructurings, the company has been able to consolidate its market share, withstand intense competition in the world market and strengthen its performance in an industrial sector in which overall activity is growing only slowly.

Some simple indicators enable us to outline the trajectory of its development during the 1980s. Table I makes a distinction between two legal - and accounting - entities. On the one hand, there is FE Company (the parent company) and on the other the FE group, which includes all French and foreign subsidiaries (in 1989 there were 42 subsidiaries and minority shareholdings in a further 8 companies). Unless otherwise indicated, references in what follows will be to the FE group, the only unit of any significance in measuring overall performance.

TABLE 2-1 Economic indicators of FE Company and Group

		1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Turn over (millions of french)	FE company	2,405	2,963	4,080	5,016	4,937	5,429	6,576	6,617	7,175	7,918
	group	3,100	3,192	5,100	6,085	6,246	7,468	8,725	9,770	11,388	14,636
Net profits (MF)	FE company	38	51	70	121	124	176	197	199	219	327
	group	61	81	102	159	176	247	285	323	450	690
Investment (MF)	FE company	98	118	120	(135) 178	(119) 253	(146) 301	(164) 355	(158) 544	(149) 3178	(178) 701
	group	136	167	188	253	305	527	(340) 520	(415) 826	(460) 3,539	(585) 1,029
Employees (number)	FE company	8,094	8,269	8,294	8,001	7,902	8,070	8,241	7,909	8,086	8,206
	group	13,345	14,179	14,298	13,991	13,996	16,440	16,997	19,210	21,122	25,021

The FE group's turnover increased from 3,100 million francs in 1980 to 14,636 million francs in 1989, virtually a five-fold increase in a decade. This corresponds to a 10% increase in sales in real terms. Even if it is not measured on a constant basis - this consolidated balance sheet being calculated with variable perimeters - this economic performance appears all the more honorable for having been achieved in a sector that, with the exception of a few specific segments, has already reached full maturity. Such consolidation of the company's commercial base (market share) naturally had an effect on profits, which rose from 61 million francs in 1980 to 690 million in 1989, an elevenfold increase. The capacity for self-financing having been strengthened by the constant flow of surpluses, the FE group could allow itself to raise its investment to increasingly higher levels. Since 1985, more than 7% of turnover has been constantly reinvested. At the same time, the number of employees has virtually doubled, rising from 13,345 in 1980 to 25,021 in 1989.

However, these excellent results were not achieved in a regular, linear way. On the contrary, the FE group experienced considerable fluctuation in its economic cycles. In particular, growth came to a halt on two occasions. These periods of stagnation occurred in 1983-84, and to a lesser extent in 1986-87; during both periods, the group experienced severe difficulties and was forced, among other things, to reduce its work force. In particular, the difficult economic situation in 1983-84, which was associated with the beginnings of large-scale restructuring in the whole of French manufacturing industry, seems to mark a real turning point in its strategic orientation. From this period onwards, when the S Group increased its stake in FE Company, it embarked on a new type of development. Three new trends have gradually emerged.

- The group has embarked upon a systematic policy of expansion, associated undoubtedly with a search for economies of scale. As a result, the rate of quantitative expansion has accelerated.

- Although there have been hiccups along the way, the FE group has implemented a particularly voluntarist investment policy.

- The indicators of profitability, which were fairly weak in the past, have improved significantly. For example, net profits, which represented less than 2% of turnover at the beginning of the 1980s, had increased to 3 to 4% of turnover by the end of the decade.

These new trends, which can be discerned from the company's statistical data, are probably indissociable from FE Company's increasing integration within the S Group, which began in 1983-84. In other words, the new mode of development seems to have arisen out of a compromise entailing a reduction in FE Company's autonomy in exchange for a massive injection of cash from the S Group. Without lingering further on this complex factor, which lies outside the scope of the present study, we shall attempt to highlight some of the industrial strategies adopted by FE Company.

C. FE Company's industrial strategies

Interviews with engineers and detailed study of the economic indicators reveal the main thrusts of the company's strategy. It seems to us that four main lines of development can be discerned. Whether explicitly or implicitly, these various lines, around which the different technological, industrial and financial logic's crystallize, give a certain degree of coherence to the functioning of the FE group. It is not our purpose here to elucidate the complex chain of causality in the construction of the company's strategy, but simply to characterize the industrial strategies adopted by FE Company.

1/ The first line of development consists of encouraging external growth (i.e. growth by acquisition), sometimes to the detriment of internal, or organic growth; this is reflected in the increased number of acquisitions of existing companies (takeovers, mergers, absorption's etc...). This strategic propensity can be demonstrated by analyzing the choices made in the utilization of financial resources. If the total sum invested is divided into two components, namely tangible and intangible assets (purchase of machinery, buildings...) and financial assets (acquisition of shareholdings), it can be seen that each component evolved in a sharply contrasting way.

TABLE 2-2 Evolution of Industrial and Financial Investments

Year	1983	1984	1985	1986	1987	1988	1989
FE Company							
Industrial inv.	135	119	146	164	158	149	178
Financial inv.	43	134	155	191	386	3.029	523
(in Millions FF)							
FE Group							
Industrial inv.	-	-	-	340	415	460	585
Financial inv.	-	-	-	180	411	3,079	444

As can be seen, financial investment is increasing much faster than industrial investment. Particularly from the mid-1980s onwards, the gap between the two has been widening to the benefit of financial investment, which has been accelerating. Industrial investment, on the other hand, has stagnated. This choice as to the allocation of resources seems to indicate that internal, or organic growth has been largely supplanted in the company's strategy by external growth. In concrete terms, FE Company has been conducting a series of financial operations involving the purchase of companies both in France and abroad. To the extent that its primary aim is to absorb companies, particularly foreign ones, specializing in the production of electrical equipment, this policy of external growth has led to a consolidation of its position in the international market, but not necessarily - a few exceptions apart - to diversification of its manufacturing activities. In effect, therefore, FE Company has purchased an increased share in the market for circuit breakers. This type of strategic orientation seems to be justified by the fact that:

"There is a critical size that has to be reached in order to survive in a sector like ours, which is mature and highly concentrated..."

2/ The second line of development, closely linked to the first, focuses on extension of the company's activities throughout the world. Traditionally very open to the international market (in 1980, 1360 million francs' worth of sales were made abroad, out of a total turnover of 3100 million francs), FE Company has constantly expanded its international trading activities, to the point where foreign sales accounted in 1989 for half of total turnover (7300 million francs out of 14636 million). One of its aims on this international level seems to be to switch from exporting products from France to setting up manufacturing units in foreign countries. As we have just seen, this is being achieved by purchasing companies. Thus the number of foreign employees has increased from 1,730 in 1984 to 8,800 in 1989, a work force equivalent to that of the parent company. This strategy seems to be required by the fact that:

"The period of segmented markets (for circuit breakers) is over. We are now confronted with products of world-wide application..."

And with powerful financial support from the S Group, it has been implemented systematically.

"At FE Company we have been able to increase the amount of capital available, thus enabling the company to make the international acquisitions necessary to its development. Since 1983, by taking over companies, we have built a spider's web covering the whole of Europe...This external growth has also led us to North America, where we have purchased F.P., the market leader in Canada with 2,500 employees... All this has enabled FE Company play a role in the world market..."

3/ For a long time,FE Company has been pursuing a policy of externalizing its production activities. This policy is reflected in two phenomena: the parent company has retained the central core of employees, which has remained stable at around 8,000 people during the 1980s, whereas the increase in employment has occurred in the subsidiaries; the reduction in numbers in the manual worker category reflects both the rationalization and the decentralization of production.

There are two ways of externalizing production:

The first is to separate production units from the parent company. In particular, FE Company has tended to transfer mass production, which, despite automation, still requires unskilled workers, to its subsidiaries and to part with specialist technical skills such as founding, casting, ceramics etc; the second is to use subcontractors. According to a purchasing engineer:

"Purchasing is an important function at FE Company, because the parts supplied from outside account for between 50 and 60% of total production cost, depending on the department... In order to reduce costs, we really have to put a lot of pressure on suppliers..."

4/ Industrial specialization may possibly constitute the fourth line of strategic development. The fact is that FE Company remains to a very large extent focused on its own particular specialty and its technology, despite a certain vague desire to diversify its activities. However, it is not easy to ascertain whether or not this specialization, observed ex-post, is the result of deliberate strategic rationality. The least that can be said in this respect is that such a strategy based on specialization cannot be dissociated from the social logic of engineers, since the development of new industrial activities or the enhancement of new technological resources are acts that, pre-eminently, call into question engineers' organized competence.

Indeed, over and above the direct influence that engineers - as decision-makers - are likely to exert over the development of strategy, it is the way in which they construct their professionality that seems to contribute most to the general orientation of the company. Such a hypothesis on the interaction between the form of professionality adopted by the engineers and the strategic choices made by the company lie at the very heart of our problematic.

1-1-2 THE STRUCTURE AND ORGANIZATION OF FE COMPANY

a. Product structure

FE Company's business is organized around the mastery of electrical energy. From the transport of electricity to domestic and industrial distribution, via high/low-voltage conversion, it offers a comprehensive range of circuit breakers (0V-800 KV) and accessories (protection relays, switches, sensors, transformers, inverters etc...).

Its activities and products can be analyzed from two points of view.

Firstly, the products can be considered on three different levels of integration:

- assembly of standard components (circuit breakers),
- construction of equipment and boards made up of these various components (distribution boards, factory built sub-stations, terminal enclosures), and
- the realization of complete installations made up of this equipment (turnkey projects).

Even if FE Company has traditionally had large contracts (turnkey projects) with specific customers - Electricié de France and its overseas equivalents, the navy, SNCF (French railways) etc. - it is the first level of activity as a component maker that is still largely predominant and most dynamic. However, the current trend is towards the creation of an intermediate range between these two levels, made up of modular installations based on the various circuit breakers. In other words, the company is working towards the integration of circuit breakers in an electronic - and computerized - system capable of carrying out various functions such as surveillance, control and command. As the emergence of notions such as "intelligent circuit breaker" or "domotique" shows, FE Company seems to want to make its mark as a producer of complete energy control systems, rather than remaining a mere manufacturer of circuit breakers.

Secondly , these activities can also be classified according to the sphere of application .

TABLE 2-3 Turnover by Activity

field	turnover
– Low-voltage distribution (0-3 kv) (circuit-breakers, distribution boards, etc...)	41%
– High-voltage transport and distribution transport (50 to 800 kv) industrial and tertiary distribution (3 to 50 kv)	27 %
– Automation and security inverters, programmable controllers, nuclear security	17 %
– Realisation of complete projects, service project engineering	15 %
Total	100 %

The "high-voltage transport and distribution" activity represents one of FE Company's historic roots. It is the construction of large, high-voltage circuit breakers, described as a "shop window for our technical skills", that sustains the company's professional identity and technical character. Even today, it is still a significant source of technical innovation, in that the efforts of the R & D department are continuing to push back the cut-off limit. However, it is undeniable that this activity has suffered in the past fifteen years from stagnation in the domestic market, caused by the reduction in industrial investment and the cessation of public programs in the electricity industry. In consequence, FE Company has been trying to break into the export market. However, despite some isolated successes in Latin America and Asia, it does not seem that this activity is to be revitalized in a hurry.

On the other hand, the "low-voltage distribution" activity is expanding very rapidly, both in the domestic and industrial spheres. This part of the company's output ranges from small-scale circuit breakers for domestic use to distribution enclosures, via protective circuit breakers attached to robots. Originally part of a license purchased from Westinghouse in the 1950s, this activity has expanded since the 1970s and now accounts for 41% of turnover and a work force of 3,800 people in France. It has been the main engine of internal growth - inexcess of 20% per annum - and is an essential source of profit. A market leader in Europe - and in the world for some products - FE

Company is implementing a strategy based not on product innovation - which may well unsettle the market - but rather on marketing - monitoring of competitors - and the rationalization of production in order to lower the cost price.

"In those areas in which we are market leaders, our strategy can only be that of a leader; we should avoid unsettling the market (by excessively rapid technical innovation) ... On the contrary, we must base our strategy on marketing, on monitoring the market..."

"We are not technological innovators. But it must be said that the company does alight. We lead the market in low-voltage equipment..."

"A healthy firm does not introduce fantastic innovations if its market is expanding..."

The third sphere of activity, "automation and security", the result of a certain desire to diversify, is concerned with the application of electronic technology. Three products are involved: "onduleurs", programmable controllers and a nuclear safety system. Apart from the last mentioned, which is suffering from the cessation of nuclear programs, these products, developed since the beginning of the 1980s, are located in promising but highly competitive world markets. Rather than embarking upon real endogenisation of electronic technologies and developing synergy with other areas of its activity, FE Company seems to be concentrating on external growth, the aim of which is to absorb outside knowledge by purchasing existing companies.

b. Company structure

The organization of FE Company is based on two major principles: on the one hand, "divisionalisation" or decentralization of profit centers, and on the other the separation of functional and operational roles. As Figure 2-2 shows, the overall structure is based on three components organized around the general management.

The first component includes central functional services such as financial and management control, technical management, quality control etc. The role of these departments is to coordinate the activities of the operational units in each sphere and to provide them with logistical services. Even though each of them draws up its own medium and long-term plan of action that has the characteristics of a "directive", it does not, in principle at least, have the power to intervene in the decisions taken in each operational unit. These central management services "are paid by a sort of tithe levied on the departments".

The second component is the central sales office which oversees the complex sales networks. It is divided into two zones: the metropolitan zone, with 1,600 employees, 32 agencies and 400 points of sale, deals with the French domestic market, while the second zone includes all overseas representatives, a total of 145 points of sale throughout the world. The essential function of the central sales office is to optimize sales at the central level. In consequence, it maintains organic, sometimes conflictive relations with the sales or marketing offices of each department whose goal is to maximize the sales of their own products.

FIGURE 2-2 General Organization

I. CENTRAL MANAGEMENT SERVICES	II - CENTRAL SALES OFFICE
- financial - employee relations - management control - information and communications - logistics and supplies - data processing and office services - general secretariat and external relations - strategy and planning - technical services and quality	France: 4 regions, 32 agencies, 400 points of sale Italy: 4 representatives Northern and Eastern Europe: 20 representatives Southern Europe, Middle East, francophone Africa: 59 representatives N. and S. America, anglophone Africa, UK and Australia: 43 representatives Asia: 19 representaives International matters

General management

III. OPERATIONAL UNITS

Divisions	Departments	Departments
Low voltage	- Terminal distribution - LV equipment projects - Condensers - Installation systems	- Systems and turnkey - Electronic safety systems - Industrial automation - HV transport systems
Medium voltage	- MV equipment - Prefabricated systems - Station equipment - Transformer stations	
Power supply	- Power supplies for mini-computer systems - High-performance electronics - Stabilised power supplies	

Finally, the third component is made up of the operational units that design products, manufacture them and generate profits. The operational units are divided into three levels: division, department and product management unit (PMU) - in other words the factory or manufacturing subsidiary. FE Company has four divisions, fifteen departments and about fifty PMUs.

The division is a loose structure, made up of several functional services, which unites several departments in a federal arrangement. Its role is to coordinate the activities of departments with complementary technical or commercial characteristics.

"The divisional organization is an attempt to pool facilities common to several different departments; these include, for example, test laboratories, methods departments, etc..."

This structure is not rigid and is likely to evolve over time as organizational changes are introduced.

In contrast to the division, which has an evolving, federal structure, the department, made up generally of between 300 and 800 employees, is a real operational decision-making unit. It is a profit center which, in exchange for a considerable degree of autonomy, is responsible for putting objectives into practice. The principle of this system is that, on the basis of annual negotiations with each department, general management draws up a budget plan and the strategic objectives - often costed - and checks the results achieved; each department, however, has a great deal of latitude in its operational decision-making.

"FE cpmpany is a conglomerate of small and medium-sized enterprises... In our organization, a department is a profit center, there is a boss who is sometimes a real little tycoon. It has its own administration, and its own marketing and technical services ..."

"The head of a department has a lot of power, but the downside of the dynamism of this kind of organization is that they are often petty tyrants".

A department, in turn, contains two types of functional and operational structure. The first corresponds to functional services such as purchasing, personnel, marketing, technical etc., while the second is represented by the PMU, i.e. the factory or manufacturing subsidiary.

In general, a department consists of 2 to 4 PMUs which are each responsible for a certain product family. Each PMU, which also has small functional services such as technical office, industrialization etc., has a great deal of room for maneuver in the day-to-day management of production. Although objectives, budget and resource allocation are aggregated and justified at department level, the PMU is an elementary accounting unit. This decentralized accounting system, in particular the practice of internal invoicing that governs the exchange of goods and service within the company, devolves responsibility to the lowest level of the organization.

In short, from central level all the way down to the most elementary levels, both the general organizational structure, in which functional and operational roles are separated, and the controlled decentralization of decision-making centers are constantly present.

C. The organization of the technical function

The technical function, an ambiguous concept, could be defined in two ways:

· In the strict sense of the term, it includes everything that contributes directly to the development of the technology and to product design and industrialization. It can, therefore, be broken down into the separate tasks of research and development (laboratory), design (design or technical department) and industrialization (methods department). These three tasks, which are mutually intertwined, constitute the basic sequence of technical innovation.

· In the broad sense of the term, technical functions may include, in addition to the tasks already mentioned, allied tasks such as quality control, standardization, purchasing, marketing and even part of the sales function . These tasks can be divided into two groups, depending on the technical content. Quality control or standardization, which are very closely linked to design, undeniably complement the technical function, whereas marketing, purchasing or technical sales may vary in their technical content. True, this variability would seem to be determined by the type of production and the nature of the market or of the technology, and also by the prevailing representation of the role of the technical actors, particularly of engineers. In this sense, the diffusion of the technical function within the organization is not determined by technical and organizational factors, but depends largely on the socialization of the actors.

Sticking here to the strict definition, we shall seek to characterize three sorts of technical activity - with varying time scales - located respectively at the levels of central management, department and factory.

1) At the level of central management services, it is the "technical and quality" service that is responsible to general management for the technical function. It coordinates and monitors the various industrial projects - forty new products are planned each year - without replacing the department, which remains independent; it fosters overall consistency in technological strategies and takes responsibility for long-term research activity. This service has 300 employees, excluding a large maintenance and after-sales office with a further 300 employees which is attached to it for historical reasons. It carries out three types of activity. The first is the provision of administrative support - such as the patent service, the technical standardization committee etc. - which serves the technical function as a whole. The second groups together those individuals with the title of "technical manager", most of whom have in the past held responsible positions in the hierarchy. As experienced experts, they work on the order of tasks - often laid down by general management - in strategically sensitive areas, namely the monitoring of industrial projects, participation in project review and the training of project managers. With their personal stature legitimated by their past

experience, these technical managers intervene selectively in all departments in order to guard against the risk of slippage in decision-making at department level.

The third involves scientific and technical studies. They are the responsibility of the "general research" service - GR - which represents the central core of technical innovation within the company. Even though "the rate of technical evolution is relatively slow in the field of circuit breakers", the GR, with a work force of 77, is responsible for providing the technical function with a constant supply of new scientific knowledge and technical know-how. In order to do this, there are three conceivable types of programs which, despite some difficulty in distinguishing between them because of the way they overlap, reflect, in decreasing order, the degree of technological endogenisation. The first of these is the development of research projects within the general research service itself, which requires the establishment of the necessary skills, the second the contracting out of research to external bodies or collaboration with universities or other public institutes and the third the setting up of a mechanism for observing scientific developments (technological monitoring).

The GR has undeniably been able to build its creative capacity around mastery of arc plasma (electric arc cutoff), a complex physical phenomenon which it is still difficult to formalize despite the power of modern computer systems. It has already proved its capabilities by developing modeling software (for scientific calculation) and by producing a series of innovations in cutoff technology ranging from turning arc or self-extinguishing systems to self-expansion. FE Company was - and still is - one of the pioneers in these technological advances.

"In the general research service there are some researchers (who remain for life) with a national and international influence...".

This knowledge, the product of highly experimental scientific work, constitutes the company's heritage.

Nevertheless, the center of gravity in technical innovation in electrical equipment is gradually shifting towards new areas. It is becoming increasingly important to integrate the technological advances in electronics, optics and new materials into cutoff technology. It is precisely in this expansion of its capabilities that the GR seems to be experiencing some degree of difficulty, despite its voluntarist policy of adaptation. The arrival five years ago of a new head of GR - a university researcher "with a broad scientific culture" - has certainly helped to change the organizational culture and opened up new areas of research. Indeed, the GR, which had until then been organized like a "super technical department in which the engineers, who are not researchers, manage the most difficult, innovatory projects right up to the prototype/realization phase, and then possibly as far as industrialization", is being transformed into an organization made up of 4 or 5 teams organized on a thematic basis - electronics, optics, magnetism, cutoff, etc. It is no long this organization's objective to take responsibility for industrial projects, but rather to generate and accumulate scientific knowledge in precise thematic areas. The GR is also trying to develop links with universities and is making extensive use of CIFRE contracts as a prelude to hiring young researchers. Despite these attempts to redirect its research efforts, areas of such important strategic importance as high-performance electronics, electronic components or new materials, where sudden technological change can occur, such as that symbolized by static cutoff or superconductivity, do not seem to be sufficiently well covered. As far as these new areas are concerned, the GR contents itself with managing research contracts with outside bodies (universities, CNRS), which account for more than 10% of its annual budget, or with implementing a policy of scientific monitoring. This relative timidity- which contrasts with the audaciousness of the company's external growth - may be institutional in origin.

"Circuit breakers are safety products, and thus we are dealing with a market that is itself conservative. It is difficult to offer someone a circuit breaker that works on a completely new principle, even if you show him all possible, conceivable tests..."
"High-performance electronics is not considered a high-level discipline in France. In any case, there are only two colleges that specialize in this area..."

But it is also the result of strategic arbitration, which as far as the GR is concerned is reflected in inadequate human and financial resources.

The human resources are limited: only about twenty research engineers are really engaged in the unit's activities. Each researcher is fairly free to organize his activity as he thinks fit, since he reports directly to the unit's director, who is a "scientific colleague" rather than a "director of research". Depending on his research needs, each researcher is allocated a certain number of technicians from among the thirty or so employed in the unit; they are specialized and attached to various sections such as "prototypes" and "development workshop" or to the analytical or test laboratories. Supported by these technicians, each researcher takes responsibility for projects, either initiated directly by the GR or commissioned by the department. However, in view of the breadth of the scientific fields to be covered, the human resources available are wholly inadequate.

"(As far as new materials are concerned, particularly superconductivity), we need 50 people working on that alone. What we have is just one person reading the articles..."

The problems caused by the lack of researchers are compounded by their rapid mobility, which reduces the efficiency of their research, particularly the cumulative effects of long-term programs.

"After 3 or 4 years (in the GR) they are allocated to another service, not to production because we're not involved in that, but to a technical or computer service, or to sales or technical sales..."
"In France it is difficult to spend one's whole career doing basic research. In order to get on you have to be mobile and versatile...".

As far as financial resources are concerned, the GR budget accounts for 10% of total technical costs , which represent almost 6% of turnover, or 300 million francs per year. Thus the GR receives annual funding of 30 million francs, 40% of which is raised "in the form of taxes" from departments and allocated automatically by general management to speculative research. The remaining 60% comes from research contracts negotiated on an annual basis with the technical services of each department. The aim of this system of negotiation is to force the two units into regular dialogue despite the differences in their time horizons; particularly since its reorganization, the GR does not always have a grip on industrial reality, while the technical services of each department favor immediate action. Despite being hampered by a certain degree of formalism - "tough bargaining over budgets", "a day's meeting between GR and each department, involving 50-60 people" - this procedure does seem to contribute to the establishment of networks for information exchange.

2) There is no doubt that it is the technical service of each department that constitutes the essential link in the technical function. They are responsible for technical strategy and the realization of industrial projects, and are thus in the vanguard of technical creativity within the company. All these technical sections, which number 16 in all, are attached to their own department, account for slightly less than 90% of all technical costs and manage 40-45 new product projects each year, 80% of which involve the updating of existing ranges, with the remaining 20% involving the development of new products.

In general, each technical service has between 15 and 25 engineers and between 20 and 40 technicians, most of whom are draughtsmen. They are organized differently from department to department. However, FE Company, in collaboration with a firm of consultants, is attempting to make all its technical services evolve towards a new model, and in a highly formalized representation of that model there are two types of groups:

The innovation group, made up of a small number of engineers, has the task of researching the development of a material, product or technique - even before there is any real need for them, and independently of the timing of any new product launch. In other words, it is responsible for developing the technical elements necessary for the future generation of new products that will appear in a few years' time.

"When you're working on a project, you might have interesting ideas that you don't have time to pursue and that you can submit to the innovation group for in-depth investigation..."

"(the innovation group) is not restricted by deadlines and can thus come up with innovations that can be used immediately or at some time in the future...".

Because its prime function is to anticipate innovations, this group is supposed, in theory at least, to have a privileged relationship with the GR and to lie at the heart of the information exchange network.

The skill groups are conceived as repositories of specific competencies, such as mechanics, cutoff techniques, electronics etc. Each group is made up of one to two engineers and several draughtsmen. The engineer in charge of the group coordinates its activities with other groups, allocates studies to be carried out or design work to the technicians and manages the group's human resources (providing leadership and assessing the technicians' performance). Within the general organizational structure, these skill groups, the custodians of specific competencies, intervene in the development of new products in all areas of the company.

3) The last link in the technical function is located in the factories or manufacturing subsidiaries (PMUs). At the heart of the production process, the technical function is represented by two types of tasks:

The application planning office, the physical size of which varies with the type of product (20-30 people), has the task of making minor modifications to existing products in order to meet the needs of the market, or of planning any necessary adaptations in the case of products being produced to order. This planning office is linked in the hierarchy to the PMU, but operates in conjunction with the technical section of the department that originally designed the products. In this sense, it functions as an outpost of the latter in the PMU.

The industrialization office does not, in theory, work on products themselves, but rather on production tools. This is the section within the PMU that receives the new product which, when transferred, is half-way between a prototype and an industrial product.

"The industrialization section tests the feasibility of products on a life-size prototype, and develops the necessary tools and production process..."

In general, these technical tasks that routinely border on the production process are considered to lie within the province of the technicians, where "the empirical, even simplistic, approach predominates", in contrast to the conceptual world of the engineers.

1-1-3 CHARACTERISTICS OF THE WORK FORCE AT FE COMPANY

This section will present some of the characteristics of the human resources at FE Company's disposal and very briefly describe two management principles that govern the formation of the professional hierarchy within the company.

All personnel at FE Company are categorized in accordance with the classification system laid down in the collective agreement covering the metal industries and supplemented by company agreements. This classification system, which hierarchies the various skill levels (analyzed essentially in terms of job content), makes a distinction between several categories of personnel and lays down their wage levels in overall terms. Simplifying matters greatly, it is possible to separate out three categories of employee with clearly differentiated status's: the manual worker category, the intermediate category, which includes heterogeneous groups such as technicians and clerical and supervisory staff, and the engineer and manager category, the members of which exercise managerial functions, either in the company hierarchy or on the technical side (see Table 2-4).

The manual worker category at FE Company seems to be extremely loyal to the company (average seniority is 19 years), and aging. It is characterized by a small proportion of female workers (180 out of a total of 2026) and by a concentration of skilled workers, or even "shop floor technicians". At parent company level, however, the category is gradually being reduced in size because few new manual workers are being hired. As already mentioned, this trend is linked in part to the externalization of production, and particularly to the shift of mass production to subsidiary companies. In the FE group as a whole, the manual worker category still includes 43% of a total workforce of 25,000, compared with 43% in the case of the intermediate category and 14% for the engineer and managerial category.

TABLE 2-4 Structure of Work in the Parent company

ANNEES	1987				1984	1989
	NUMBERS	AVERAGE SENIORIY	AVERAGE AGE	MONTHLY WAGE (F)	NUMBERS	NUMBERS
I . Ingineers and managers	1.580 (20%)	14 years	41 years	22.600	I 1.522 (19%)	I 1.732 (22%)
II . Supervisory staff	172 (2%)			14.400	II + IV 1.506 (19%)	
III . Technician + draughtsman	2.588 (33%)	II + III + IV 15 years	II + III + IV 38 years	11.600	III 2.343 (30%)	II + III + IV 4.544 (55%)
IV . Clerical staff	1.543 (20%)			9.000		
V. Manual workers	2.026 (25%)	19 years	43 years	9.100	V 2.531 (32%)	V 1.930 (23%)
TOTAL	7.909 (100%)			12.700	7.902 (100%)	8.206 (100%)

On the other hand, two other categories have expanded. The intermediate category, particularly technicians, is growing rapidly and is being given an infusion of new blood with the arrival of large numbers of young people with two years' training after the baccalaureate. The engineer and manager category has also seen an increase in its numbers, although with a relatively high turnover rate (departures + hiring/average numbers employed in the year) of 10% per annum.

In addition to these changes within the categories, which have favored the higher skills (more "intellectual" jobs), there is another, important aspect of this hierarchy that should be stressed. This is the socio-professional distancing that is reflected in the differences in pay between these various categories of employee. In this case, it should be noted that pay in the engineer and manager category is almost double that in the technician category. This difference in pay reveals that there is a considerable professional distance between engineers and technicians who together play the leading roles in the technical function; this might indicate a certain degree of difficulty and conflict in their relations.

In the case of FE Company, the formation of this professional hierarchy obeys two principles of management.

Firstly, the conditions of selection, recruitment and allocation for new personnel are determined to a large extent by the level of formal qualification each individual possesses. The stratification of the various professional categories is one of the ways in which the educational hierarchy is reflected. This link is being increasingly strengthened by FE Company's preference for turning to young people, with or without work experience, in order to meet their labor needs. At the present time, the technical baccalaurereat is a de facto requirement for manual workers, two years' post-baccalaureat training for technicians and an engineer's diploma or its university equivalent (baccalaureat + 5 years or more) for engineers.

Secondly, as is well known in French industrial circles, FE Company has a tradition that stresses the importance of "promotion through work". This means that the company provides generous opportunities for internal promotion - particularly between the various occupational categories - on condition that employees agree to develop their professional capabilities through the in-house training system. In other words, the tradition is based on motivating employees through the linking of internal promotion, individual investment in training and the gaining of company certificates or state-recognized diplomas. FE Company devotes more than 6% of its total wages bill to continuing training, and each year between 1,000 and 1,500 employees embark on training courses ranging from evening classes to full-time courses lasting a year.

The result is that the occupational hierarchy is structured by the various trends in internal promotion: a quarter of the engineers and managers are what is known as "self-taught", having benefited from several internal promotions, sometimes from the manual worker category; more than half of the technicians (1,400 out of 2,600) do not have the formal qualification of two years' post-baccalaureat training, and most of them are former manual workers promoted through the in-house training system.

Thus human resources at FE Company are cultivated both through the acquisition from outside of young people's skills and through the internal development of professional capabilities. These two principles of management, both of which have proved their effectiveness in the past, tend nevertheless to create organizational tensions, since they are increasingly in competition with each other. In this case, the quickening pace of technological innovation has given rise to a certain contradiction between the growing use of young, better educated people, the increased need for training in order for existing employees to adapt to the changing circumstances and the blocking of internal promotion. This last phenomenon is particularly serious among young technicians with two years' post-baccalaureat training who have been recruited in large numbers in recent years and whose "careers come to a halt at age 35 because there are no longer any great prospects for promotion to the status of engineer".

At FE Company, as elsewhere, personnel management is entering a transitional phase in which the old principles are crumbling away without the new ones being clearly discernible.

1-2. THE SOCIAL FORMATION OF THE ENGINEER CATEGORY

In this part, we will examine the way in which the engineer category, which constitutes the hard core of actors in the technical functions, is formed within FE Company. This choice of topic is not fortuitous. On the contrary, it appears to us to become essential as soon as the notion of technological determinism is rejected in favor of the hypothesis that the very type of technical or industrial dynamism found within a firm is, together with other factors, such as its relationship to the market, the characteristics of the technologies, etc., indissociable from the form of socio-professional existence displayed collectively by the engineers within the firm. Once this hypothesis is accepted, examination of the way in which the actors, particularly engineers, are constructed becomes crucial to a better understanding of the working of the technical functions, and hence of the nature of technical and industrial creativity.

We believe that the construction of the engineer category is based on the complex interaction of two logic's.

<u>The first</u> is the company's management logic. Its aim is to develop engineers' skills in accordance with the company's real needs, and to optimize utilization of those skills. In order to achieve this, the company puts in place those management tools that will maximize the involvement of the engineers - both individually and collectively - in the objectives laid down by the company. Nevertheless, such a logic can obviously not be implemented in either an atemporal space or a social vacuum. It must take account both of the organizational inertia inherited from the past and of external constraints, whether these be pressure from the labor market or institutional rules such as the industry collective agreement, etc...

<u>The second</u> corresponds to what might be termed the social logic of the actors, which determines the engineers' mode of operation. This is based on a process of socialization through which the engineers forge, within a given societal context, the identity that is the source of their mode of operation. Although it is linked closely to the nature of the education system, this socialization cannot be dissociated from the way in which the engineers form their professionality at the work place itself.

These two logic's converge and mutually influence each other in order to create an interactive social dynamic within the firm. We shall attempt here to see how this interaction is structured in the case of FE Company. After a brief presentation of the various groups of engineers, we will analyze the main management tools put in place, and the way in which the engineers' professional capabilities are constructed.

1-2-1 THE HETEROGENEITY OF THE ENGINEER CATEGORY AT FE COMPANY.

FE Company. employs around 1,400 engineers out of a total of 1,800 individuals included - under the terms of the collective agreement - in the engineer and manager category. There are thus 400 non-technical managers, most of whom are graduates of business schools or of non-scientific university courses (5 or more years post-baccalaureat education). However, this does not include about one hundred senior managers at central level, who are themselves often graduates of the major engineering schools (grandes ecoles d'ingenieur). It should be noted that engineers occupy a dominant position in the company hierarchy.

Far from being homogeneous, this engineer category has many micro-divisions depending on educational background or career path. At the risk of oversimplification, it is possible to identify three groups: graduate engineers and university science graduates classified as engineers; former technicians who have been through engineering school as part of a program of continuing training; and "self-taught" engineers with no formal qualifications who have been promoted within the company.

At FE Company, the first two groups, those in possession of formal qualifications, account for three quarters of the engineer category, while the last named, whose classification as engineer is not readily recognized in the external labor market, accounts for the remaining quarter. Having been pressed into the same classificatory category, even into a sort of management culture specific to FE Company, these various groups of engineer do, it is true, have certain logic's of action and certain interests in common. In this case, the first group of graduate engineers, which is the largest group and an archetype in the social representation, constitutes a reference model to which the other groups have more or less to conform. However, it is also obvious that they have neither exactly the same outlook on their careers, nor the same type of perception of the role of the engineer nor the same style of behavior in their relations with other categories of employees.

a. Although they dominate in quantitative terms (900 individuals), the group made up of graduate engineers is itself heterogeneous. Largely attributable to differences in educational background, this heterogeneity is reinforced by a management practice that places them in one of three categories according to the institution in which they were trained and offers them, from the outset, somewhat different job profiles. Considered in terms of the importance of the "jobs that an engineer is likely to occupy at around the age of 40 or 45", "their potential" is identified, evaluated and gauged at an early stage.

"... There's a natural tendency to be elitist, and at a very early stage we tend to consider natural talents rather than those that have been cultivated. What emerges naturally is more important than what is built up gradually. With the young ones, we very quickly identify the talented ones, and we put them on a fast track (to the hierarchy). And we don't check very frequently the knowledge they're accumulating. We often take risks..."

Despite a certain vagueness in the company's career management strategy , engineers are placed at a fairly early stage "on different career development curves". According to one manager, such an early assessment of potential "proves to be valid in 80% of cases, even if we occasionally make mistakes...". Thus in order to understand his own position, each engineer tries to pick up and interpret the indications that management gives him in the annual assessment of performance, in his job allocation, selection for a training course, etc... He constructs his professional strategy on the basis of his interpretations.

This process is intended particularly to motivate the better elements and to create an elite which, "by feeling quite successful, drags the others up with it". From this point of view, the case of the "reserve engineer" is revealing. A booklet produced by FE Company for newly recruited engineers states explicitly that:

"Each year, a few young "reserve engineers" judged to be capable of performing at a high level go on a six-month course prior to their first appointment. Their development during the first two years is monitored closely in order to confirm the potential identified when they were recruited".

These "reserve engineers" have a specific career pattern: they move frequently between a wide range of different positions, both operational and hierarchical, in order to confirm their ability to adapt to a variety of job contents.

"The method of hiring was very elitist... The engineers who were taken on were potentially very good, and in order that they could be tested they were moved quickly from one section to another. And the result is that we've probably been able to build up a pool of department heads, but in my view we've failed to develop an adequate reserve of less good engineers, less good in the sense of being less suited for promotion through the hierarchy, but who would be able to ensure that experience was retained..."

Since his peers are more or less aware of this career pattern, the role of the "reserve engineer" is above all symbolic. He shows the route to be followed in order to reach high-level management. By serving as an example in this way, the reserve engineer's career pattern cannot fail to influence the career strategies of other graduate engineers.

b. The second group of engineers, who acquired the status of engineer through continuing training, represents almost 10% of the total. Most of them are former technicians who have been able to acquire the title of engineer by making a considerable personal investment, and sometimes even taking a pay cut in the short term. With financial support from the state and from FE Company, they either followed a full-time course at an engineering college or took evening classes at a specialist institution such as the Conservator National des Arts et Metiers (CNAM - Conservatory of Arts and Crafts), while FE Company kept their job open for them. Although the contract does not specify in detail the obligations of both parties on completion of training, most of those who complete their courses seem to return to FE Company. In addition to the obvious opportunities this type of formation offers to individuals, it also has certain advantages for the company. It would seem to be the case that these engineers are better able to marry on-the-job vocational training with the acquisition of theoretical knowledge, in contrast to the engineers in the first group, who have extensive academic training but "do not have quite the same degree of motivation developed by this type of training".

"When [an engineer in the second group] is being trained, when he is acquiring knowledge, he is fulfilling an expressed need, [whereas an engineer in the first group] is fulfilling a need that does not exist... "

By the very nature of the knowledge they have acquired, these engineers fit very well into the technical career paths, particularly in the technical services. The paradox is that this very fact means that the strategic space within which their mobility can be deployed is restricted to the technical career paths.

c. The third group comprises the engineers promoted by the company through various selection mechanisms, in this case the thesis system. Since engineers in this group do not have a nationally recognized qualification, their status as engineer is recognized only within the company. Self-taught engineers of this type are of course more numerous among the older generations, even though FE Company still continues to produce them at the rate of 15 to 20 individuals per year. At present, it is often technicians with a good educational background (2 years' post-baccalaureat training) who are promoted in this way, whereas the older members of this group tend rather to be holders of the CAP (a vocational qualification for skilled manual workers).

The internal selection process is directly dependent on the wish of the hierarchy, since it is the immediate superior who plays the role of selector, and then tutor.

"I was told I had a potential engineer..."

The candidate approached in this way has 18 months in which to prepare a thesis. His immediate superior helps him choose the subject and monitors the progress of his research. The subject of the thesis must be "out of the ordinary" or "close to the job held by the individual, without being too close", in order that the quality of the research might provide evidence of both a certain capacity for theoretical abstraction and a concrete concern linked to the real work situation. The candidate is thus encouraged to write a thesis putting forward "original solutions" to concrete problems, in order to confirm his potential as an engineer. At the end of this period of time, the candidate has to present himself for examination in front of a panel of examiners made up of "fifteen directors"; this is as much a test of the candidate's personality as of his technical knowledge.

"I did my presentation, they asked some questions, some of them were awkward, some didn't even have anything to do with my subject, just to test my ability to react..."

Despite this initiation rite, which marks the transition to the status of engineer, the engineer trained in the firm is considered to have neither sufficient "relational openness" nor the capacity to establish "a relationship between theoretical knowledge and knowledge of the product". Thus he often finds himself straddling the world of the engineer and the world of the technician, which cannot fail to create conflicts of identity:

"There is a cultural demarcation between [engineers and technicians]. They do not eat together in the canteen, so there is a problem for those who cross the barrier... "

"In any case, technicians do not have access to posts of responsibility... even when I've done my thesis..."

We have been engaged thus far in drawing up a typology of the engineers at FE Company. This typology, based on three groups of engineer, must of course be qualified or extended, depending on whether such variables as age, sphere of activity, career path etc. are taken into account. It is obvious that a young engineer in our third group, with two years' post-baccalaureat training in electronics, does not have the same type of identity as an older "self-taught" engineer promoted from the shop floor. Nor does he have the same level of knowledge as a graduate electronics engineer aged 50. Even if it revolves around the central model of the graduate engineer, the collective dynamic of the engineer category is a product of the permanent recomposition - both quantitative and qualitative - of these groups of engineers.

1-2-2 THE SYSTEM OF ORGANIZING ENGINEERS' COMPETENCIES : some management tools

The management of engineers is based on the coordination of various levels of authority. This coordination is complex, to the extent that it not only brings coherence to human resource development but also creates conflicts of authority and sometimes even perverse effects.

On the one hand, the management of engineers turns out to be highly centralized at FE Company. The central personnel and human resources service (PHRS) contains a section that deals exclusively with employees in the engineer and manager category. The function of this section, which has a staff of ten, is to draw up the strategic plan for overseeing managers, to develop adequate management tools, to define the rules governing career development and to issue "directives" to be heeded in dealings with the operational units. At the same time, it exercises final control, "having the last word in decision-making". Thus it keeps a central record of all individual files, particularly reports of the annual interview, ratifies all important decisions (hiring, internal mobility, promotion etc...) and coordinates all movements of engineers within the company.

This central management service has its counterpart, responsible for the management of engineers, in the departments or divisions. This intermediate level has a dual role: as a representative of central management, it claims to have a privileged relationship with the engineers with respect to their career development in the medium term. In other words, it fulfills a career guidance role; it also has a functional role in the operational hierarchy, to the extent that it is there in order to assist in the implementation of the management tools and directives drawn up by the PHRS by adapting them to the specificity's of each department.

TABLE 2-5 The Correspondence between the Collective agreement for the Metal Industry,the Company agreement and the Hay method

Collective agreemen for the metal industry		Company agreement		Distributio n of staff in 1984 (managers ingineers)	HAY Method
Positions	Index	Classes	Index		Levels
I	60 68 76 84 92 100	I	Idem	9%	1 and 2
II	100 108 114 120 125 130 135	II	Idem	36%	3 and 4
III A	135	III A	Idem	28%	5 and 6
III B	180	III B	Idem	15%	7 and 8
		CS 1		5%	9 and 10
		CS 2		5%	11 and 12
III C	240	CS 3	Idem	1%	13 and 14
		CS 4		1%	15 and 16

<u>On the other hand,</u> however, direct management at the most decentralized

levels (usually heads of service) still bears the main responsibility for the day-to-day management of engineers. It is to managers at this level that all the responsibilities for channeling communications and organizing and assessing engineers are devolved. Direct managers have a great deal of room to maneuver in this respect, and although this is a potential source of conflict it is not inconsistent with the centralizing management structure already described above. By virtue of the fact that the department in FE Company is a profit center, the operational hierarchy enjoys considerable autonomy in decision-making. Such autonomy is even essential, since managerial staff are obliged to supervise engineers under the pressure of severe temporal or organizational constraints, and sometimes even of the "blackmail" that engineers may be able to exert. At this point, the technical and social aspects of human resource management merge and become entangled in the immediacy of day-to-day working.

The articulation between the central and decentralized levels is not always self-evident. The central level issues "formal" directives, while the decentralized level proceeds on an informal, even an "improvisational" basis. The efficiency of management tools depends to a large extent on the balance within this dichotomy, which is difficult to achieve. We shall see here how FE Company applies the various management tools, not without tension or perverse effects, in order to create the collective dynamic of the engineers. In particular, we shall analyze three of the main tools that together form a coherent system. They are job evaluation, wage determination using the Hay method and the annual assessment interview.

a. job evaluation

One of the management tools used by FE Company in dealing with its managers and engineers is a quantitative method known as job evaluation. This method, American in origin and in fairly widespread use in France, consists of analyzing job content, evaluating the importance of jobs relative to each other and drawing up a detailed job hierarchy. By reducing each job to a figure, it enables comparisons to be made between jobs in different functions, careers or specialisms within the same company. A method of this kind, which emphasizes the job rather than assessment of the job holder's competence, fits well into the French tradition of personnel management.

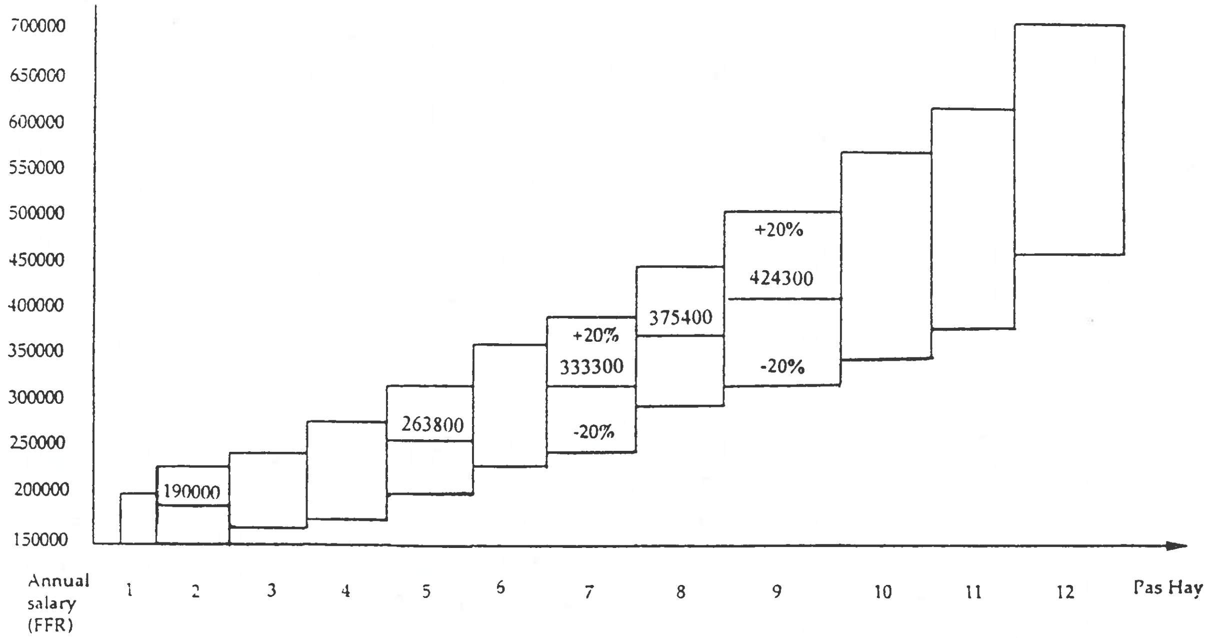
The actual evaluation is carried out on the basis of three criteria:

· Competence, or the totality of technical, administrative and organizational knowledge and know-how required to hold down a given job.

· Creative initiative, which corresponds to the degree of autonomy offered by a given job for personal initiative.

· End result, which measures the direct or indirect impact of the job on the results to be produced.

FIGURE 2-3 Salary classification by Hay metod



Each of these three criteria is scored separately, and the total score reflects the importance of the job in question. In order to reduce the uncertainties inherent in subjective assessment, all the jobs evaluated in this way are then placed on one of 16 levels, with each step on the scale corresponding to an increase in responsibility of approximately 15% (Figure 2-3). In general terms, levels 1 and 2 represent novice engineers, levels 3 and 4 established engineers and levels 5 to 8 experienced engineers. Levels 9 to 12 correspond to various hierarchical responsibilities - or equivalent jobs in functional careers - which range from head of service to head of department. Between levels 12 and 16 are the senior management posts.

On the procedural level, this evaluation procedure involves several assessors. First of all, the responsibilities of each job are defined, a priori, by the job holder's immediate superior responsible for supervising him. As part of this theoretical definition, the job holder himself, with the agreement of his superior, draws up his own assessment of his job. This consists of a description of the real content of the job: its purpose, the range of tasks and the means of performing them, its place in the organizational chart, the hierarchical and functional articulations with other jobs, etc. In order to take account of changes in job content over time, this assessment has to be updated from time to time, which requires regular consultation between the parties involved.

The job holder's own assessment is then sent for preliminary examination to the evaluation committee set up in each division. After any necessary changes have been made, it is sent to the central committee that conducts a comparison with several other jobs before finally validating the evaluation; this final exercise serves as a yardstick and is also a means of harmonizing the totality of jobs in the company.

Despite the somewhat cumbersome procedure, this system of job evaluation is a management tool that is essential, at least in theory, to obtaining the maximum personal involvement of engineers in the company's objectives. It serves to define typical career profiles by mapping out in advance several types of career pattern that combine a succession of increasingly highly valued jobs. By giving engineers a fairly clear idea of their career prospects, the construction of these career profiles gives them the motivation to develop the required professional skills. At the same time, by being directly linked to the remuneration system, it also enables them to anticipate the likely evolution of their salaries.

However, one of the major drawbacks of this method is that the evaluation procedure tends - quite naturally - to accord too great a value to jobs producing immediate results (in the sales section) or involving more obvious responsibilities (in the production section), to the detriment of jobs in the technical services that only produce results in the long term. As we shall see below, such distortion has the effect of "diverting engineers from the technical careers for which their training best suits them".

"The job [of research engineer] is by its very nature restricted, because we are evaluated by the Hay method which stresses the number of people answerable to you. The Hay method assesses the responsibility attached to a job ... I'm on Hay level 4. I've been cheeky. They give the impression of attaching importance to technical jobs, but basically they're not considered important at all."

b. Wage determination by the Hay method

In determining wages, account has to be taken of two elements if consistency is to be achieved with both the external labor market and the job hierarchy within the company. The first element is the collective agreement, the aim of which is to fix minimum wages, and the second is the job evaluation system based on the Hay method.

The collective agreement for the metal industries lays down a certain number of minimum conditions with respect to the employment and salary of engineers and managers, which FE Company is of course obliged to fulfill.

"[In conjunction] with a fairly complicated points system [Hay method], FE Company sometimes finds itself breaking the law [the collective agreement]..."

It grades engineers into one of five positions and defines their wage hierarchy by the index system. As Table 2-5 shows, the index coefficients for each position are given, and the amount of the annual salary is obtained by multiplying this index by the value of the point expressed in francs. It is the value of the point in francs that is altered periodically in accordance with the economic situation.

We shall merely note here two rules that govern salary increases in the first two positions: graduate engineers must reach index point 100 of position II by the age of 27 years at the very latest; This rule which applies particularly to the early stages of young engineers' careers, does not apply beyond position III A.

"The rate of progress to position III A may vary, but it is automatic."

The sketchiness of this type of national classification can obviously not satisfy the complex needs of engineers in a large company. Consequently, FE Company uses the Hay method in order to refine its job classification and salary range. However, as Table IV shows, the Hay method maintains a correspondence with the system laid down by the collective agreement.

As we have already seen, this Hay method makes it possible to analyze, evaluate and classify jobs on sixteen levels. By making comparisons with the salaries of engineers in the external labor market, FE Company each year determines the average salary for each Hay level (see Table IV). A range of 20% above or below the average is fixed for each Hay level, one being the floor and the other the ceiling for that level. This provides scope within each level for individual salaries to evolve in accordance with performance and the experience acquired by the engineer in a given post. This evaluation of individual performances is carried out by means of the annual interview between each engineer and his superior. Thus, while remaining in the same job, an engineer starting on the minimum salary for his level could - in theory - see his salary rise by at least 50%. Having said that, such immobility is not advantageous, since pay increases can be obtained more easily by transferring to more highly valued jobs, which encourages engineers to move internally between jobs.

c. The annual assessment interview

The purpose of this management tool is to organize the formal dialogue by means of which each engineer and his line manager take stock of the forger's performance.

"Once a year there is an opportunity for both parties to express grievances and to clarify things a little... [the annual interview] also provides an opportunity for looking back over the work done in the past year..."

The fundamental purpose of this interview is to negotiate the performance contract required as part of the system of management by target. There are two aspects to this negotiation. Firstly, the superior appraises the engineer's work over the past year. In doing this, he looks at the results achieved in relation to the jointly agreed targets. He then lays down the targets to be achieved in the coming year, taking into account both the views of the engineer involved and the overall objectives of the department. Thus this negotiation involves the evaluation of individual performances. Indeed, the superior makes a judgment of each engineer, with which the engineer is entitled to express his disagreement. "I do not agree with the judgment made of me...", in which case the individual in question may address himself directly to the hierarchical level N + 1. In any case, the engineer is placed on one of five scales. Individual salary increases vary in accordance with this classification, which ranges from "clearly inadequate" to "excellent" via "satisfactory", a median scale reflecting a situation in which "the engineer has just fulfilled his contract, neither more nor less, and thus his annual salary increase will simply make up for the loss of purchasing power and will be equal to the rate of inflation..." .

In a broader sense, this interview offers an opportunity for both parties to broach various subjects relating to the construction of career paths.

"The interview should enable the engineer in question to participate in a real sense in consideration of the direction of his career, his professional development and his training".

In particular, they negotiate a mobility (or non-mobility) plan covering the next 18 months. This planning tool enables the hierarchy to anticipate possible reorganization of its service, while each engineer can prepare the development of his professional abilities in the medium term.

"... The next phase of mobility should be discussed between the engineer and his boss... Normally they say OK, we agree that on such and such a date we should go and see the personnel department... In this way we have lists of people who will be moving in the next 18 months. For each individual, a list of jobs he might go to is drawn up. For each job requested, a list of candidates is drawn up and an attempt is made to match the two. We rework everything, change it all around, until we reach the point where we have a plan for the next 18 months in which all the movements that might take place have been identified... Then there are all the things that happen unexpectedly in the course of the year, people who resign, or fall ill... In recent years , two-thirds of internal mobility has taken place according to plan...".

After this dialogue, the supervisor writes an interview report. This report, countersigned by the engineer and checked at the hierarchical level N + 1, is filed with the PHRS for use in the individual management of the engineer's career.

Taken together, these three management tools form a coherent whole which apparently succeeds in enlisting engineers' support for this system of personnel management, stimulating their motivation and encouraging their involvement in the company's activities. However, this coherence, which from one point of view is excessively procedural, inevitably gives rise to contradictory tensions when it comes up against the engineers' social logic. In particular, tensions emerge within the technical careers that lie at the very heart of industrial creativity. The next section will examine the types of tension running through the process by which engineers at FE Company are socialized.

1-2-3 THE FORMATION OF ENGINEERS' PROFESSIONALITY

Within certain limits, the rules of management are fairly well explained at FE Company. Within this given framework, each engineer tries to carve a niche for himself within the company environment, to develop his professional abilities and to build a career. This section will present an analysis of the process by which engineers' professionality is constructed, based on four dimensions: entry into the work environment; the acquisition of competence; the nature of engineers' knowledge and the division of labor; mobility and career development.

a. Entry into the work environment

There are two different recruitment paths, intended for two different types of engineer. The first is for those who already have more or less substantial careers behind them; the second is for young engineers aged 27 or less who have just graduated or have very little professional experience. The relative size of each group varies of course, depending on the year, the area of activity and career path. For example, FE Company has hired 240 engineers and managers in the past two years. Of these, 132 engineers fell into the first category and 108 into the second. If the technical career path is taken in isolation, 27 engineers fall into the first category and 35 into the second.

These two groups are recruited and placed within the company in slightly different ways:

Engineers who already have professional experience are considered to be holders of a specific competence. In the light of its actual needs, the company purchases, for an agreed price, a competence that has, in theory, already been constructed and is thus operational. However, this recourse to the external labor market does not always go smoothly: FE Company's specialty, electrical engineering, is specific and the labor market for engineers in that specialty "is not very extensive". Thus "we do a quick tour of [French] companies in the specialty... and competition is very strong...". FE Company also has difficulties in attracting electronic engineers and computer specialists, since "FE cpmpany is not a leader, is not well known in these areas". Thus when it was diversifying into electronic products, such as inverters, FE Company, which "has trained only 2 or 3 electronic engineers since the beginning", was obliged to seek outside specialists by any available means, including "the use of head hunters". "We hired them from outside and paid a high price...".

In contrast to the selection process, which proves to be sophisticated (interviews with directors, psychological testing etc...), the entry of these engineers into the organization is fairly abrupt.

"When I arrived, I was given an office and a sphere of activity. Nothing else... It is only by discussing things with more senior colleagues that you start learning..."

"I've hardly ever seen my predecessor... The period of overlap with the old boss lasted two days... I've wasted time getting information, finding documents".

A magnet firm in the region, and located in a university town, FE Company has developed special relationships with the scientific and academic communities. These cooperative relationships affect both research and continuing training as well as recruitment. The company has no hesitation in exploiting this situation in order to attract young novice engineers who, on graduating, often apply to the company on their own initiative . The reception and integration of these young engineers seem to be better organized, or surrounded with precautions, even if there is a tendency - generally in France, to consider them as "a relatively finished product delivered by the education system to the world of industry" and thus as "being operational fairly quickly".

After a "symbolic" induction course lasting two weeks, during which "you meet the vice-president and the general directors, who talk about the financial aspects of the company, personnel matters etc...", the young engineers are welcomed socially and initiated into the work environment under the general guidance of the head of service.

"A young beginner is firstly dealt with socially... he's given a training program. He is introduced to colleagues and gathers experience alongside them... He's also introduced to the marketing and electronics sections of the other departments ... That all takes two months..."

"Young people joining the company are thought to require six months' training in order to understand principles, how to draw up a schedule of conditions, getting to know the internal rules..."

This phase, during which young engineers are initiated into the code - formal or unspoken - of the "community of peers" constituted by the engineers, gives way to another in which they have to go through their professional and technical apprenticeship. During this second phase, there is constant emphasis on the importance of on-the-job training. Placed in a working environment, the young engineers come up against the reality of the industrial world, sometimes under the guidance of senior engineers.

"In this first job, my technical training was of little help, but it was important for the general education of a young engineer to be confronted with the concrete approach to daily problems."

Depending upon individual circumstances, which obviously differ, they carry out a calculation or write a computer program, do a small study on behalf of another engineer or perform a task as understudy to an experienced engineer. It is as if they are supposed, through a sort of osmosis with their working environment, to absorb unwritten or unspoken technical knowledge.

"The [young ones] are not prepared. They learn on the job in the technical service. We arrange things so that there are entry-level jobs in which the [young ones] can observe what happens on the technical side..."

However, this period of professional initiation does not seem to last very long, especially since the notion of operationally is already included in the training of graduate engineers. Their entry into their first job is accompanied by adaptation, but not by a complete split between the classroom and the world of industry. But their very status means that these young engineers are also encouraged at an early stage to take on management responsibilities, to learn how to supervise technicians.

"Someone who starts straight out of college will be considered an apprentice for a year...."

"If it is [a small project] we might let him loose on it all by himself after a few months, or after 1 or 2 years, it depends on the individual involved..."

b. The acquisition of professional competence

Engineers have two means of constructing their professional competence in the course of their career: off-the-job training and on-the-job training. As far as the content of that competence is concerned, it varies a great deal, depending on the type of career or on the concept of the engineer's role in the organization of work.

Firstly, although FE Company allows each engineer an average of between 10 and 14 days per year without loss of pay for attending courses, off-the-job training still plays only a small role in the acquisition of the new technical competence. Irrespective of the wishes of each individual engineer, formal courses seem fairly difficult to set up, considering the enormous variety of important technical needs. Only research activities do not fit into this pattern. Indeed, research engineers need permanent contacts with the world of science outside in order to keep up to date with scientific advances.

"They make [general research engineers] do all sorts of training courses. It costs a fortune... a conference in Canada, seminars in the USA, CNRS summer school in superconductivity..."

This knowledge, assimilated by individuals, is stored, digested or adapted for general research purposes. However, it is also intended for diffusion - more or less widely - within the technical services, either through the relational networks or as a result of the mobility of research engineers within the operational units. Apart from this specific case, other engineers are not very eager to take the opportunity of adding to their knowledge, since they believe their initial technical knowledge is adequate for the tasks they have to perform at FE Company. "We're not in aeronautics, where technologies evolve very rapidly". On the other hand, some engineers are fairly opportunistic in using the training on offer to benefit their own career strategies. From this point of view, a serious training experiment that finished in failure is revealing; in collaboration with a school of engineering, FE Company set up a full-time course lasting 6 months that was intended to train specialists in electronics who were much in demand because of the company's plans for diversification.

"Sixteen engineers from FE Company went on the course. Only things didn't really work out very well. Only three [engineers] went to the department that needed them. Eight [engineers] left [FE cpmpany] for other companies, where they cashed in their training, with interest..."

Although it is only one episode, this experience clearly reveals the tensions running through the diversification of the company's activities, the endogenisation of technologies, the investment in training and even engineers' individual strategies.

In contrast to purely technical courses, management courses are very much appreciated by most engineers. Some even go so far as taking the opportunities offered by continuing training in order to obtain an additional management qualification; the holding of a double qualification is considered a major asset in the race for promotion. In general, engineers consider they have never been taught either to manage people, to lead an operation or to understand economic problems.

"What I did not learn at college was management. It's perhaps what I most needed..."

"The fundamental part of an engineer's work, that is all aspects of the organization and management of time, is not taught in college..."

Secondly, since the work of an engineer in manufacturing industry cannot be formalized or taught in college, on-the-job training constitutes an important route for the development of professional knowledge. Theoretical knowledge provides the basis of an approach to technical problems, but practical competence is built up on the job. This is obvious even in the case of engineers who started off as technicians. Such acquisition of knowledge and know-how through osmosis is, it is true, universal. However, the scope of this type of apprenticeship and the nature of the competence that is thus constructed depend to a large extent on organizational contexts, in this case on the way in which engineers' careers are organized.

Let us consider separately two types of careers, the generalist manager and the technical expert, which are in reality intertwined or barely distinguishable, particularly at the beginning of an engineer's career. Although it is fairly ambiguous, this distinction serves at the very least to highlight two different modes of apprenticeship.

- The objective of a manager's career is to acquire as wide a range of experience as possible. It is based on frequent rotation between operational and functional posts. This mobility, which is common to the various career paths - technical, marketing, finance etc... - makes it possible to develop a managerial competence in the taking of general or strategic decisions with a certain overview. However, this type of career also runs the risk of producing not real expertise but rather "engineers whom we don't know what to do with when they reach 45" or "proletarian engineers whose job requires only 10% of their skills".

- The career of an expert is organized around a particular type of product or technology. Engineers are supposed to master either a technology or the organization of industrial projects. The development of such expertise is a long-term undertaking, implying stability or even a certain immobility. The ideal profile for specialist engineers would appear to be the following: they make their debut close to the production process, becoming involved in adapting products, or transferring prototypes to production etc...; after this initial period of 4 or 5 years, they take on full responsibility for a product development project; "When they finish their first project, their second project should benefit from what they have learnt". However, such a logic of accumulation comes into conflict with the engineers' own individual interests.

"However, the problem is that if you do two projects in the research department, then the game's up. You're saddled with an image that it becomes difficult to get rid of. So if you make people stick to a career as an expert, you're not ensuring they have a good career curve".

As far as acquiring this expertise on the job is concerned, it should be noted that the process takes place essentially within a "community of peers" in which experience is created, accumulated and transmitted more or less collectively.

"FE cpmpany is a company with an oral tradition [in which] knowledge is transmitted through interpersonal exchange. We don't write things down..."

This community of peers is not fixed, but is constantly being renewed as engineers move within the company. It represents a space in which, without excluding individual competition, engineers develop their relational abilities in an informal way. And it is the bonds formed by these abilities that really lie at the heart of industrial creativity.

"It's in the corridors and the canteen that you learn most. This informal method works well, within its limits - you have to ask the right person the right question..."
"When problems crop up, we discuss them with colleagues.."

These two types of careers give rise to two modes of apprenticeship, and thus to two sorts of competence. The paradox at FE Company is that all its management practices combine, in a favorable context in which the company is growing, to create a situation in which mobility is valued at the expense of stability, and careers in management are more highly regarded than those on the technical side. This phenomenon is particularly evident among graduate engineers, but is less prevalent among other engineers, whose career paths confine them to jobs on the technical side. This has the effect of devaluing and destabilizing the community of peers, which is the guarantor of the collective technical expertise.

c. The nature of engineers' knowledge and the division of labor

Engineers' professionality, and with it the modality of its construction, cannot be properly understood unless they are considered in the context of the form of the division of labor prevailing within FE Company. The function of engineers is clearly distinguished from that of technicians, reflecting the wide organizational, professional and social gap that exists between these two categories of actors.

"[In the technical services], there is a split between an experienced core [of technicians, project managers and draughtsmen] who have been there a long time, and the engineers [who move around]... And yet if there's no symbiosis between the engineer and his team, nothing happens. The product will not materialize..."

The engineers' function is divided into two main components: technical guidance and management. The two are very closely linked, it is true, but the relative weight of each one changes quite considerably as an engineer's career evolves.

The first component is located in the purely technical dimension. Here, it is considered that the role of the engineer is to "generate an expert system" and "to provide the impetus for the basic idea". The technician's role, in contrast, is to "apply the expert system to concrete problems" or "to put that idea into concrete form". This distinction can also be expressed in the following way.

"On the technical level, the engineer draws up models and provides the synthesis... the technician experiments and calculates the dimensions..."
"As far as the finished product is concerned, the engineer is able to anticipate and envisage solutions to problems that will occur during the development phase, whereas the technician has a shorter-term view of the problems".

As can be seen, these two categories of actors have assimilated two distinct forms of knowledge: that of the engineer is theoretical, abstract and conceptual, while that of the technician is concrete, practical and "real". These two types of knowledge, which are complementary and interactive, must mesh perfectly if real industrial creativity is to be produced. At the individual level, few engineers manage to synthesize the two, with the exception of those who have made the transition from technician to engineer. In fact, engineers' technical apprenticeship rarely takes them into a peripheral part of technology , an accumulated amalgamation of assorted practical knowledge which for them constitutes a "black box". In such a case, "there are conflicts of competence" between the conceptual engineers and the technicians, who are the guardians of practical know-how. At the collective level, synergy between the two forms may exist at FE Company, but only randomly and fortuitously.

"[As far as symbiosis between engineers and technicians is concerned], that depends on the personality of the engineers".

In all case, the marked difference in status between the two actors tends to create a sort of non-communication, an impermeable barrier, even animosity.

"I spend a lot of time trying to pass on knowledge to my technicians, but they're not very receptive. They don't hold conversations very often. They've all got the BTS (advanced technician's certificate, awarded after two years' post-baccalaureat study), but after that their curiosity just disappears, they don't read enough...'

"[The engineers] have virtually nothing to do with the design of the machine. They are involved in relational work, management... In fact, the machines could be made without engineers. The technicians have the impression that they do all the work, while the engineers get all the praise..."
"An engineer at FE Company doesn't produce any drawings. he makes a sketch, but it's beneath his dignity actually to work at the drawing board".

"[The technicians] are supervised by engineers who sometimes know less than they do". (Observation by the former chairman and managing director in "l'usine nouvelle", no, 2288, 1990)

The second component relates to management. This aspect of the engineer's function varies according to the type of activity or the type of job. For example, research engineers provide technical guidance only for those technicians who "are allocated functionally to him", whereas a production job can be reduced entirely to "[hierarchical] man management". The degree of involvement in management generally increases as they work their way up the career ladder. For the majority of engineers, however, including the young ones, the acceptance of responsibility - management - is an intrinsic part of their professionality; it sets them apart from other categories of employee and underpins the legitimacy of their function within the company.

"Engineers are polyvalent. They must be able to speak the language of technology, commerce and management, and to manage a budget. This is not required either of technicians or of managers who are not engineers".

"Engineers have overall objectives... Technicians are not associated with these objectives. Theirs are more selective..."

"It's not technical competence that makes an engineer. Rather it's his overall abilities... they're more generalists than experts... On the technical level, engineers rely on the knowledge of others..."

d. Mobility, transfer of knowledge and career building

FE Company manages overall to stabilize its engineers despite a certain degree of tightness in the labor market: excluding retirements, the annual leaving rate has hovered around 3 to 4% in recent years. Such integration may seem fairly commendable, since in the case of engineers - particularly graduate engineers - who are able to influence each round of bargaining, it is achieved by arguing that "their career prospects are not limited to FE Company". It is the result of a compromise between the general management logic and a sort of day-to-day "blackmail" which hangs over line managers.

Thus in addition to the favorable circumstances, in which the number of managers is growing - this integration is based on the effectiveness of the management tools analyzed above. As we have already seen, these three management tools (job evaluation, the Hay method and the annual interview) enable each engineer to use internal mobility between jobs to construct an interesting career prospect for himself within FE Company. It is expected that an engineer will change jobs every 3 or 4 years: the annual rate of change is between 25 and 35%.

These changes ought, in theory, to be managed by the PHRS in the light of the individual preferences expressed during the annual interviews and of the company's needs. These engineers recognize that a change never takes place against the wishes of the individual concerned (right of refusal), and that it is initiated by the engineers themselves rather than by management. In reality, these changes are often settled through informal conversations between the engineer and his immediate superior, or between two heads of service. The company itself recognizes the existence of "unofficial job changes, arranged hastily in corridors or car parks" . Thus the informal (social management at the decentralized level) takes precedence over the formal (management at central level), particularly since FE Company is expanding in quantitative terms.

It is undeniable that the space for strategic maneuvering opened up by a mobility policy of this kind reflects to a large extent the engineers' aspirations and contributes enormously to sustaining their motivation and their integration within FE Company. However, this management practice also has disadvantages. It produces contradictory effects, particularly as far as the development of the technological dynamic is concerned.

Firstly, combined with the symbolic effect of the "reserve" engineer, the excessive importance attached to internal mobility encourages engineers to favor careers as generalist managers. This striving after promotion through the hierarchy has the effect of devaluing the expert career, both at the level of social representation and of the wages hierarchy.

"I think a lot of people have shown that by changing jobs frequently they will get better, more highly valued jobs, whereas [the expert engineer] is in a corner, unrecognized etc... That's what people are escaping from ultimately..."
"In order to keep people in technical jobs, we have to pay them more. That's the solution, not equal pay, but better pay..."

Secondly, if engineers are perceived in this way, staying in a job becomes synonymous with a lack of ability. Engineers remaining for long periods in the same job are considered to be lacking in motivation or unable to change, whereas competence or expertise is often developed in the long term, particularly on the technical side.

"... nevertheless, [internal mobility] is a source of motivation... the problem is that it has become the sole key to career development, that is to say that those who don't change jobs are considered to be somewhat lethargic and incapable of developing..."

"There are people who stay 3 to 4 years [in research] and those who stay there all their life... Those who stay do so because they are psychologically incapable of doing anything else...".

Thirdly, job changes tend to happen most frequently within a division. Despite their great openness to change, engineers at FE Company display a marked reluctance to change division.

"To change division is to change culture... If you leave here as an engineer to go to another division, you're going back to the starting line. You have to learn your job again from scratch ... Whereas [internal] mobility should be a step up, changing division is nothing of the sort..."

As a result of this resistance to mobility between divisions, each division functions as if it were an autonomous entity. This impermeability, which is reinforced by the organizational compartmentalization arising out of the decentralization of profit centers, seems to weaken the potential for synergy that might exist between the various types of products and technologies. This is also one of the reasons why FE Company is experiencing difficulty in diversifying its activities.

Fourthly, even if it is possible to restrict job changes on the technical side, excessively frequent mobility between jobs tends to disrupt the "community of peers" in which the collective construction of knowledge takes place. Technical expertise or experience of industrial projects represent fragile, perishable stocks of knowledge, to the extent that that knowledge is personalized and difficult to transmit in writing.

If it is to play a full part in the creation and transmission of knowledge, the community of peers needs a minimum level of cohesion that is likely to emerge only after a certain period of time.

However, systematic mobility on the part of engineers disrupts the collective memorizing of knowledge and weakens the accumulation of experience. It is true that the technicians and engineers trained by the company are there as guarantors of lived experience. However, as we have seen, the division between engineers and technicians makes the convergence between the former, the holders of conceptual knowledge and the latter, the guarantors of empirical techniques, if not impossible at least subject to the vagaries of chance.

In concluding this second part, it should be noted that FE Company, aware of a certain degree of perverseness in a policy that overemphasizes internal mobility, and in particular of the loss of technical skills and knowledge that this entails, has already begun to take some corrective measures. The status of reserve engineer has been abolished, the salaries of those in technical jobs are being raised, the Hay method is being re-examined and a "competence strategy" is being put in place with the aim of keeping engineers in jobs where they can use their expertise. These recent changes, initiated by the PHRS, are clearly an attempt to encourage the emergence of new rules and to reorientate the behavior of engineers. It is obvious that such a strategy can succeed only if the engineers go beyond their own strategic reactions to accept the new rules in their entirety and, internalizing them, change their behavior. The outcome of this new interactive dynamic that FE Company have deliberately set in motion remains uncertain, but it will be interesting to observe from a longitudinal perspective.

1-3. THE ORGANIZATION OF INDUSTRIAL CREATIVITY

Having outlined the technical organization and characterized the engineer category, we shall now attempt to analyze the work space, and particularly the process of product development. It goes without saying that the development of new products is a vital activity for all industrial companies, since it is this process that can provide a coherent framework for coordinating the various sections of the company, for organizing learning and for developing new competencies. As a result, firms will be better able to withstand competition and ensure their continuing existence.

The development of new products is based essentially on the use of internal resources, and hence on internal growth; this contrasts sharply with a policy based on external growth, in which companies buy market share, new activities and new knowledge and skills. In both cases, of course, there is some financial risk involved. However, the difference is that the latter type of policy, even if implemented in the name of industrial coherence, all too often fails really to endogenous a company's capacity for technological creativity, whereas the former type seems capable - whatever the outcome - of generating learning effects that lead in turn to constant improvements in the organization of creativity.

FE Company organizes its industrial dynamic - the development of new products - around the project system known more commonly as the "new product project", or "industrial project". In general, the notion of project is used to denote the sequential process by which ideas are turned into new products. This process seems to be subject to serious technological constraints, even if only at the level of its sequentially. Although at first sight it is a mechanical or universal process, it is nevertheless embedded in organizational and social processes, since it is implemented by socially constructed actors. Thus it seems to us essential, in any consideration of the project system, to go beyond its purely technological dimensions. Rather, we define the project as a central notion that regulates the interaction of the various actors, thus channeling the internal tension of technical creation towards the market.

After a brief outline of the project system in its general context, we shall examine the chronology by which projects proceed and then extract some major themes that will serve to characterize the form taken by creativity in FE Company.

1-3-1 GENERAL CONTEXTUALISATION OF THE PROJECT SYSTEM

Our purpose here is to locate the project system within the overall organization of FE Company. This contextualisation will enable us to understand more clearly the internal logics underlying projects as they pass through their various phases.

Firstly, in any given year, there are between 40 and 45 projects at FE Company. Since the average duration of a project is between 3 and 4 years, a certain proportion (around 10) is replaced each year. The number of projects managed by each department varies. On average, however, each department is responsible for between 2 and 5 projects. Taken as a whole, these projects account for "500 million francs' worth of technical costs, out of a total industrial investment of 600 or 700 million francs".

Thus at any given time, each department has responsibility for several projects, each of which may be in a different stage of development. One project may have reached the preliminary marketing stage, another may be at the prototype testing stage and a third may be nothing more than the germ of an idea in an engineer's head. Each department, and in particular its technical service, which plays the leading role in project management, has to juggle its financial and human resources in order to manage this coexistence and the sequential ordering of projects. In this case, the management of human resources proves to be fairly complex because manpower needs fluctuate depending on the phase of the project: in general, the number of people involved in a project increases up to the industrialization phase and then gradually decreases as volume production begins. Apart from this quantitative problem, consideration also has to be given to matching project content to the quality of individual engineers. This problem, which arises particularly when a project manager is being chosen, seems to be difficult to resolve, especially in the light of engineers' propensity to strategic mobility. Thus the scheduling of projects is heavily dependent on the availability of engineers; this contingency cannot always be controlled.

"The decision whether or not to involve such and such an engineer in a project is very contingent, since it depends on each engineer's availability... On the day you want to appoint a project manager, for example, you can draw up the ideal profile of the person you want, but alongside that you have to put the list of who is available. And that is necessarily contingent, knowing that you'll have to put a line through the ideal profile and take the chap who happens to be available..."

Secondly, departments are given a great deal of autonomy in managing both projects and engineers. As we have already seen, FE Company has traditionally emphasized decentralized dynamism, giving each department the status of profit center. It is true that general management controls this decentralized autonomy, particularly when it comes to investment, through the three-year budget plan that each department has to negotiate with it every year. However, this financial or budgetary control is not accompanied by control over the content of each project.

"[Department heads] take their decisions [on projects] on their own, without much consultation... little information gets as far as general management, which knows nothing at all about projects..."
"Projects were managed in individual units in a very autonomous way, with no external control..."

This absence of any centralized coordination sometimes gives rise not to dynamism but to a loss of control or even a certain degree of confusion.

"The stupid things they did [while involved in a project] remained within the departments... We knew only what the departments wanted to tell us".

FE Company has been trying for some time to systematize the project monitoring system, which involves central management "legitimizing decisions" on the transition from one phase to another. The establishment of such a system is intended to symbolize the first step towards the exertion of central management control over projects. However, since this monitoring system is currently the responsibility of a single individual (a technical manager in GR) who admits that he does not "have the time to devote more than half a day to each project, it does not seem to constitute a real attack on the departments' autonomy in the sphere of project management.

Thirdly, projects obviously differ in their nature and origins. The nature of a project varies according to the characteristics of the market at which it is aimed, the nature of the technology it uses or even the intended length of the production run. Without listing all the possible variants, it is possible to point to three representative examples.

The first is the kind of project that might emerge from a contract with an organization such as Electricité de France. The aim of a project of this type is to meet the specific needs of a single client. Since the schedule of conditions and specifications are drawn up by the customer, the project becomes a fairly passive affair, unless it involves a prestigious technological procedure.

The second, and most common type is concerned with the renewal of products that already exist. The scope of such projects changes quite considerably, depending on whether the range is being renewed in whole or in part, whether the process is staggered over a period of time, and so on.

The third type is concerned with the creation of new products. This type of project, prompted by speculation within the company on the emergence of new technology, generally involves research taking precedence over production, a long incubation period and keen strategic awareness on the part of management.

Despite such variability, the vast majority of projects, whatever department is involved, are concerned with the renewal of existing product ranges. Indeed, most projects form part of what is known in FE Company as "commercial or marketing innovation". This type of innovation involves the modification of existing products in accordance with the new competitive criteria that have emerged in the market: it is aimed, above all, at improving the products' price-quality ratio, and thus the competitiveness of those products in the market. Three main methods are used: diversification, i.e. extension of the product range, simplification, i.e. a reduction in the number of parts (group technology or value analysis), and the replacement of strategic components, particularly electronic ones.

"... at FE Company, 9 times out 10, a project, or the creation of a new product, simply means reviving an existing product, but with a reduction in price, technological updating, etc... [There is not] really much development of new products. There is some, but it only accounts for 10 or 20%..."
"[In project X], I have 6 product [ranges] and I want to replace them, if possible, with a single range. The benefit is both economic and industrial. There are a lot fewer different parts, and so the volumes [for any given part] are higher and the costs lower..."
"The life [of a product] is currently 2 to 4+ years... It used to be 5 to 8 years.
[This reduction in life cycle] is a result of the emergence of competition and of technological change, and also of an economic problem, namely the reduction in the selling price by 5 to 7% per year. Products are renewed in order to cut costs..."

<u>Fourthly,</u> not all projects are equally important, either in terms of the mobilization of financial or human resources or of the strategic issues at stake. Thus they do not all carry the same weight, either in management practice or in the order of managerial decisions, or in the way projects are perceived by engineers. The importance of what they entail is more or less unofficially evaluated and hierarchised on the basis of various factors. The first of these is undeniably the level of technical costs incurred by a project.

"There are projects, small ones, that cost 1 million francs. And then there are projects that incur 100 million francs in technical costs, like the one being run [by a project manager with more than 20 years' experience in one department]... large projects are those costing more than 10 million..."

In addition to this financial consideration, two other factors are taken into account, namely the degree of strategic urgency in commercial terms, and the technological importance of the product being developed.

"This product was absolutely essential... When it affects the company's location decisions (in this case, in the USA), even if it is a small project costing 5 million [francs], the project is a strategic one".

"[The electronic relay] is of concern to all departments in FE Company. This project, which costs only 3 million, is a major project, because several people are waiting [for its technological spin-offs]..."

These various factors help to hierarchise projects, even if only at the level of the image engineers have of each project. Such hierarchisation - subjective and objective - determines the degree to which engineers are mobilized and motivated, and in particular the degree of cooperation between various actors, which in turn influences the way in which the project is conducted.

"[At factory x], they recently renewed all their product ranges. This change was absolutely vital for that factory. All those involved [in this project] played the game... Everybody lent a hand... On the other hand, [at factory F], they're currently replacing a part of their product range. The change is being made just to increase productivity... [This project] doesn't interest people... It's just a nuisance."

Fifthly, the project system and the organizational matrix that accompanies it, both of which are American in origin, were introduced by FE Company in the early 1980s. This change, initiated by a constancy company, was introduced gradually, department by department, which explains in part why the system is formalized to differing degrees in each department.

Even though some engineers consider that the change simply "systematized what [engineers] were doing previously, without being aware of it", this grafting of American methods on to the organizational culture of FE Company seems to have introduced two contradictory elements into project management. On the one hand, the strict codification of tools and procedures gives rise to rigidity, while on the other there is a certain degree of improvisation in the actual implementation of the project.

As Figure 2-4(see after) shows, the project system rigorously formalizes both management tools and the progression of the project. The division into phases, the sequencing of the various procedures, scheduling (the allocation of time to each phase) and the organization of the reviews that evaluate progress and sanction the move to the next phase are all strictly defined, as are the roles, functions and responsibilities of all personnel involved in the project. In this way, the system contributes to the codification of the innovation space. For example, the organizational matrix clearly distinguishes between functional jobs (the skill group in which specialists are mobilized) and management jobs (project team, particularly the project manager, who has overall responsibility for the project) and thus helps to define skill content, the nature of responsibility, etc....

Nevertheless, it seem obvious that the actual implementation of a project cannot correspond entirely to the strict framework imposed by this normalization or to the coordinated and cooperative relationships constructed in advance by the codification of roles. Depending on the various constraints (time, resources, technological content,etc.), the actual organization of a project and its progression take a variety of different forms and routes. This organizational plasticity requires that the actors, who "sometimes fly without instruments", should have a certain amount of room for manoeuvre. It is in this constant process of readjustment in relation to the initial focus of the project that the actors' social logics are expressed.

The project system is a methodology of American origin, and the engineers have perceived it as such. However, the system as implemented at FE Company has been subjected to considerable "Frenchification", the result of a collective effort by the actors which has not, however, eliminated tensions and conflicts with the existing organizational culture.

1-3-2 INNOVATION CYCLE: the chronological progression of a project

By referring to Figure 2-4 and 2-5, which summarize the progression of a project, we will attempt to reconstruct chronologically the way in which projects are implemented at FE Company. This reconstruction is intended to be synthetic. It takes account neither of the variety of forms that a project can take, nor of the specific difficulties it may encounter or the degree of success it may achieve. Far from being an accurate snapshot of a single project, it is based on fragmentary descriptions of various projects mentioned by engineers in the course of interviews. Despite the loss of nuances, this synthesis has the merit of revealing the salient features of the system of project management at FE Company. As required by the methodology currently in use, we shall divide the progression of projects into five phases: the preparatory phase, the orientation phase, the design phase, the industrialization phase and, finally, the production phase.

FIGURE 2-4 Product Development: from the Design to the Production

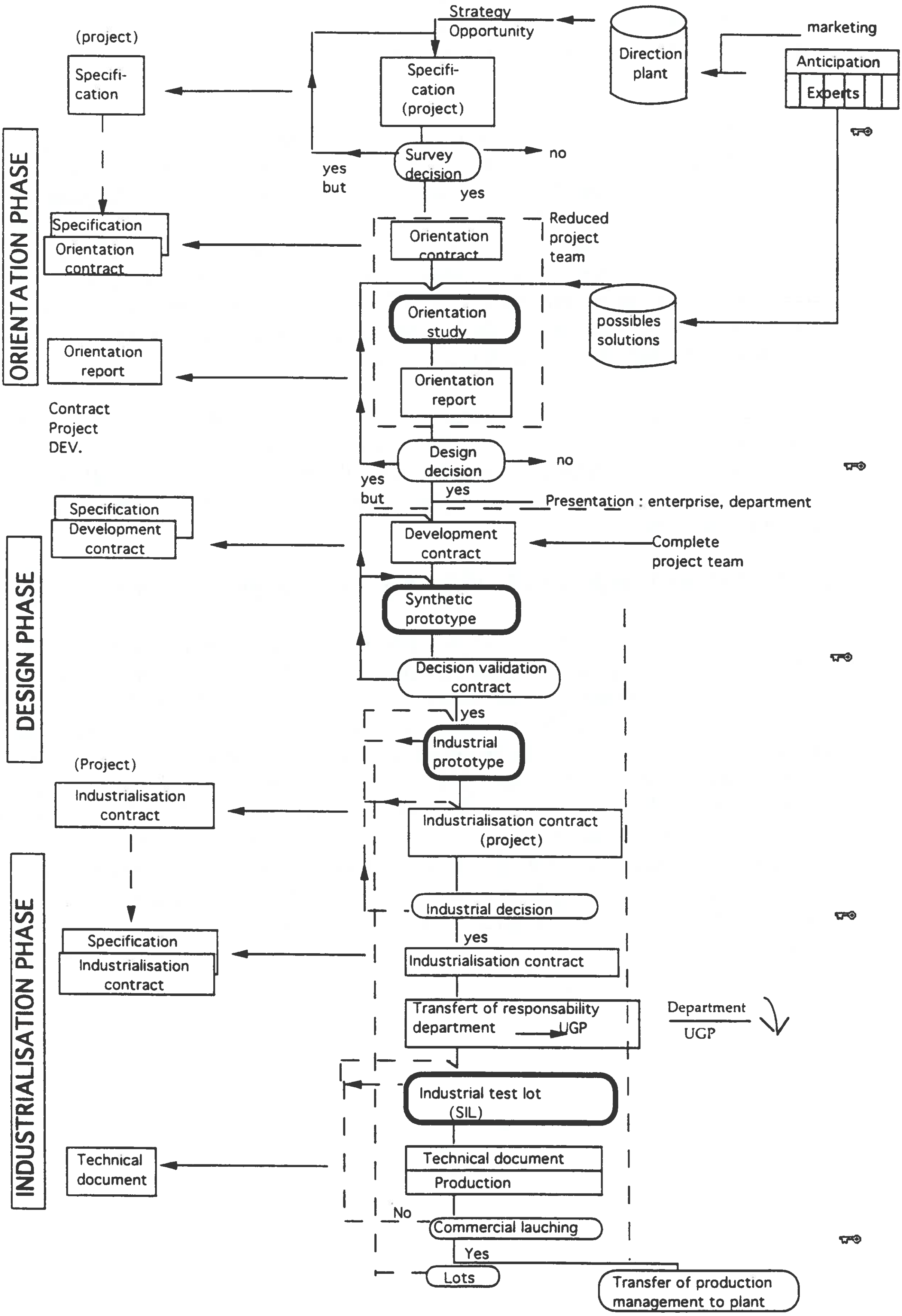
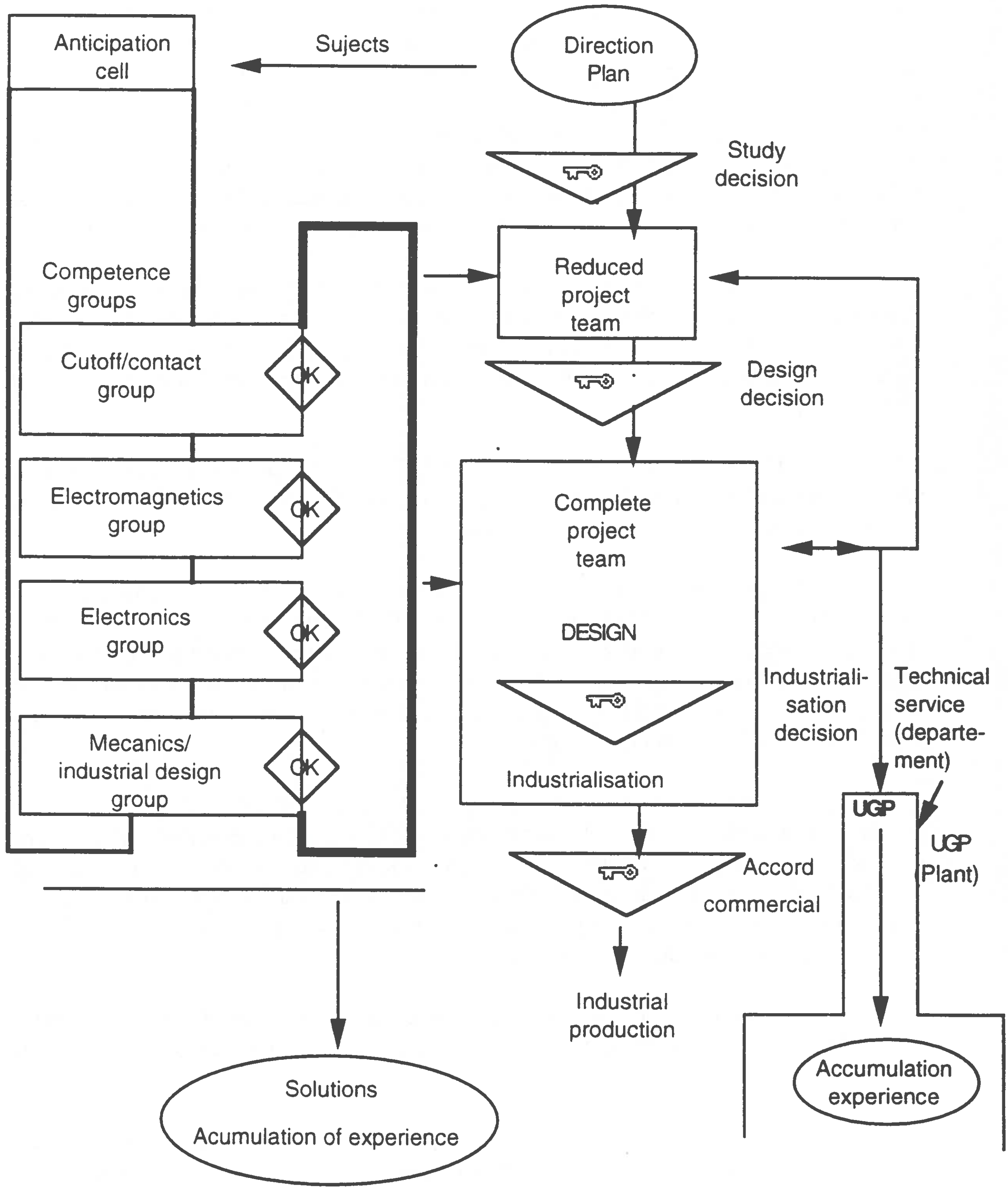


FIGURE 2-5 Trajectory of Project and Actors



a. The preparatory phase

Strictly speaking, this preparatory phase is located outside the actual time frame of the project. It takes place before the project is officially born, and is more accurately described as its incubation period. The task of those involved in this phase is to give thought, not necessarily continuously, to new projects, the development of a material, a technical function or a component before the technical service actually needs to incorporate its technological spin-offs into a new product. In other words, without being directly linked to the immediate constraints of the markets, or abiding strictly by deadlines, the purpose of this preparatory phase is to understand and anticipate the evolution of the technological environment in which products exist, to extract technical potential from it and if possible to translate this potential into operational applications.

This sort of technical marketing, carried out by the technical service, does not mean that commercial concerns are entirely absent, in contrast to the general research activities that take place in the laboratories. The engineers involved are very much aware of the differences between these two activities, although they are both concerned with future prospects.

"[This preparatory function] can be clearly distinguished from general research, since we are no longer working in the long term. We are concerned with new projects that will be completed in the foreseeable future" xc

The links between general research, where "applied research is carried out on a thematic basis (materials, plasma, etc.)" and GR the preparatory function, "which develops sub-groups of products or product functions", are recognized and formalized - particularly through the funding system - in such a way that the activities of the two sections are coordinated and knowledge transferred between them. In reality, however, these links are diffuse and unstructured.

"The links are virtually non-existent. In theory, the GR program is drawn up in consultation with the units. To some extent, therefore, they are working on the basis of guidance given by the departments. In fact, the departments give to GR long-term work and reserve work with a time horizon of two to three years, which will lead quickly to the next project, for their own preparatory groups. What is expected from GR is ideas, prospects for products in 5, 6, 7 years."

As a result of this clear distinction that tends to be established, these links - which, though weak, actually exist - are seldom activated during the process of product development.

It should be noted, moreover, that this preparatory phase was not initially included in the project system. It has been developed gradually after a few experiments. The establishment, at the very heart of the technical service, of "a specific place at which product innovation takes place" is of course not unconnected with the recent acceleration in the pace of technological change. Such normalization is significant in three further respects. Firstly, it cannot be dissociated from the need - increasingly strongly felt - for better project management, particularly in respect of the length of time required, which has now become one of the basic elements in the company's competitiveness.

Secondly, it obviously represents an extension of the chain of innovation, which reflects the growing need to enhance the technical content of products. Finally, FE Company's organizational response to these changes has been to recreate a specific innovation space by separating the innovation function from the general process of project implementation. "Previously, when we were setting up a project, the innovation required was carried out within the framework of that project. However, when a project starts off with a lot of innovation [to be done], there is every chance things will not turn out as hoped and take much longer and cost more than planned. So people gradually realized that the amount of innovation required for each project had to be limited, and that the actual innovation had to be done somewhere else, prior to the start of the project. This is the purpose of the preparatory group...'

"At any given moment, you have to have the courage to set up a preparatory team, not really to work on products but rather on subsets that might or might not be used subsequently. It's an investment for the future. It's a bit risky sometimes, but it's always an investment, because even if what they do doesn't lead to [a new product], it's worthwhile not having any illusions about such and such a technology, and to know there's no point using it..."

On the operational level, this phase is the responsibility of one or two small teams, known as "preparation cells", set up in the technical service of each department. The head of the technical service has overall responsibility for the teams. The preparation cell may sometimes be just one engineer working alone in a corner, and sometimes a real team with an engineer and one or two technicians. Its task, the incubation of new projects, depends largely on intellectual deliberation, and is therefore loosely structured. Even though the resources allocated are modest, this preparation function seems to offer some engineers, often younger ones under 30, an opportunity to develop their technical imaginations, to accept a worthwhile challenge and to undergo a real learning process. If they have already been socialized into the "community of peers", this type of function helps them further to consolidate their personal networks and to develop their relational abilities.

"We know there are lots of ideas that can be exploited. We look elsewhere, in order to integrate them. We pick them up here and there... You have to go where the new ideas take you. How do we find out? ... Basically through personal contacts. You have to develop personal networks with other departments and general research..."

b. The orientation phase

The vast majority of projects, which are concerned with the renewal of existing products, start from this phase. The preparation phase is reserved almost exclusively for a handful of projects intended to be highly innovative.

Even if a new product never has its origins "either solely in marketing or solely in technology", it is the marketing service's responsibility at FE Company to make the initial proposals, by recognizing the need for new products or for the modification of product lines, etc. It should be noted, in passing, that the marketing function, like the sales function, is full of engineers who "alone are capable of translating the needs of the market into technical terms" and that it is considered to have a "higher profile", to be "more prestigious" and to carry "more weight" than the technical function.

As soon as the new needs are defined, the product manager drafts the preliminary specifications. It is his task to supervise a certain product range, and he is the person best qualified to provide information on the state of the competition, customer demand, etc. On his initiative and on the basis of the initial specifications, a meeting of the departmental management team is held. This team includes the director of the department, the heads of the technical and marketing services and the head of the PMU - the factory or manufacturing subsidiary - to whom "the project must be sold" . It is this departmental body that will, as a last resort, decide whether or not to launch the new project. This decision, which is often described in FE Company as a "collegial" or "consensual" one, seems in fact to be based on good formal or informal coordination and the effective exchange of information between the marketing and technical services.

"There is good reciprocal knowledge: on the part of the product manager on what the technical service can do, and on the part of technicians on what the market demands... thus the technical service also anticipates the demands of the marketing service..."

However, when tensions manifest themselves, the balance of power clearly favors the marketing service.

"In general, the product manager wields considerable power in a department. Very often, when there is a dispute [between the technical and marketing services], the department director will decide in favor of the product manager..."

As soon as real interest is shown in a project and agreement has been reached, management launches the project and at the same time sets the stopwatch going (a project should ideally be completed in 36 months). In this initial stage, the person appointed project manager, in theory at least, sets up a small team to carry out a feasibility study. In the case of major projects, this team comprises, in addition to the project manager, the product manager and the product designer, assisted by several technicians. In the case of small projects, the project manager often takes responsibility for the technical study. In all cases, the project manager is chosen, with very few exceptions, from among the engineers in the technical service. Consequently, he continues to report not to the department director but to the head of the technical service, contrary to the "ideal situation" in which "each project manager is given full authority over his project by the department director". The result is a certain ambiguity between this traditional hierarchical allegiance and his position as project manager, for which he requires "real functional authority" over people from various services, such as quality control, purchasing, industrialization, and so on.

The project manager plays a central role in the implementation of the project.

It is his job "to pilot the entire operation, guiding the product from the initial specification right through to production". "His responsibilities cut across" the structure of the organizational matrix, "since it is his job to mobilize, at various stages, the expertise of different services"; "the project manager oils the wheels, managing and coordinating the input of the various services". In the light of this coordinating function, it is clear that the project manager's expertise lies not so much in his technical proficiency as in his relational abilities, methodological rigor, knowledge of the workings of the organization and ability to balance the economic and technical dimensions... in short, the ability to manage.

"The role [of the project manager] is not so much to find new ideas as to focus his team's efforts on points that remain vague and to find the best possible compromises [between the economic and technical dimensions]..."

Furthermore, two major objectives have to be met during the implementation of a project: "set deadlines and meet them, draw up budgets and keep within them." Given that "in addition to the loss of profits, delays in projects cost a department one million francs per week", any "drift" from the initial planning targets gives rise to great anxiety. It is obvious that project managers take personal responsibility for ensuring that deadline and budget targets are met.

The team remains small during this orientation phase, and its main task is to carry out feasibility studies with a view to drawing up a (theoretically) final specification. The product manager reviews his initial proposals in order further to improve the economic data, such as market volume, price, profit margin, etc. For his part, the product designer closely examines the technical possibilities, compares the costs of different choices and evaluates the overall development budget. After comparing these various data, decisions are taken on the basic technology, the provisional budget and the marketing date.

"[In project G], we're currently doing a feasibility study. The solutions that might be adopted have to be costed from the technical and economic point of view... and from the marketing point of view, the hypotheses about market volume and the profitability of the project have to be tested..."

These decisions serve as guidelines, even if the projections obviously do not eliminate all uncertainty caused by extrapolating from past experience and the time gap of 3 to 4 years between the drawing up of the initial specifications and the marketing of the product. It is the project manager's responsibility to guide the project intelligently, in such a way as to minimize uncertainty and to adjust the projections to changing realities.

Once the specification has been drawn up, this preliminary phase leads to a project review in which the entire department management team takes part, together with a representative of general management. The purpose of this review is to decide whether or not to validate the specification and whether or not the project should be continued. A project may be deferred at this stage, but is rarely canceled.

c. The design phase

At the beginning of this phase, in which the product actually takes shape, the project team increases in size, in two ways.

Firstly, the team develops into what is known at FE Company as an "interdisciplinary team" or a "project activation team". In addition to its original members - the project manager, the product manager and the product designer - the team now includes representatives of the various services, such as quality control, standardization, purchasing, industrialization, etc... These representatives, whether engineers or technicians, are responsible for following the progress of the project in their own services; they monitor the project, exchange information and put themselves at the disposition of the study group in the technical service whose task it is, under the leadership of the product designer, to complete the technical design of the product. This interdisciplinary team then becomes a structure that accumulates and synthesizes data of various kinds, with the reports being sent to the project manager.

"The [interdisciplinary] team is essential for the transfer and synthesis of information from the various services..."

"The project manager stays on the project until it is completed, because there are decisions and choices that have to be made in the course of a project, and the reason for these choices are not always formalized or written down..."

Contrary to appearances, this interdisciplinary team remains a loosely structured, flexible organization. The representatives of the various services, although they are associated with the project throughout its life, are brought in only to meet specific needs. Indeed, the contribution of each service tends to be made at different points in the progression of the project, and is spread out over a period of time. It is the project manager who has to orchestrate these contributions into a coordinated sequence.

Secondly, this same project team will be supplemented by technicians from the technical service (draughtsmen, designers, model makers) who form a technical study group around the product designer. It is this group - the size of which is proportional to the importance of the project - that is responsible for the main activity in this phase, namely the technical development of the model, which occupies half to two thirds of the total time allocated to the project. If he has participated in the preceding phase, the engineer (product designer) knows the technical objectives laid down for the project. "The essential technical functions of the device are laid down in the specification drawn up by the marketing service... They have to be achieved at all costs..." Together with his group of technicians, he will try to find the best technical solutions. Different types of device give rise to problems that vary in kind and field (material, dielectric, electromagnetic, etc). Depending on the nature of the problems to be solved, he calls on different skill groups led by experts in electronics, electromechanical devices, etc. (see Figure 2-5). During this phase the engineer in charge of the study group often tends to focus on purely technical questions, while the project manager has to stand back a little in order to make the best possible compromises between technical performance and economic cost.

The first task of the technical study group is to make the prototype (test model) in order to test in the laboratory the soundness of the chosen technical applications. At this stage there is a great deal of shuttling backward and forward between conceptual thinking and experimentation.

The expert engineers and technicians play a dominant role here. They are in the same boat, and are capable, indeed sometimes actually give the impression, of speaking the same language. However, it is not easy to achieve any kind of symbiosis between these categories of actors. There is a split between the engineers, who monopolize all the conceptual and relational functions (modeling, calculation, test planning, analysis of results, etc.), and the technicians, who are often restricted to execution tasks.

This form of division of labor, with little overlap between functions, makes dialogue within the group fairly difficult, or even a potential source of conflict.

"Engineers don't often get their hands dirty. They stay in their offices, while the technicians get on with the rest of the work..."

"Engineers have a global purpose... technicians are not involved in the end product, but in specific tasks... The difference is the personal involvement you may or may not have in the end product..."

"[In project z] there were four engineers and around ten technicians at the beginning. Each engineer had a specific task in the technical development of the product. In the follow-up stage, he split his task into various sections and gave the technicians one section each... the overall design had already been drawn up by the engineer. I was able to modify it from the technical point of view, by about 20%, in accordance with the tests..."

After this phase of experimental trials, which ends in a review involving the same senior management team and in a decision on whether to carry on, this study group then tackles the task of producing the industrial prototype.

This prototype is a confirmation of the previous one, but for the first time it takes account of the product's future industrialization: the model is created by highly skilled workers who machine each part on a milling machine in the workshops of the technical service. With this industrial prototype, the main focus of attention is on the structure of the economic and industrial costs, rather than on the purely technical functioning of the product. The use of methods such as value analysis and group technology makes it possible to reduce the number of parts or replace a material with another, more economic one, etc. At the end of this stage, the product is 60 to 70% complete; at the same time, the development of the necessary industrial tools is planned (manufacture of machines or moulds, automation of the assembly line, etc.) and the search for possible suppliers is begun. The "industrialization specialist" in the industrialization service and the "buyer" in the purchasing department begin to work together with the product designer within the framework of the "interdisciplinary team".

And as soon as the first prototype phase is finished, a few engineers in the production unit where the product is to be manufactured try, in theory, to make their presence felt in the study group in order "to supply the designer with information on production".

d. The industrialization phase

The industrialization phase, which is considered one of the most critical in the life of a project, involves managing the transfer of the product from design to production. In addition to the specific difficulties arising out of the transfer of the formalized technical knowledge relating to the product, entry into this phase involves at last two significant changes in the management of the project.

The first relates to the transfer of responsibility for the management of the project from the department to the PMU, or production management unit. The management of the PMU takes control of the project, in both administrative and accounting terms. The second has at least three dimensions to it, involving a change of geographical location, form of work organization and technical culture: the project leaves the technical service's design office or test laboratory and moves to an assembly line in one of the production plants, which are sometimes quite remote geographically. In other words, the prototype produced by craftsmen is subjected to the test of being manufactured on an industrial scale.

This transition from the design to the industrial phase considerably increases a wide variety of constraints on the project, ranging from marketing deadlines, through the organizational rigidity of the factory to the "finishing touches" required for industrialization. If it is not thoroughly prepared, such a change may well cause dislocation within the project team, a certain degree of confusion as to who is responsible for the project and sometimes even a change of project manager.

In this phase, operational responsibility for the transfer - even if it is formally supervised by the titular project manager - very often falls to the engineer responsible for the industrialization process, who works in the technical service of the production unit. Since it is his task "to bring the project to production in as complete a state as possible, so that it can be processed as quickly as possible", the engineer responsible for industrialization, together with his team of technicians, has to tackle two main tasks.

The first of these is to produce limited production or pre-production batches. As we have seen, the industrial prototype is "made from the block", that is the parts are specially produced for it by highly skilled workers. The engineer in charge of industrialization has to design the tools capable of mass producing those parts and to plan their assembly. The pre-production batches are assembled and tested on the assembly line by production workers, "choosing a slack period in order not to upset production schedules too much".

Some design errors will have to be corrected, without "necessarily having a suitable structure for doing so".

"If a part has been wrongly specified during the design phase, it will still be wrongly specified at the industrialization phase". Mistakes made at the design phase are transmitted down the line and often re-emerge in an acute way at this stage. "When we move to the industrialization phase, the product has not been 100% checked... technical problems cannot be solved here... we have to make do and mend..." Thus it is not unusual for the engineer in charge of industrialization to find himself in an "inextricable" situation, caught between the imperatives of the specifications (deadline, cost, technical performance, etc.) and the delay - or technical errors - built up over time. "Even if all the services want to work well together, at some point the machine jams because of unresolved technical problems..." However, the greatest constraint is that "after industrialization, there's the customer".

The second task is to compile a technical file for the product.

"The engineer in charge of industrialization is responsible for doing all the administration and gathering together all the paperwork. This is called the technical file, that is, he collects together all the parts lists and specifications and puts them on to the computer. He also draws up all the manuals, the manufacturing ranges, the operating ranges and the instruction, assembly and adjustment sheets that go to the subsidiaries or the customer..."

"They get through a tremendous amount of paper and computer work, and they also put the last little finishing touches to products... But it's still intellectual details".

The pre-production batches are then sold to customers; these pre-production sales constitute a "life-size" test of market reactions.

"This means that the first orders can be placed and the teething problems ironed out; it also means that when it goes into production, the product and the process have already been industrialized and tested".

When the pre-production batches have been sufficiently tested, the engineer in charge of industrialization establishes liaison with the production service, in order to make official the commercial launch of the product and to bring the product into full production. This second transfer is perceived to be in some ways more difficult to manage than the first one, at least until production is stabilized. The difficulties are of two orders.

Firstly, the production service, preoccupied by the day-to-day management of production and the need to meet daily output targets, is not always ready to receive the new product.

"[The production service] does nothing to take delivery of new products. If a new product is to be successfully introduced into the existing product range, the task has to be made as simple as possible for them, [because the new product] means nothing [to the production service]".

Secondly, the increase in production rate depends on various uncertain factors, particularly the speed with which sales of the new product take off. It is very difficult to synchronize the marketing launch, the increase in production capacity and the substitution of products. In this case, any delay on the marketing side slows down the rate at which production can be increased, which in turn delays the emergence of defects revealed by mass production. Indeed there are defects that are revealed only by large-scale production; these often minor problems have of course to be resolved by "tinkering" on the job. It seems to be mainly technicians with a background in manual work who are called upon to solve these problems.

"The product is 98% ready for industrial production, but the remaining 2% is a real headache... we try to solve these minor problems by using the resources on hand..."

More fundamentally, however, the aim at this final stage of the project is to set in motion a virtuous circle between rapid entry into the market, improvement in productivity and product quality.

"When you increase production capacity very rapidly, there is an enormous flow of products... so statistically speaking, it is probable that technical problems will appear quickly... and since the earlier phases will have taken place only a short time before, it's possible to find the guilty parties (the designers), if there are any slight defects... we can always re-examine all the experiments carried out during the project. When production is slow to pick up, nothing will happen for a long time, and during that period it's easy to lose track of the teams and the designers. So when problems do become apparent, you can't find the person who's got the records and all the information [on the project]..."

e. Production phase

When the product has gone into mass production and is sufficiently stabilized, the project and the task of the project manager are considered completed. The technical study group (the largest group in the team) is disbanded when the project is transferred to the PMU, so it is mainly the project manager or the engineer in charge of industrialization who, with the assistance of technicians in the production unit, follow the project through to its conclusion. At this stage, general management seeks to formalize the last phase with a final review. The aim of this is to assess the project's progression, evaluate the overall performance, analyze the successes and failures and make sure the experience obtained is fed back into other projects.

As for the product itself, its life cycle is normally determined by its commercial success. However, it is not often that a product remains in its original form. Small changes are constantly being made in order to adapt the product to customers' specific requirements or to general market trends. These modifications are carried out by the technical service in the production unit.

1-3-3 SOME REMARKS ON THE PROJECT SYSTEM

We shall now seek to extract from the general description of the project system presented above several features that best characterize the product development process at FE cpmpany.

1) The methodology applied to the project system is explicit, precise and rigorous: the project management tools are highly formalized and some of them (division into phases, scheduling, timing, etc.) are even regarded as non-negotiable rules that must be observed. The existence of these rules, which seem to be taken on board by the majority of engineers, means that the same methodological language can be shared by all the various participants in a project, thus giving it a certain coherence as it progresses through its various phases.

2) These methodological rules seem to attract widespread consensus, particularly on the need to divide projects into different phases and to make a clear distinction between one phase and the next. As we have seen, each of the five phases has a specific objective, a concrete task and managerial responsibility. The chronology of the project is organized on a sequential, linear basis. Thus the transition from one phase to the next is accompanied by the review system, whose function is to evaluate and verify the accuracy of the work carried out (i.e. its conformity to the original specifications).

This strict sequentiality undoubtedly reflects the original desire to rationalize the project management system. At FE Company, however, it seems to be championed and even reinforced in order to prevent projects from "drifting", which is the most feared risk in project management.

"Telescoping between the design and industrialization phases must be avoided at all costs. This means that the various phases must not overlap..."

"This is the situation that is most likely to knock a project off course. Any deviation or drift may be very expensive..."

"It is essential to pass as cleanly as possible from one phase [of product development] to the next. One shouldn't have to go back to a previous phase..."

"Once a phase has come to an end, the file must be complete and ready to pass on to the next phase..."

In contrast to the rigorous control over project management that is achieved in this way, this rather mechanical sequentiality tends to create two not inconsiderable disadvantages. It increases the compartmentalization of each phase in a project's development, which gives rise to acute problems in the transfer of knowledge or experience: each phase creates its own information. However, such sequentiality encourages information to flow "downstream", from the start of a project to its conclusion. Thus the difficulty of placing a retroactive loop in the chain of communication - which in a way becomes an irreversible process - reduces the effect of the collective learning process inherent in the project system.

3) The product development process is not only divided into phases in order to meet the requirements of management, it also cuts across three professional spaces in which engineers seem to behave rather differently. The simultaneous coexistence of

these two types of division, in which each link in the chain is connected in series to the next, makes the progression of each project very complex.

The first space is the one in which the preparatory phase takes place; it contains the engineers working on future possibilities (general research, preparation group). The second one corresponds to the design phase, which is the responsibility of the technical service (design/planning office). The third is the space closest to the shop floor, where the product is industrialized and goes into production. These three professional spaces each cultivate their own specificity, even though they are linked by engineers or technicians moving between them. This differentiation arises directly out of the way in which two constraints inherent to product development manifest themselves, and indirectly out of the way in which engineers relate to those constraints.

On the one hand, the technical constraint (technical choice), although it exists, is very weak in the first space, in which engineers are expected to allow their technical imaginations to roam freely. In the second phase, the range of technical choices is reduced as the technical service makes progress in specifying the product. As soon as the product's design is confirmed with the production of the industrial prototype, the industrial dimension takes precedence over the design factor, which reflects the nature of the change in constraint. In the third space, the technical option previously decided upon is the decisive factor, leaving little room for manoeuvre, except for a few "do-it-yourself" adjustments. On the other hand, the time constraint is virtually self-managed both in the preparation group and in general research, since the very specificity of their work lies in the deliberate creation of a certain distance from immediate demand. In the second space, the notion of time regains its full significance and increasingly becomes a deadline which has to be met and which determines the rate at which work progresses. "In the technical service, the minimum is 50 hours. Anything less than that and they can't manage. Those people are under pressure...". In the third space, industrialization proceeds under the inescapable shadow of the deadline of the marketing launch. "We have to go through a painful period... sometimes we find ourselves caught between accumulated delay and the customer, a situation from which there is no escape".

The form in which these two constraints are manifested goes a long way towards characterizing the professional spaces, and also towards forging the behavior of the engineers in each space.

The first space, dominated by engineers in their most technical guise, is characterized by an advanced technical professionality. In this space, engineers enjoy a certain degree of professional autonomy and better relations - relatively speaking - with "competent technicians with whom one can discuss things". The second space is characterized by a clear distinction between engineers' sphere of competence and that of technicians, with the former being responsible for technical and organizational management and the latter for technical execution. This distinction engenders conflict within the enclosed confines of the technical service. In the third space, in which technicians predominate to a large extent, the number of engineers is diminished. Since their function is often reduced to that of man management, the image of the engineer as expert becomes considerably blurred in favor of a hierarchical, managerial image.

4) Among the many splits that can be observed in project organization, there is one that undeniably marks the trajectory of a project. This is the gap that separates the design phase from the industrialization phase. The transition between the two is generally considered to be difficult, since it involves a considerable leap in task content, form of work organization and approach. The difficult nature of this transition, described by some engineers, particularly non-graduates, as the "French disease", proves to be linked also to the way in which engineers are trained, define their role and perceive the role of production.

"Graduate engineers design a product... and since they have never mixed with manual workers, they cannot imagine how the product they design is going to be manufactured..."

"People in the technical service are so concerned with the fundamental problems of the circuit breaker that they attach greater importance to the general design of the circuit breaker than to subsidiary functions [which are, however, of great importance at the level of production]... thus they seek to solve these fundamental problems without worrying about the problems that this may pose during the industrialization process... The engineer in charge of industrialization often has to say that the device is not completely finished, although the technical service says it is... it turns into a dialogue of the deaf..."

"Most of the problems that have to be solved are human ones. There are types of activity in which you have to mix with people in production who have much less technical knowledge... dialogue is much more difficult... we have to go through that in order to get on more quickly, supposedly, it's people who've worked in production who get to the top jobs more quickly..."

Nevertheless, aware of the difficult nature of this transition, FE Company has for some time been trying to bridge this gap by setting up an "outpost" of production in the technical service, or by involving the engineer in charge of industrialization at a very early stage of the design phase.

5) Product development requires a long time (3 years on average) and the participation, at different stages, of the various services (marketing, purchasing, standardization, industrialization, etc...). This discontinuous process, spread out over time, is not viable unless it is monitored by the interdisciplinary project team, and particularly by the project manager leading it, who has a central function in the project system. He has a dual role, that of "keeper of the records" in the long term and that of "synthesizer" of the various competencies in the organizational matrix.

In the light of this strategic function, the chairman and managing director of FE Company ordered the introduction of a course for project managers. The course is considered one of the most "elitist" in the company: there are 12 places each year, allocated after a selection process, and 25 days of seminars per year, in which a whole range of methods required for project management is taught. The annual cost is 200,000 francs.

However, despite this program, it has proved difficult to stabilize the status of project managers and to have its legitimacy recognized. Two closely linked reasons for this may be advanced.

Firstly, it seems that, in French organizations, functional authority cannot be clearly defined or easily accepted if there is a well-established hierarchical authority (the classic line of command such as head of service, head of unit, etc...). The project manager does not in fact have direct responsibility for the people with whom he works in the project team. According to a young project manager "if they don't want to listen to me, nobody listens... I have a vague role that is not on the organization chart". In theory, he has neither the power to give orders - whether to technicians or to manual workers - nor the right to settle disagreements between services. The reality is a little more complex. It is above all the "personal" authority of the project manager that may - or may not - legitimize decisions taken during the course of a project. In the case of a strategic project, for example, the project manager is selected from among the most experienced engineers who have acquired sufficient professional recognition. On the other hand, young engineers, even if they have already been initiated into the methods of project management, often have "difficulty in getting things moving".

Secondly, the post of project manager is only a transitional one for most engineers, whose aim in building their careers is to move up the hierarchy. In consequence, there is a high turnover rate among engineers in such posts. This mobility, which is sometimes excessive, is not only a waste of investment, since half of the 60 engineers who have been on the project manager course are no longer exercising that function five years later, but may also destabilize the project management system.

"[In a project that had suffered considerable "drift"], there's been a high turnover of people in certain jobs ... we've had two heads of department, three heads of technical service and 7 project managers in the course of this project... despite everything, we've nearly finished..."

In fact, the engineers themselves are aware of the conflict "between the collective interest of the company", which is "to build up a body of experienced project managers by keeping them in that function", and the "personal interests of individual engineers". From this latter point of view, "keeping engineers in the post of project manager for two or three [successive] projects, that is 7 or 8 years, does nothing to increase their standing..., it's not a good career path". Thus this conflict destabilizes the status of head of service, dissipates the drive to accumulate experience and reduces the efficiency of the learning process in the technical service.

2. A CASE OF THE JAPANESE COMPANY

2-I. PRESENTATION OF THE COMPANY

This monograph examines the R&D system of "JE Company", a consolidated manufacturer of electric machines, in order to identify methods for organizing R&D personnel and for performing the research and development necessary for new product development within an environment of increasingly rapid technological progress and change. Organizational structures, the administration of the work of R&D personnel and the patterns of their career formation will be examined in order to identify the structures and practices which are essential for the effective transfer of technologies from the Central Research Center to Development and the Design Departments of the Operating Divisions.

2-1-1. MANAGEMENT STRATEGY AND FIELD OF CORPORATE ACTIVITY

JE Company was established in 1923 and is one of the leading manufacturers of electric machines in Japan. By March 1990 JE Company had capital reserves of the value of 467,610,000,000 yen, sales of 5,919,640,000,000 yen and 13,445 employees.

JE Company was originally founded as a manufacturer of heavy electronics and was formed as the joint venture of a Japanese manufacturer of power conduction cables and a German manufacturer of heavy electrical machines. Since it's establishment JE Company has positively undertaken new ventures and generally followed the path towards diversification. In the 1950's JE Company entered the home appliance market with the production of electric fans, washing machines and refrigerators, sales composition for the 1960-62 period shows that heavy electrical machines comprised 54 %, measuring equipment 6 %, general application electrical machines 18 %, and electrical home appliances 22 %. In the years to follow however, with strong competition form home appliance manufacturers, JE Company failed to attain mass production volumes and a favourable market position and by 1976 had withdrawn from the home appliance industry. In place of home appliances, JE company expanded into the new field of automatic vending machines. In the years to come JE Company was to become the world's leading manufacturer of automatic vending machines.

Recent management strategies are based upon the 1985-1990 long term business strategy which was first initiated in 1985. This long term business strategy is called the E&E (energy and electronics), and places it's emphasis upon the strengthening of JE Company capacity and performance in the electronics field. In concrete terms JE Company planned that by the year 1990 it's gross annual sales should reach a value of 710,000,000,000 yen and its operating profits should reach a minimum of 42,000,000,000 yen, within this the goal was to make the income from products in the electronics field reach at least fifty percent of the value of gross sales. In 1980 electronics products represented seventeen percent of total output (electric devices eight percent, power electronics three percent, information, instrumentation and control equipment six percent). By 1986 products in the electronics field had reached thirty five percent of the total (electric devices 13 %, power electronics 6 %, information, instrumentation and control equipment 16 %).

Basing it's activities in the two main fields of electronics and energy, JE Company is positively undertaking diversification. JE Company develops and produces semi conductors, process control systems, and industrial robots in the electronics field, and hydraulic and combustion electricity generation equipment and amorphous solar batteries, in the energy field. By March 1991 36 % of sales are derived from heavy electric machinery, 12 % from measurement and information systems, 15 % from electronic devices, 21 % from control equipment and 16 % from sales of automatic vending and special order machines.

Seen over time, heavy electric equipment which had comprised fifty percent of production in 1980 had decreased markedly in proportion to the steady growth evident in the electronics field (see Table 2-6).

Table 2-6 Weight of Sales by Area of Production (%)

	1980	1985	1991
Heavy Electrical	50	40	36
Instruments/Information Systems	10	14	12
Electronic Devices	10	13	15
Control/Receiving Equipment	18	19	21
Automatic Vending Machines/Special Machines	12	14	16

The goal of attaining total sales to the value of 710,000,000,000 yen by 1990, as laid out in the long term plan of 1985, is yet to be attained. In the light of this situation the following basic measures were proposed :

1/ reorganization, rationalization and relocation overseas of production facilities for those operations made enviable by the strengthening of the yen,

2/ reorganization of domestic production facilities to avoid a "hollowing out" effect because of the overseas relocation of production,

3/ the positive development of electronics related equipment in fields with good prospects for future growth, 4/ strengthening marketing capacity,

5/ increasing speed while reducing the costs involved in product development.

These various policies are presently being applied and the relevant issues involved in each are being examined in most of the major operating divisions and product groups.

2-1-2. CORPORATE ORGANIZATION

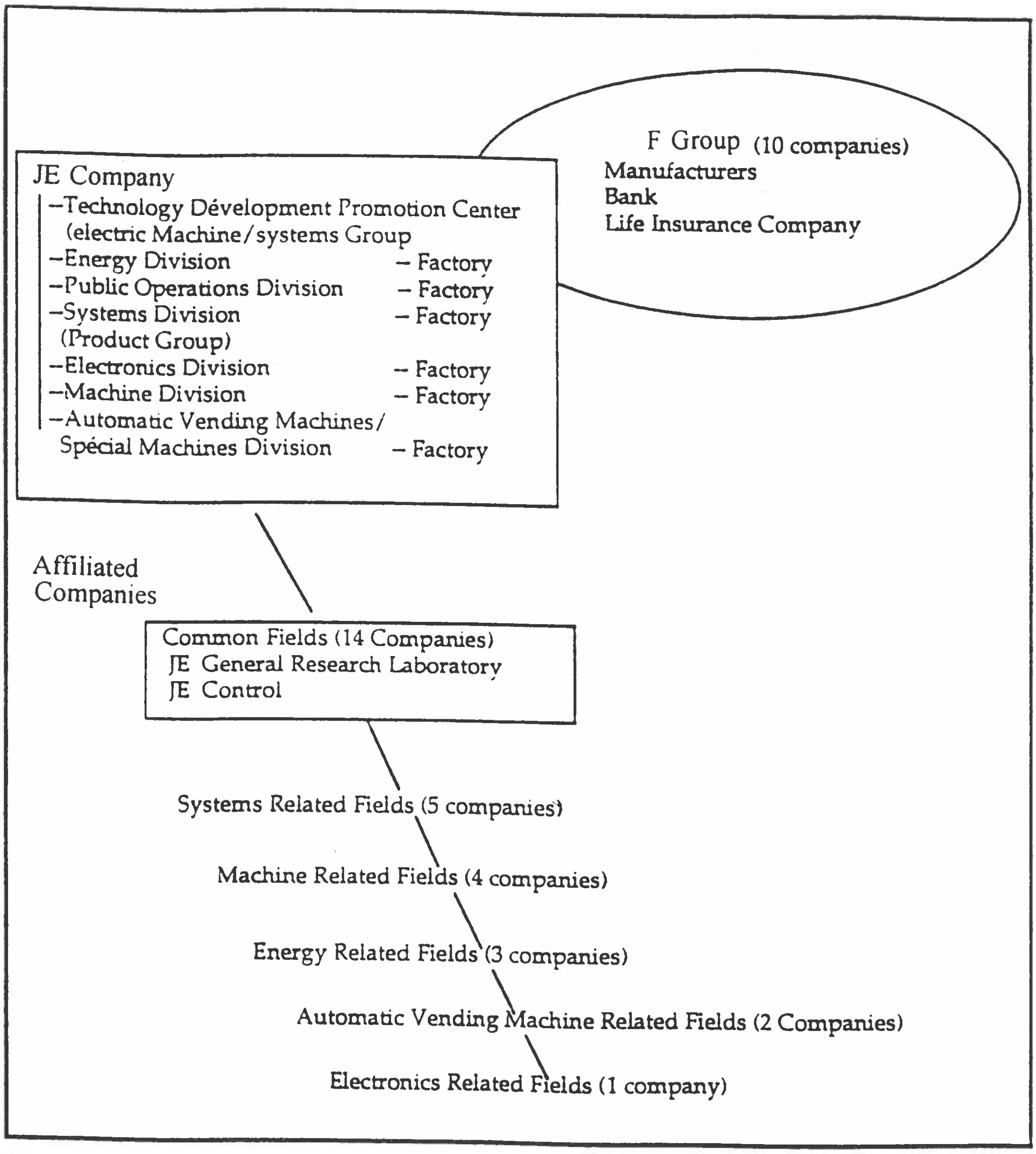
The corporation is comprised of seven divisions, which are organized into an electric machine and systems group dealing with the development and production of special orders for heavy electric machinery, and a products group which develops and manufacturers products for general marketing. This reorganization of operations into groups took place in a major restructuring of the overall organization which was realized in 1987. JE Company had been pressured to make this change because of changes in operations due to development in industries, markets and product ranges, and had been under particular pressure to strengthen it's system marketing capacity because of the move from custom made machines towards an electronics orientation. The reorganization of 1987 made it possible for each operating division to independently initiate new products from the planning stage and carry them through to production. Operating divisions were divided into one of two groups, the machine and systems group responsible for customized machines or the product group responsible for general market oriented products. The Energy, Public Operations, and Systems divisions together became the systems group, while the Electronics, Machines and Automatic vending and special machine divisions together formed the product group.

Below these two groups, nine domestic production sites are organized. The Kawasaki and Chiba factories are connected to the Energy Division, the Tokyo and Kobe factories are connected to the Public operations Division, the Tokyo and Kobe factories are also related to the Systems Division, Matsumoto Factory is connected to the Electronics Division, the Fukiage, Odawara, Mie and Suzuka factories are connected to the automatic vending and special machine division.

Apart from these divisions there are three important organizations related to R&D; the Technology Development Promotion Center, JE General Research Laboratory, and JE Control. The Technology Development Promotion Center is a co-ordinating organization which administers the allocation of funds and research themes across the whole corporation. The JE General Research Laboratory is a fully owned subsidiary company of JE Company responsible for basic research and product development. JE Control is a joint venture with the F Company (one of the leading manufacturers of computers in Japan) which concentrates on the development of large scale software primarily for application in heavy electric machinery.

Including JE Company General Research Laboratory and JE Control, JE Company group consists of 29 major affiliated companies. 14 of these companies are responsible for functions common to the whole group such as research and development, training and education, sales and distribution, while five companies are related to systems, another four to machines, three to energy related to major corporations including such diverse members as a manufacturer of computers, an electric cable manufacturer and a major bank. This corporate organization is illustrated in Figure 2-6, below.

Figure 2-6 Corporate Organization of JE Company



2-1-3. HUMAN RESOURCE DEVELOPMENT

a. Workforce composition by educational qualifications

Human Resource Development at JE Company can be basically explained as follows. In March of 1989 the total number of employees was 12,260, Including those employed in R&D oriented subsidiary companies, the number reaches 13,884.

Of the 12260 employees of Scientists and Engineers comprise 4,656 (38 %). However this number also includes high school graduates. Divided upon educational background one finds 1,950 university graduates, of which 7 are doctorates, 182 are master holders, 1,761 hold bachelor degrees. The remainder comprise of 224 graduates from technical high schools and 2,482 high school graduates.

Including the three R&D subsidiary companies there is a total of 13,884 employees in the group. Of these, 5,902 or 42.5 % of the total are research and development personnel. Seen in terms of composition based on educational qualifications, 23 are holders of doctorate degrees (0.4 % of the total number of research and development personnel), 385 are masters (6.5 %), 2,511 are bachelors (42.5 %), 294 are graduates from technical high school (5 %), and 2,689 are high school graduates (45.6 %). It can be seen that the ratio of research and development personnel (engineers) to skilled workers is high. The distribution of the 2,919 research and development personnel with bachelor level or higher educational qualifications (twenty one percent of the total workforce) are deployed across JE Company as shown in Table 2-7 as follows.

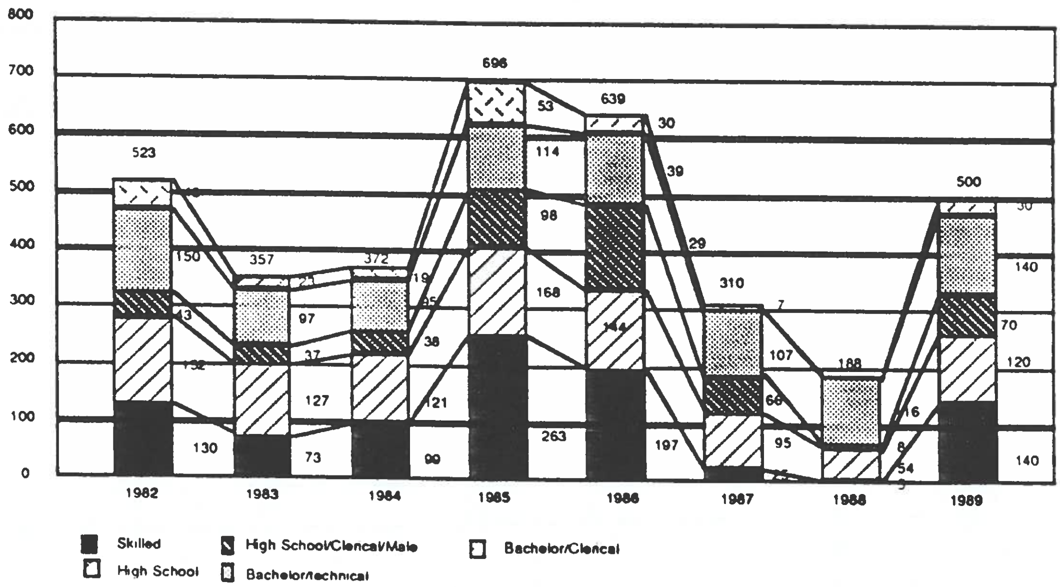
Table 2-7 Educational Composition of Workforce in JE Company and Related Corporations as to 1989

	JE Company	JE Control	JE General Research Laboratory	JE Nuclear Power	Total
Total Employees	12,260	765	740	119	13,884
Average Age	38	31	34	39	37
Average Length of Service	17	8	11	16	16
Technical Staff	4,656	623	518	105	5,902
Average Age	37	31	35	40	36
Average Length of Service	16	8	11	16	14
Final Educational Achievement					
Doctorate	7	0	16	0	23
Master's	182	56	134	13	385
Bachelor's	1,761	458	228	64	2,511
Total	1,950	514	378	77	2,919
Technical High School	224	54	9	7	294
High School	2,482	55	131	21	2,689

b. Recruitment

While JE Company annually employs new graduates on a regular basis, the numbers employed change considerably year to year. Analysis of recruitment statistics however reveal that within these yearly changes recruitment of blue collar workers tends to vary widely; in 1988 five new graduates were employed, while in 1989 this was increased to 140. By contrast the recruitment of university graduates in technical fields and female clerical high school graduates remains fairly stable. Over one hundred university graduates in technical fields are recruited each year, in 1989 140 were recruited. The reasons behind this are twofold, one reason is the corporate strategy for the developing and maintaining a strong R&D capability. The other derives from the practice of recruiting graduates upon the recommendation of certain university professors which has resulted in the labor market wherein it is necessary to take in a set number of new graduates each year. The practice whereby female clerical workers retire upon marriage also makes it a necessity to employ new recruits annually in order to make up the loss (see Figure 2-7).

Figure 2-7 Recruitment Pattern



2-1-4. PERSONNEL ADMINISTRATION SYSTEM

Conditions such as wages and placement for general employees are determined according to a Shikaku (see below) and a Tokyu (see below) system, while conditions for executive employees are fixed according to an executive employee system.

a. Shikaku system

General employees fall under a Shikaku and a Tokyu classification system. The Shikaku (grade) system ensures employees of regular promotion providing that they meet the basic requirements of experience and seniority, is the key factor in the calculation of the basic wage and provides the stability which supports the seniority system and lifetime employment practices. Experience is calculated under this system upon the basis of the individual's educational qualifications and total years of employment in other companies (see Figure 2-8).

Figure 2-8 Shikaku System

Shuji
↑
Shujiho
↑
Employee Grade 1
↑
Employee Grade 2
↑
Employee Grade 3
↑
Employee Grade 4
↑
Employee Grade 5

After assignment to a starting grade, new employees are subject to further promotion after a set number of years of service and after attaining a certain level of performance as determined by the evaluation reviews held annually every April. The starting grade for those recruited upon graduation is determined on the basis of educational qualifications, for those recruited mid-career the starting grade is determined for each individual according to their age and evaluation of their experience in previous work and activities (see Tables 2-8 and 2-9).

Table 2-8 Criterion of Starting Grade

Starting Grade	Educational Qualification
Employee Grade 1	
Employee Grade 2	Bachelor
Employee Grade 3	Technical High School
Employee Grade 4	High School
Employee Grade 5	Middle School

Table 2-9 Criterion of Promotion

Grade	Required Period of Time in Each Grade	Upper Limited Age
Shuji		
Shujiho	11 ~ 14	58
Employee Grade 1	7 ~ 10	55
Employee Grade 2	3 ~ 5	45
Employee Grade 3	3	35
Employee Grade 4	2	25
Employee Grade 5	3	18

Although differences in evaluated ability give rise to different speeds in promotion through the grades, this difference in promotion speeds between members of the same cohort is usually kept within a range of three or four years at the most. It follows therefore that employees are ensured of promotion providing they spend the required period of time in each grade, and given sufficient years of service any employee is therefore capable of reaching the trade of "Shuji", the highest grade for general employees. It is possible that the years of service required for promotion to the higher grades may be shortened.

b. Tokyu system

The Tokyu system (rank) is used as the basis for calculation of the work performance wage portion of an employees salary as well as being used as a standard for rotation, promotion and training. An individual employee's Tokyu rank is determined upon the basis of the quality of their work and their ability to perform their work. Because an individual's seniority, age and educational qualifications are not taken into consideration here, actual ability and achievement are stressed in this process.

The Tokyu system recognizes five groups (areas) of work ; Planning/Professional, Clerical/Technical, Skilled, Supervisory and Special Duties. Each of these groups are divided into an introductory, a middle and an advanced level which are in turn divided into either two or up to four ranks (see Figure 2-9) .

The work content and abilities required to perform the work for each group, level and rank is set according to a standard which is detailed and explained in the company's "manual of work standards".

An individual's Tokyu is determined by comparing their performance and ability in their present work with the standards of performance as set out in the manual of word standards. Of course the manual of work standards does not contain all the forms of activity which an individual in each occupation may perform. Only the major forms of activity are covered in the manual. In order to remain up to date with changes in work due to corresponding changes in product lines and technologies the manual is reviewed annually. Despite these precautions to keep the manual up to date, in parts it differs considerably form the actual situation. The section manager from the personnel department made the following comment :

"Because of the speed of technological change and reorganization of product lines the manual of work standards differs considerably from the actual situation in a lot of places."

Figure 2-9 Tokyo System

Planning/Professional				
Grade	4	3	2	1

Clerical/Technical											
Level	Advanced			Regular				Clerical			
Grade	11	10	9	8	7	6	5	4	3	2	1

Skilled											
Level	Special			Advanced			Middle		Introductory		
Grade	11	10	9	8	7	6	5	4	3	2	1

Supervisory								
Level	Advanced				Regular			
Grade	8	7	6	5	4	3	2	1

Special Duties				
Grade	4	3	2	1

Beyond this approximately 5 % of those entering the company as high school and middle graduates are promoted up form the level of skilled worker to that of clerical/technical worker. Those promoted have displayed high levels of ability on par with that of university graduates and have been transferred to production management, testing, sales or system development departments. There are also some who are promoted in this manner who go on to specialist level and a few who have reached executive level.

c. Personnel administration for executive level employees

Executive employees, divided into the four levels of Riji, Sanji, Sanyo and Fukusanyo, come under a different personnel administration system to regular employees. For promotion to executive levels candidates must be of Shuji rank and have reached the highest class in the Tokyu system. The most common promotion course is from 8th grade clerical/technical to 1st grade planning/specialist, and then from planning/specialist 4th grade to Fukusanyo. The position of Fukusanyo is roughly the equivalent of section manager (see Figure 2-10).

Although most employees who reach executive posts are university graduates there are also some middle and high school graduate skilled worker class employees in executive positions. In the manufacturing and testing divisions there are approximately twenty employees holding Fukusanyo rank. Apart from these there are also fifty skilled workers who have been promoted to the rank of Fukusanyo after receiving national "Modern Crafts Master" awards.

Figure 2-10 Personnel Administration System For Executive Employees

Riji
↑
Sanji
↑
Sanyo
↑
Fukusanyo

d. Salary

The salaries of regular employees consist of a base wage, basic allowance, ability wage, family allowance and various other allowances. The average salary is comprised of 44.2 % ability wage, 25.6 % basic allowance, 44.2 % ability wage, 5.5 % family allowance and 0.6 % various other allowance (see Table 2-10).

Table 2-10 Salaries of Regular Employees as to 1987

	Average	
Base Wage	52,187 Yen	(24.1%)
Basic Allowance	55,567	(25.6%)
Ability Wage	95,674	(44.2%)
Family Allowance	11,914	(5.5%)
Other Allowance	1,271	(0.6%)
Total	216,613	(100%)

The basic wage is calculated upon an individuals rank and seniority. The basic wage of all employees starts at the same starting wage level and increases thereafter with annual rises. The basic allowance consists of annual rises and adjustments made according to age or year of graduation in order to give conformity to the wage curve. Annual rises are calculated by evaluating each individual employees performance and ability development over the last year against the standards set for their respective grade and rank. With the exclusion of exceptional cases, however, differences between the rises received by individuals are kept within 90 % of the average. The basic allowance is used to regulate the level of the basic wage. Because the work ability wage is calculated according to the individuals rank within the Tokyu system it represents a merit principle in contrast to the basic wage.

Bonuses and retirement pay are also determined upon the basis of an individual's rank and Tokyu grade. The bonus is comprised of a rank calculated and a grade calculated portion. Retirement pay is calculated by multiplying basic wage by a coefficient based upon seniority.

While the salary of regular employees comprises of a basic wage calculated upon rank and grade, a work evaluation and other portions, the salaries of executive employees are comprised of a fixed monthly sum. This monthly sum is set according to the individuals "level", which is reviewed in April each year. Because of this executive employees do not receive annual salary rises as do regular employees.

2-1-5. RESTRUCTURING OF PERSONNEL SYSTEM

The personnel management system described above, having been in effect for fifteen years since it was first introduced, has come to display a number of running problems in the current situation. Because of this in 1990 the personnel system was made the subject of a thorough reorganization. The aim of this was threefold, to make the system more readily understandable, to give an opportunity for each individual to feel a challenge in their particular work, and to make it possible for ability and achievements to be clearly and fairly reflected in personnel management itself. The section manager from personnel explained the environmental changes in the following manner :

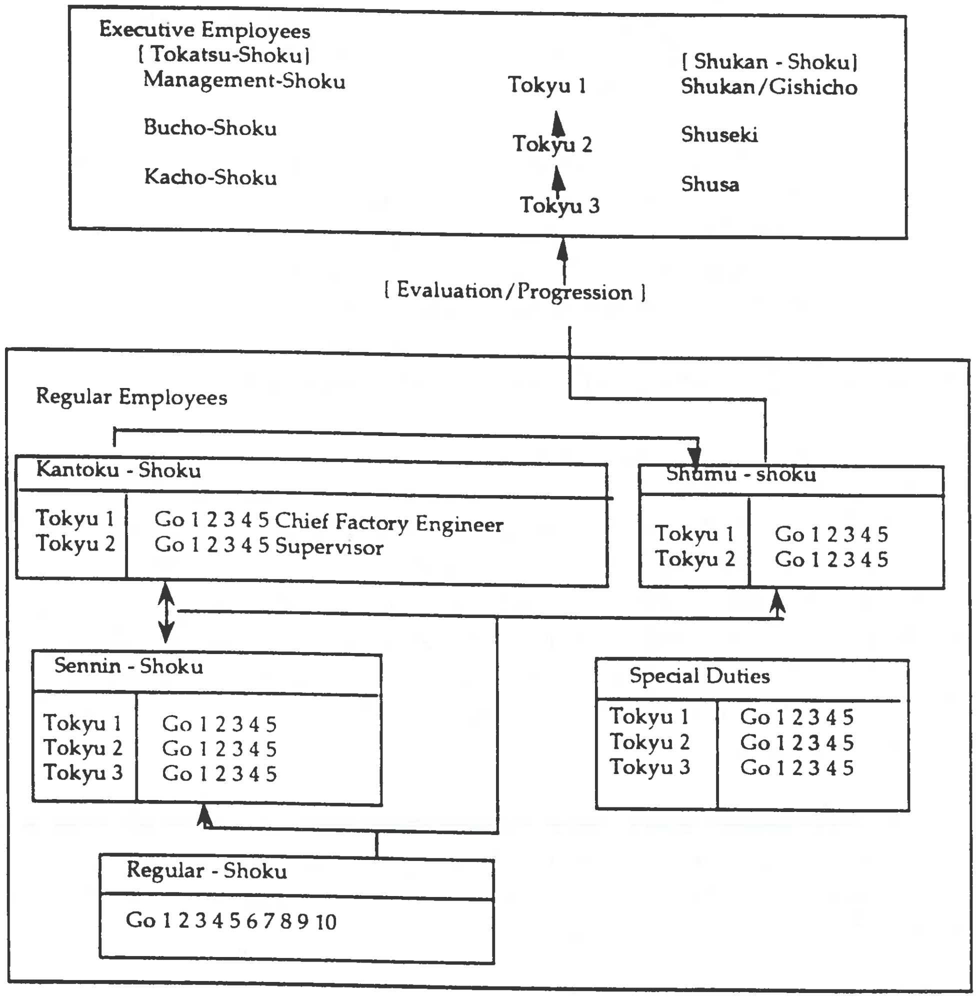
"After fifteen years using the old system the Tokyu had come to represent seniority more than ability. The old Tokyu system based on education and occupation was no longer able to give an adequate sense of challenge for new jobs and this was compounded by the increase in the numbers of mid-career recruits."

After the restructuring the personnel management system came to take on the following form :

a. Personnel management system

The new personnel management system is based on the three factors, Shoku, Tokyu and Go. Shoku refers to work content, Tokyu to the level of difficulty of a particular job, and Go to the accumulated level of ability. Shoku can be roughly divided into Tokatsu and Shukan level employees, Tokatsu include all responsible for a line organization over the size of a section (or Ka) whereas Shukan staff refer to advanced specialists. Compared with the past the number of line managerial posts are decreasing and there are developing frequent cases whereby employees are appointed to Shukan status while they await a post to open which will permit them to be changed over to Tokatsu. Regular employees are divided into regular employees who perform standard and typical tasks, Sennin who perform tasks requiring particular knowledge, technologies and skills, Kantoku who are responsible for workplace management, Shumu who perform tasks of an irregular or extraordinary nature and employees in the special duties category who work as drivers and security guards (see Figure 2-11).

Figure 2-11 New Personnel Management System



The biggest change to come from this restructuring is the fact that in place of the old Tokyu system which divided employees up on the basis of educational qualifications, it is possible for all employees (with the exclusion of those in the special duties category) under the present system to advance up to the highest levels of the system. Under the new system all newly recruited graduates are given the status of regular employees. Under the new system an individuals Go level is determined on the basis of years of schooling -high school graduates are allocated to Go level 4, technical high school graduates to level 6, university graduates to level 8, and master graduates to level 10.

Promotion for those on the level of regular employee is based on seniority, with the Go level advancing one level with each year of service. Under this system those recruited as university graduates are eligible to become candidates for promotion to Shumu grade after three years of service. Employees are eligible as candidates if they have received above average ratings on their personnel evaluations for the previous three years, and if they receive the recommendation of their division manager. On top of this a two stage selection process takes place on the level of the division and then on a company wide level. In the first level of selection held on the divisional level candidates are required to have achieved a level or performance on the management by objectives system and to pass an examination covering general knowledge language and specialist knowledge on their own particular area of work. On the second level of selection a committee judges candidate's performance from a group discussion and an essay on a set topic. Those who fail the selection process are promoted to the Sennin grade and permitted to apply for promotion again. The section manager from personnel had the following to say about the state of the administration of selection examinations :

" At present the success rate for university graduates is running somewhere between 70 to 80 percent. Because of the recent labor shortages we have been hiring more widely than we usually would and this test is proving to be a very effective 'second entrance examination'".

There are three conditions necessary for further promotion from Shumu to executive level. Candidates must be of the first level in the Shumu grade, they must have accumulated at least 12 points on their personnel evaluation on the year of their application, and they are required to have the recommendation of their division manager. The selection process is structured around an examination of managerial knowledge, an essay on a fixed topic and performance in the management by objectives system.

The personnel evaluation system which lies at the heart of this process takes the following form. All employees are evaluated annually and awarded a grade from A to D (C is graded as a satisfactory performance). The evaluation points generated form that evaluation are then added on to those of previous years thus becoming the accumulated evaluation score. For employees on the Shumu grade an A is scored at 5 points, a B at 3, C at 2 and a D at nothing. Before the restructuring of the personnel system seven grades were used in the evaluation process.

The management by objectives system operates on the following lines. All employees on the Shumu level, and all those applying for promotion to this level are subject to the system and are evaluated twice a year at six monthly intervals. The objectives are set through the interaction of all relevant employees with their immediate superior (on the managerial hierarchy these superiors must be of Kacho rank). Objective are set in a meeting between the employee and their superior and progress is then assessed after six months in another meeting between the two where the final evaluation result is determined.

b. Salary system

Under the new system the weight of seniority has been reduced and in its place achievements and ability have been emphasized. The standard wage consists of the basic wage, ability wage, special work allowance and living allowances. The basic wag e is based on seniority, the ability wage is based on evaluation of performance. The basic wage is the foundation for calculating retirement payments and pensions.

The amount of the ability wage is calculated according to the Shoku, Tokyu and Go, and it becomes the basis for calculating the bonus. It follows therefore that differences in the value of salary arise form differences in individual employees Go level - as it reflects an individual employees accumulated level of achievement. As a result of this restructuring of the wage system the basic wage has come to contribute fifteen percent of the total wage, ability wage has become seventy five percent and the various allowances add up to about ten percent of the total. As a result of increasing the weight of the ability wage, differences in bonuses have risen from the old ten percent to about twenty percent between higher and lower achievers (see Table 2-11).

Table 2-11 Ability Wage (Yen)

Shumu-Shoku

	Go 1	2	3	4	5
Tokyu 1	232.000	244.000	255.500	266.500	277.000
Tokyu 2	182.000	192.000	202.000	212.000	222.000

Kantoku-Shoku

	Go 1	2	3	4	5
Tokyu 1	221.400	228.900	236.400	243.900	251.400
Tokyu 2	187.400	194.900	202.400	209.900	217.400

Sennin-Shoku

	Go 1	2	3	4	5
Tokyu 1	200.400	207.400	214.400	220.900	226.900
Tokyu 2	170.400	177.400	183.900	189.900	195.400
Tokyu 3-1	152.900	157.100	161.500	165.600	169.400
Tokyu 3-2	142.400				

Regular-Shoku

	Go 1	2	3	4	5	6	7	8	9	10
①						111.500	118.500	126.400	129.400	134.700
②	90.800	98.100	99.900	102.400	105.500	109.500	115.500	123.400	126.400	131.700
③						107.500	112.500	120.400	123.400	128.700

2-2. R&D SYSTEM AND THE MANAGEMENT OF R&D PERSONNEL

The R&D system of JE Company is supported by the technology development promotion center, JE General Research Laboratory, the Main Development division and JE Control.

2-2-1. TECHNOLOGY DEVELOPMENT PROMOTION CENTER

The Technology Development Promotion Center is located within Company Head Quarters as a separate division responsible for R&D for the entire company. The Technology development Promotion Center responsibility is for setting R&D themes, allocating funds and human resources to R&D related sections such as the production divisions, JE General Research Laboratory and JE Control. The JE General Research Laboratory and the combined development departments of the operating divisions each receive a half of the group's total R&D budget.

2-2-2. JE GENERAL RESEARCH LABORATORY AND THE MANAGEMENT OF R&D PERSONNEL

a. Organization

The JE General Research Laboratory was established in 1980 after the Central Research Center was upgraded from an R&D division and established independently. The reason for establishing JE Central Laboratory as a separate Company lay in the need to stabilize R&D funds, establish a special personnel system for the R&D personnel, and provide a new level of organization fluidity and energy to the R&D organization.

The R&D organization consists of five Laboratories concerned with basic research and three development divisions responsible for development research. The five laboratories are the Basic Research Laboratory, Electronic Device Research Laboratory, IC Laboratory, Applied Equipment Laboratory and Production Technology Laboratory. The three development organizations are the Electric Power Development Division, Electronic Equipment Development Division and the Combustion Battery Development Division.

Apart from these laboratories and development divisions there are also four departments located near the development departments of the production divisions. These departments act as outlets of the JE Central Laboratory by promoting technology transfer form the JE Central Laboratory to the division's development departments. These departments are used to move technical staff from the laboratory to the divisions in order to afford the smooth transfer of new technology for product development in those cases where the technical staff in the divisions have no experience with the new technologies involved. In this way these departments act as a midway point connecting basic and applied technology with production development.

b. Reorganization

In the electronics industry, where the speed of technological development is particularly rapid, it is frequently necessary to reform organizations in order to adapt to technological progress and change. In 1991 the JE Central Research Center underwent just such a major reorganization. A comparison of the organization before the change, as has been discussed in the above is compared to the post reform organization in the following Figure 2-12.

Figure 2-12 Reorganization of the General Research Laboratory

Pre - Reform	Post - Reform
--Administration Department	--Research Survey Office
--Survey Office	--Research Administration Department
--Basic Research Laboratory	--Advanced Materials Research Laboratory
--Electronic Device Research Laboratory	--Ceramic Technology Research Laboratory
--Integrated Circuit Research Laboratory	--Basic Materials and Analysis Research Laboratory
--Applied Equipment Research Laboratory	--Advanced Device Research Laboratory
--Production Technology Research Laboratory	--Applied Equipment Research Laboratory
--Power Engineering Development Division	--Water Treatment and Biological Research Laboratory
--Electronic Equipment Development Division	--Environmental Technology Office
-Combustion Battery Development Division	--ADM Project Office
------------Tokyo Works	--Information Systems Research Laboratory
------------Kawasaki Works	--Power Engineering Development Division
------------Chiba Works	--Electronic Equipment Development Division
-----------Matsumoto Works	------------Tokyo Works
	------------Kawasaki Works
	------------Chiba Works
	------------Matsumoto Works

This reorganization was made as a part of the new long term vision of JE Company in an attempt of facilitate the new policy of promoting electronics technologies and products. The aim is to concentrate and strengthen the activities of the central research laboratory around basic research and facilitate the movement out to the operating divisions and factories of new technologies which display a potential for commercialization as a product. In concrete terms the reorganization represents the expansion of the old central research laboratory by the addition of the advanced materials research center, basic materials analysis research center and the ceramic technology research center. Because the most advanced technologies within the electronics industry are within the materials field, three research centers devoted to materials research have been added to the old central research laboratories organization in an effort to further promote materials research.

The old Electronic Device Research Center and IC Research Center have been reorganized to form the Advanced Device Research Center. The Advanced Device Research Center is located in two cites - on in Yokosuka near the Central Research Center, and the other within the factory at Matsumoto. The site at Yokosuka is continuing the work of the Electronic Device Research Center, performing next generation technology development into solar batteries, liquid crystal displays and semiconductor production equipment. The cite at Matsumoto has taken over the work of the IC Research Center and specializes in the development of technologies such as silicon semiconductors and thyristor and MOS gate bipolar transistors which are already commercialized. Most of the work that the old IC Research Center had performed before the reorganization has been transferred over to the factory.

As a further result of the pressures of changing technology the applied equipment research center has been divided up into the applied device research center and the water treatment and biological research center, the combustion battery development department has been transferred to the Chiba factory and the Information Systems Research Center has been established to develop software for application throughout the company.

c. R&D budget

The present R&D budget consists of independent research funds (25 %) derived from selling the R&D results of JE General Research Laboratory to JE Company, funds from research commissioned by Head Quarters (50 %) collected from each division by the R&D promotion center, and production division commissioned research funds (25 %) derived from funds given directly to the R&D Laboratory by the production divisions. Most of the independent research funds are used in the Laboratory's basic research projects, while funds derived through research commissions are used in development. A review of R&D activity reveals that although the relative weight of basic research was high in the past recent years have seen increasing weigh being placed upon applied technology and development.

d. Human resources and personnel management

Including the members of the clerical administrative department the JE General Research Laboratory's workforce comprises 740 persons, of which 518 are scientists and engineers directly concerned with R&D. The average age of the R&D personnel is 35 years of age and is kept as this relatively young age in order to avoid the problems related with ageing.

In terms of educational qualifications there are 16 doctorate holders, 134 master holders, 228 bachelors and 140 graduates from technical and high schools. The high school graduates are responsible for making test models, general testing and research assistant work. The major fields of university graduates are electronic 47 %, nuclear energy and mechanics 20 %, chemistry 15 % and physics 7 %.

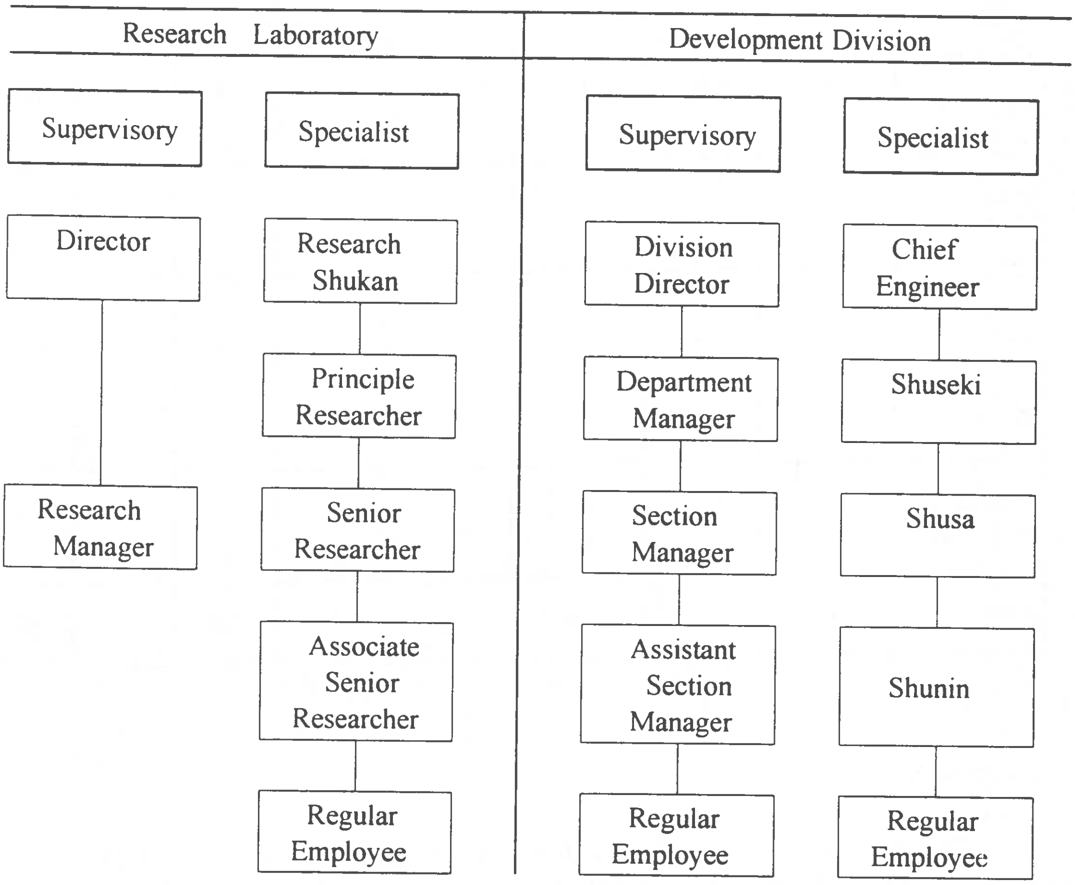
Examination of the workforce composition by department shows that after the reorganization the Advanced Device Research Center and the Electronic Equipment Development Division have come to take on a large number of research and development personnel. Because both departments are charged with carrying out the move to electronics as laid out in the new long term business strategy, and both departments are directly connected with product development there are a large number of research and development personnel holding either master degrees, bachelor or high school certificate level qualifications (see Table 2-12).

Table 2-12 Educational Qualification of Technical Personnel by Department as of 1991

	Doctorate	Master's	Bachelor's	Technical High School/ 2 Year College	High School/ Middle School	Total
Administration Dept		2	9	2	36	49
Equipment Development Dept			2	2	36	40
Advanced Materials Lab	1	12	15		14	42
Ceramic Technology Lab		12	9	1	18	40
Basic Materials Lab		5	8		25	38
Advanced Device Lab	11	35	37	1	43	127
Applied Equipment Lab	2	9	9		12	32
Water Treatment and Biological Lab		7	6	2	4	19
Environmental Technology Office		1	1			2
ADM Project Office		2	4		2	8
Information Systems Lab		13	31	1	1	46
Power Engineering Development Div		17	39	2	23	81
Electronic Equipment Development Div	1	37	87	6	35	166
Total	**15**	**152**	**257**	**17**	**249**	**690**

The personnel system of the General Research Laboratory is different from both that of the Central Research Laboratory and the Development Divisions. In the Central Research Laboratory in order to secure the greatest possible degree of freedom for research a flat organization has been emphasized in which the number of line managerial posts has been reduced to the minimum number, and at the same time a career ladder for specialists -outside that for managerial post - has been established in order to offer a multi-career course personnel system. In contrast to this, the development center which is directly concerned with the development of products has adopted the same system of posts and positions as has JE Company. The wage system for the general research laboratory and the development division are practically the same as that of JE Company (see Figure 2-13).

Figure 2-13 Post Structure of the General Research Center



Basically this system is intended to operate not on the basis of final levels of educational qualifications but upon a merit oriented system based upon achievement since entering the company. Analyzed in terms of actual educational qualifications there are cases where high school graduates have achieved the rank of divisional manager or the equivalent which suggests that opportunities for promotion are fairly available. A system has been introduced whereby excellent personnel among those recruited as high school graduates may be developed as engineers instead of as skilled workers. This system is showing considerable results as shown in Table 2-13.

Table 2-13 Educational Composition of Workforce by Position as of September 1991

	Doctorate	Master's	Bachelor's	Technical High School	Junior College	High School	Middle School	Total
Directors		1	9					10
Operation Manager Laboratory Director Research Shukan		1	6			1		8
Department Manager Shuseki Shuseki Researcher		5	17			4		26
Section Manager Shusa Research Manager	10	26	38	2		19		95
Shunin Researcher								
Deputy Section Manager Assistant Shunin Researcher Shunin	2	28	32	2		25	6	95
Regular Employee	3	91	155	4	9	156	38	456
Total	**15**	**152**	**257**	**8**	**9**	**205**	**44**	**690**

e. Recruitment

The recruitment of university graduates is managed by JE Company. However, directors from the general Research Laboratories attend interviews of candidates. In the past new recruits were selected from only a few universities, but recently a serious undersupply of technical graduates has led to recruitment from many universities. Furthermore, while recruits previously came mostly from schools of physics and chemistry, the emphasis has switched recently to hiring electronics related personnel.

In JE Company as well as in most other major Japanese corporations there are certain specific practices involved in the recruitment of university graduates. Rather than a formal and open process of advertisement and application, this process includes informal routes by which recruits are obtained from several professors in a number of famous universities. Company recruiters visit the professors each year and request introductions to the more promising graduates, in some cases professors in turn request research funding. As a result professors of the major universities usually introduce the graduating students of their classes to a number of companies each year. The section manager of the general affairs section of General Research Laboratory explained this practice in the following manner :

"We hire several graduates from the classes of certain professors in major universities annually. As a result of good relationship with these professors is essential in order to recruit the best personnel. Because of this it is not possible to turn around one year and say that because the economy is not all that good we won't hire anybody - that's just not possible. Because of this relationship we are able to secure a steady supply of good university graduate engineers each year."

It can be said that these recruitment practices whereby companies regularly recruit graduates from a number of universities each year has an equalizing effect of the ability pools of corporations and may explain why often several Japanese companies embark on a new for of technological innovation at almost the same time. These informal connections remain after recruitment and give the personnel employed themselves a network of contacts in a variety of corporations which helps in promoting communication and in gathering technical information.

These practices are, however, changing with the introduction of the mass recruitment of graduates needed graduates needed to meet growing personnel needs created by the recent corporate emphasis on research and development. Mass recruitment of graduates of course aggravates the shortage of technical personnel and subsequent increases in the numbers of students entering companies without their supervising professors introduction erode these practices. A typical example of this is the increasing number of technical graduates finding employment in highly paid jobs in the financial sector. The movement away from the manufacturing sector of course adds to the shortages of technical personnel. It makes impossible to secure an adequate supply of new recruits relying only on the informal channels represented by the introductions and recommendations of university professors and thereby further altering existing recruitment practices. The numbers of corporations widening the range of universities from which they recruit are presently increasing. Of late JE Company has also increased the number of universities from which it recruits. In April of 1991 the General research Laboratory had hired thirty eight new graduates, one fourth of which were masters graduates.

2-2-3. MANAGEMENT AND EDUCATION OF RESEARCH AND DEVELOPMENT PERSONNEL

a. Rotation for technology transfer

After recruitment by Head Quarters and consideration of individual preferences a certain number of new engineers are allocated to the General Research Laboratory. Newly allocated recruits undergo a two year introductory training period. The content of this introductory training is the same for all university graduates (including doctorates) and involves an initial period of practical factory experience and two weeks of computer training. After this follows a period of On the Job Training under the direction of deputy chief research level personnel. Because work content is often different from professional education at university, new engineers are frequently sent out to training sessions and conferences.

The reason why an individual's research theme within the company can differ from the theme of university is because there is often a gap between the level of technology and research within the company compared with the educational content and themes of research within universities. The director of the Advanced Device Research Laboratory explained this trend in the following manner :

"Lately at lot of the people newly recruited are quite happy to leave the themes they worked on in university and change to newer themes in recently developed areas such as combustion batteries and amorphous materials. It really looks like a lot of students get their research themes decided for them unilaterally by their professors."

After about six months to one year of placement new recruits are given a further months practical work at related factories, sales offices etc... . At the end of this two year period participants are required to prepare a report on their work and present it at the Laboratory in the presence of their peers and superiors. The content of the report is then reviewed by a review board whose members are of section manager rank. Their reports are then evaluated and after interviews, final placements are decided. Those who are judged not suitables for research work are then transferred to the development divisions. JE Company's personnel department performs the evaluation and interviews through which final deployment is determined.

The training and development of new recruits is supported by all members of the workplace and co-ordinated by the researcher designated as responsible for on the job training. The extent of this support can be seen in the factor that most workplaces hold rehearsals where new recruits can practice before having to give their presentations. Poor performance on the part of a new recruit is taken not only as a sign of possible ability problems but also of a sign of problems in the supervision and education process in the workplace to which they were assigned.

At the conclusion of training new personnel commence full scale research activity, but they are not necessarily located in the General Research Laboratory for the rest of their careers. In order to keep up with technological change it is imperative that the laboratory be staffed with young personnel. On the other hand moving experienced research personnel along with newly developed technologies through the development stage and on to production is an effective method for efficient technology transfer. For these reasons it is common for researchers over forty years of age to be moved out to development departments within the operating divisions or affiliated companies.

These rotations are not however performed on a regular basis, but they occur when there is a need to transfer a newly developed product or technology down stream. As such these moves do not mean a transfer to a totally new area, most of those moved go instead to departments working in fields where their experiences are relevant. Since most of the researchers are transferred to the development departments of the operating divisions, organizations with which they have frequent contact with in the course of their normal activity, these transfers are relatively smoothly achieved.

These forms of transfer are common in development divisions which deal directly with themes related to product development. After about ten years of serviced in the General Research Laboratory almost half of the researchers experience such transfers. This is because as large projects are completed and transferred out to the relevant division, the personnel who worked on the project are moved out along with the project. As a part of the reorganization, the combustion battery development department was transferred out to the operating division and this involved the transfer of most of the personnel.

In the laboratories where more long term projects are undertaken there is less movement of personnel than in the development departments and a considerable number of people over the age of forty are present. There is also less movement between research laboratories and between laboratories and development departments. Movement of personnel between research groups within the laboratory is, however, frequent. Movement of personnel between groups is determined by the laboratory director and the research managers. The personnel department plays a role only in the case of transfers outside laboratories. Looking at the level of transfer's of university graduate research personnel in and out of the General Research Laboratory for 1988 shows four people entering from outside and eleven people being transferred from the laboratory to positions outside.

b. Human resource development

The human resource development of researchers and engineers is achieved by a variety of education and training methods. Of these the principal methods are individual development planning (composition of a three year job plan and follow up schedule), work goal system (setting work goals every six months and working toward them through On the Job Training), Self Development Goal Systems (development of a two year self development plan), holding lectures and courses about special technologies within the laboratory, domestic and overseas study and rotation systems based on individual consultation.

Individual ability development is based upon the construction of a three year work and education plan for each individual. This takes the form of a number of short term work objectives and a system of long term goals for self development. Engineers meet every six months with their group manager under the work objectives system in order to set competitive objectives, the stages, methods and schedule by which they may be achieved. These discussions are followed up after the six month period expires, the group manager and individual meet again and discuss a degree of achievements. A work objectives form is completed covering the objectives, stages, methods and schedule, and the group manager adds to this their evaluation, opinion and the individual researcher adds their self evaluation. The self development system involves the setting of objectives for self development (including plans for off the job training) in a meeting with the group manager every two years.

Special courses are conducted within the research laboratories and at JE Company's Training Center. The courses held within the laboratories center upon advanced technological topics and involved inviting lecturers from outside the company. There were twelve such courses held in 1988 covering such topics as new materials, artificial intelligence, semiconductors and advanced fabrication techniques. Serving all the needs of JE Company the courses held at the Training Center also concentrated upon specialist technological topics. These courses mainly concerned electronics and while some lecturers were invited from outside the company, most of the lecturers were research and development personnel from JE Company. Many Japanese corporations use their own personnel as lecturers in such courses - this has the merit of enabling courses to concentrate upon technological issues particular to the specific situation of the company. Rather than relying on lecturers from outside the company, this permits the relatively smooth adaptation of new technologies to the whole company.

Study programs whereby personnel may study at both domestic and overseas universities and institutions are also maintained. For domestic universities these study periods usually last from one to two years, in 1988 eleven people undertook such study programs. Overseas study usually lasts two years and in 1989 there were two participants, one in the United States and another in West Germany. Candidates for these programs must be around thirty years of age and have recommendations on their section manager. Apart from this researchers are also encouraged to participate in conferences and to use them as opportunities for obtaining new information.

Apart from the mechanisms mentioned above there is also a system of job rotation by consultation whereby researchers meet with their manager every six months and discuss their ability development and any wishes they may have for movement to another department. This is considered to be a very effective method for widening and enriching an individual's technological scope.

c. Actualisation of R&D

In order to facilitate efficient R&D and in order to motivate the R&D personnel the Group System and the Research Proposal System are used. The Group System involves rearchers being organized into flexible groups instead of fixed sections and departments. With the current trends in technological change which go towards the integration of technologies it is difficult to organise the R&D personnel according to different technological fields. In order to avoid these management problems, researchers are organized into flexible teams.

The Research Proposal System is a system wherein researchers themselves can suggest themes for research other than those decided by management. This system was initiated in 1983. The possible scope of suggestions are :

1. Technologies needed for the future.

2. New technologies which differ from those already within the company.

3. Combinations of existing technologies which result in new applications.

Suggestions usually come from specialist graduated from university with about three years of experience. Suggestions may come from either individuals or groups and must pass a review at the survey office followed by another check by the director and related specialists. In 1988, 135 suggestions were received in this system and of these 3 were investigated as possibilities for innovation with only one being finally taken up as an R&D theme. In 1989, eight such suggestions were chosen.

d. R&D management system

As an example of the actual operation of R&D let us take the example of the Advanced Device Research Center. The Advanced Device Research Center is composed of twelve groups. Each group is manned by from ten to twenty personnel and is administered by a research manager.

Excluding a few rare exceptions most of the actual R&D work takes the form of project teams. Projects can be divided into those in which personnel form other research centers are involved and those which are composed of personnel from several group within the research center. Typical of the former type of project are national projects which are managed by the national government and participated in by private corporations, along with this are special projects which are aimed at some strategic research and development project effecting the whole company. Past national projects of note include the solar battery project and the micro-machine projects, these projects have been of considerable benefit in promoting the ability development of the researcher who participated in them. The deputy director of the center had the following to say about say his experience in participating in a national project :

"I participated in the Sunshine Plan for the development of the solar battery. The stimulation gained from contact with researchers from other companies, universities and research institutes was enormous. My ability form theoretical questions which would normally not arise in the course of other work. Along with this my presentation and information gathering ability also were developed with the need to present my research findings and I think that on the whole my grasp of research itself advanced. Participation in the national project was the greatest chance I ever had for ability development."

Groups from a number of other research centers participate in special projects. The function of project leader is filled by either the director or deputy director, beneath which several groups participate. Projects are structured upon three layers that of project leader, research manager and group researcher. Group researchers are taken from those researchers who have the strongest connection with the technologies involved in the project, but not all of the researchers become specially assigned group researchers. Rather than participate fully in the actual reseach itself the research managers participate in overall project planning and watch over the progerss of the researchers involved. In other words the research managers is responsible for the personnel evaluation of the participating researchers. Upon attainment of it's goals the projects are disbanded and the researchers return to their previously assigned research groups. Technorogies in such special projects transfer many related research groups.

Although the personnel department is involved in selecting researchers for inclusion in inter-center research projects, the selection of personnel for projects within the center is the prerogative of the research director and the respective research managers involved. Most of the project themes which research group researchers are involved in are of a co-operative nature and take place in the form of research projects. Although there are some cases whereby a theme may be subdivided and dealt with by a single researcher there are virtually no cases of a single researcher taking charge of an entire theme alone. A core researcher in his early thirties commented that "the project themes at the present are proposed as group research topics and manned by two researchers".

In the course of a project there frequently arises the need of assistance from other groups in order to meet deadlines. Because most of the research themes at the JE General Research Center are commissioned by the operating divisions deadlines become a important factor. Apart from this commissioned research seeds research is also conducted on themes of potential future growth suggested by research managers and senior researchers or upon the suggestions of younger researchers.

It can be seen from this that the JE General Research Center is managed in an extremely flexible manner, but how are the actual researchers involved in the management of the center? A thirty one year old researcher in the Advanced Device Research Center responsible for the research and development of semi-conductor production equipment had the following to say about the management of the General Research Center.

"I graduated from a national university with a masters degree but the research theme which I was given in the JE General Research Center was completely different to what I had studied. At university I studied the memory mechanism of neural networks but upon entering the company I was put to work on R&D for plasma semiconductor production equipment - a field which the company saw as one of strategic future growth."

There are numerous cases such as this in which there is no relation between the material studied in university and the research themes allotted after entering the company.

"The semiconductor production equipment field was at first an entirely new field in the company. A researcher one each in their forties, thirties and twenties formed a three man team and began research which was at first almost just feeling our way around. At that time theoretical research was wide spread and we were able to study this new field through conference presentations and papers. We found a manufacturer of semiconductor production equipment at an exhibition and obtained information and parts in order to build a test model. The test model was completed but failed to meet the customers requirements. Four years after that, following a long period of information exchange with the customer we were finally able to set up for mass production. Mass production was moved out to the Kawasaki Operating Division and control related activities were moved to the Tokyo Operating Division and preparations began for the full scale production of semiconductor equipment. The project which had started with three people increased to twenty members at it's height. Moreover the project, members and all, were transferred from the Applied Device Research Center to the Advanced Device Research Center with the nearing of commercialization."

In this project a young researcher was made to work on a field which he had not experienced at university. His ability development in this new area was promoted by close contact with the client during a series of deadlines and follow up improvement cycles and finally by the attachment with the theme which developed over the course of the project. The young researcher had the following to say about this period :

"At first we began by just groping around in the dark but we were able to achieve the technological levels needed by obtaining information from the semi conductor equipment parts makers. Furthermore we had great trouble for clearing the demands of the customers. In the meautime we were not able to perform the research systematically but after transfer of the project and assignment to advancement of the equipment I gained confidence. I was very concerned that the project should succeed and even now when problems arise in the factory or anywhere in the operating division I make a point of going down there and looking things over. I would even be willing to move out to the sales division in order to promote the sales of my product."

As explained above, the R&D system of the JE General Research Center is based on a flexible project system wherein researchers are in charge of themes from basic research through to development, have close contact with clients throughout the process which results in the ability development and a high level of morale of the researchers involved. This mechanism is accredited with permitting the smooth transfer of technology. Most of the researchers express a strong preference for specialist posts over manegerial functions-even the deputy director of the Advanced Device Research Center mentioned that "I wanted to be a specialist when I was in my thirties. I did not choose to become a manager and was very upset at having to leave my work in materials research". The young researcher who developed the semiconductor equipment also expressed the wish to become a "wide ranging specialist in the research field".

2-2-4. TECHNOLOGY TRANSFER SYSTEM

a. The nature of the technology transfer system

Belonging to the Advanced Device Research Center and located within the grounds of the Matsumoto Factory, the Matsumoto Operating Division is responsible for the development of custom IC's and power devices including thyristors. The staff numbers 80 engineers - of which 10 are assistants. 3 of the engineers are in their 50's, 10 in their 40's, 30 in their 30's and the remaining 37 are aged in their 20's.

Most of those aged 30 or more years of age hold a bachelor degree, while the younger engineers are a mixture of master degree holders and technical high school graduates. There has been increasing deployment of master degree holders in recent years. Of the eight engineers newly deployed this year only one is not a masters degree holder. There are approximately 20 high school graduates presently deployed and engaged in such activities as circuit design.

The Matsumoto Operating Division is responsible for the development of custom IC's and power devices such as the thyristor, MBT technologies which have already been commercialized. In such fiercely competitive technological areas the need for rapid technology transfer from R&D to production has led to the establishment of the research center within the factory cite. Because JE Company's IC production facilities are concentrated within the Matsumoto Plant, the IC Research Center was moved there in 1985 and in the latest reorganization a test production line and it's staff have been relocated into the Matsumoto Factory.

Because of it's close connections with the Matsumoto Operating Division, approximately 60 % of the research centers activity is concerned with projects which have been commissioned by the Operating Division. The remaining 40 % centers around projects for the development of new technologies for the future. There is, however, no rigid distinction between commissioned research and research aimed at the development of new technologies for the future as ultimate the aim of all projects is commercialization and therefore involves it's eventual transfer to the factory. The roles of the engineering personnel is also therefore not rigidly defined between the two forms of research but is also flexible, with most engineers finding their centers of activity shift from the development of technologies to product development.

In order to further expedite commercialization, lateral communication with other departments is encouraged. In the case of integrated circuit production a regular monthly meeting is held which brings together staff from the research center, operating division, marketing and production. The aim of this meeting is to promote swift commercialization of technologies and encourage research into developing fields through information exchange across departments. While there are rarely any problems between research and marketing, differences of opinion are not unknown between research and production about the viability and production cost of new technologies.

Technology transfer to the factory takes place after the research center has produced a test model of potential new products (at it's own expense) and the factory has assessed the product's viability. In cases of complex technologies, such as the GTO Thyristor, where many problems are associated with mass production repeated consultations are held between the center and the factory. In the case of semi-conductor production, because the same production equipment differs between manufacturers, the equipment in the center and factory often require different adjustment. Because of this, close co-operation between center and factory personnel is needed in the early stages of the mass production of difficult, new products where it is necessary to fine tune parts and at times all of the processes involved.

b. Work distribution

At the Advanced Device Research center located at Matsumoto there are two forms of research - research organized into projects and research performed by individuals. A typical example of project research is the development of new technologies for semi-conductors. Although there are differences depending upon the nature of the project, project leaders are chosen from the ranks of either research managers (line managers of "Kacho" rank usually aged between the late 30's to early 40's) or senior researchers (technical specialists). Research managers are usually made leaders in the case of projects close to commercialization where co-ordinated activity in concert with the factory is essential. Senior researchers are usually made leaders of projects still distanced from commercialization.

Research performed by an individual usually takes the form of circuit design. Several engineers are usually involved in the initial overall planning stages of circuit design, but once planning is completed the separate parts are performed individually. Circuit design is usually performed by highs school graduate level personnel. At the moment a major project occupying high school graduate engineers is the design of IC's for the control of automatic focuses for cameras.

c. Personnel development and rotation

Personnel development procedures are the same for both master and bachelor degree holders. After placement OJT, course work, language training and work targets are used as the main forms of personnel development. Course work involved basic education in technical fields. Work targets are set in discussions with research leaders. Progress and achievement are assessed at the end of every six month period in further "man to man" discussions.

After three years of service and training, individual aptitude is assessed upon the basic of submissions. Those deemed suited to work in the research center remain, while those deemed unsuited are rotated out to other centers, operating divisions or factories. Those remaining either attain line manager rank as research managers by their early 30's or go on instead to become senior researchers - in any case this choice is usually finalized by one's late 30's. Upon reaching their late 40's research personnel are submitted to a strict evaluation, the result of which many are transferred to survey or planning departments of to the factory.

The best of the high school graduates recruited at the factory are trained as development engineers. But, because of the number of cases of individuals showing limits in their technical ability by their early 30's, most of them are transferred over to the factory. Although, given the necessary experience, these engineers are capable of circuit design they do not seem to be suited to more advanced R&D work. Before being relocated to the Matsumoto Operating Division there were several high school graduates aged in their late 30's working as engineers and even a high school graduate Kacho, but with the reorganization these personnel were transferred to the Factory.

2-3. PERSONNEL MANAGEMENT IN THE PRODUCT DEVELOPMENT DIVISIONS

JE Company's product development is carried out by the design departments located within the factories within the operating divisions. This survey looks at two such factories. One is the design decision of the Fukiage Factory which is responsible for the development of mass produced products, and the other is design department within the Kobe factory primarily responsible for the development of customized products.

2-3-1. HUMAN RESOURCE MANAGEMENT WITHIN THE MASS PRODUCTION DEVELOPMENT DIVISION

a. The characteristics of the products

Although Fukiage Factory is an older factory established in 1943 its product range has undergone rapid change. The current production composition is 55 % starters, switches and brakes, electronic equipment such as programmable controllers and mechatronic devices such as factory automation systems comprise 45 %. Recently the ratio of new products has been increasing. While there a few customized products the majority of equipment produced is mass produced and standardized equipment. A characteristic of Fukiage Factory is its wide product range. Newly introduced products tend, however, not to be entirely new but rather based upon innovations of earlier models.

The subject of this survey is the Fifth Design Section which is responsible for design for mass production products within the existing product field. Because profits have failed to rise in the mass produced products department it is presently experiencing efforts to increase efficiency while reducing it's workforce. The monthly production volume of heavy electrical devices differs. Within this the monthly production volume of low voltage products is around several tens of thousands of units, this vastly exceeds that of high and medium voltage products which are produced at a rate of several hundred to several thousand per month. The fifth design section mainly handles high voltage breakers. Low voltage breakers are the responsibility of another smaller factory located nearby.

Because the heavy electrical equipment treated here is essentially of a mature technological nature there is no real change in it's basic capability despite it's being the subject of technological innovation. Although there is little expectation of increasing market share, reductions in cost, miniaturization and employment of electronic technology are important factors in market competition. Leaving aside basic technological specifications, electronification and miniaturization become important technical issues in realizing a distinction between one's own and other companies products. Moreover, because of the profusion of electronics equipment the market share of small and medium sized manufacturers is increasing along with the demand for low voltage products making diversification into the field of low voltage equipment an important issue for the future.

b. Workforce composition

The number of employees in Fukiage Factory reached 1,548 as of may of 1989 and is expected to stay at that level for the near future. While overall numbers are stable, the composition of the workforce is moving away from a majority of skilled workers to a majority of design workers. The reasons for this lay on the one hand in the ongoing automation of production equipment and on the other hand in the need to develop numerous new products in ever shortening periods of time due to the shortening of product life cycles.

Educational composition of the workforce reveals that only 13 % are university graduates, 57 % junior college and high school graduates, and 30 % middle school graduates. The average age of employees is 37 years of age and women workers comprises 13 % of the total workforce.

Placement in April of 1989 shows fifty people allocated to clerical/technical and only ten to skilled worker positions. Of the clerical/technical ten are university graduates and twenty one are male graduates of high schools. High school graduates are at the center of new recruitment and allocations and most of then are assigned along with university graduates to the design departments.

Overall the factory is organized into seven departments. The Fifth Design Section, the subject of this survey, is located in equipment design department (see Figure 2-14).

Figure 2-14 The Organization of Fukiage Factory

Factory Manager
- Administration Department
- Production Department
- Equipment Design Department
- Electronic Control Design Department
- Factory Automation Department
- Production Department
- Quality Control Department

The workforce distribution among departments is : Manufacturing 56 %, Design 18 %, Administration 18 %, and Testing 8 %. There are a total of 150 management staff who constitute 15 % of the total workforce.

The composition of the engineering workforce shows no development engineers, 170 design engineers, 120 production engineers, 90 testing engineers and 30 others in various roles.

c. Worforce composition of design department

The design department is divided according to product lines into three groups. Along with these three groups is the Design Administration Section which manages the overall budget, information management, rationalization of design work and promotion of CAD.

There are a total of 276 people allocated to these four departments, 15 in the Design Administration Section, 116 in the Equipment Design Dapartment 77 in the Electronic Control Design Department, 68 in the Factory Automation Department. 40 % of the personnel in the Equipment Design Department are design engineers indicating that Fukiage factory remains mainly concerned with the mass production of mature technology products (see Table 2-14).

Table 2-14 The Distribution of Design Engineers between Department

Design Administartion Section	15	(5 %)
Equipment Design Department	116	(42 %)
Electronic Control Design Department	77	(28 %)
Factory Automation Dapartment	68	(68 %)
TOTAL	276	(100 %)

Review of educational qualifications shows that half the workforce are higt school graduates. This is a result of the difficulty in employing university graduates at present. Efforts are being made, however, to assign as many university graduates to such higt growth departments such as the Applied Electronics Device Design Department. As a result of this the trend is to increase the number of graduates with majors in electronics rather than those specializing in mechanics.

The departments within the design division are composed in turn of between two to five sections. Routine design work is handled on the section level, each section comprises of a co-ordinator (the equivalent of a section manager), a leader (equivalent to a section chief assistant), three designers and seven female design assistants.

Actual product design is divided by work content into either development or production design. Development Design, divided into basic and detailed design phases, is performed by the new product design group. Production Design, by contrast, deals with the design of innovations on existing products. Because of emphasis placed upon cost efficiency an increasingly widespread recent trend is for the re-designing of products already under manufacture in order to utilize new materials and technology. This is leading to an increasing emphasis on design to the extent that there are currently two production designers for every one development designer. The development design of production equipment and machines, however, is performed by the production and not the design department.

d. Product development system

Product design performed at Fukiage Factory is primarily concerned with the innovation of existing products and is essentially the responsibility of the design division. Although Fukiage Factory also independently develop its own new products, the usual pattern is for new products to be developed jointly with the General Research Laboratory's Technology Transfer Organization and then mass produced. A technical information exchange meeting is held twice yearly between the laboratory and the divisions in order to promote the search for ideas of new products. Because of this chance for information exchange, there are more cases of new products arising from commissions from the production divisions than from technologies developed in and transferred form the General Research Laboratory.

The development of new products in the area of programmable controllers, especially the development of computer software, is performed in co-operation with JE Control. JE Control essentially takes responsibility for developing software for higher level equipment while Fukiage Factory performs software development for lower level equipment. The section manager responsible for software development in Fukiage Factory has work experience in JE Control and is therefore familiar with both organizations and has access to human networks in both.

Beyond these close co-operative relationships between the Fukiage Factory and JE Control a further close relationship is maintained between the factories design and manufacturing departments. Even though designs completed by the design department are handed over to manufacturing after having passed the final testing stages, there are frequent design modifications made on the basis of feedback from the manufacturing shop floor. This feedback, or information exchange, is made possible by the "Innovation suggestion system". This system makes it possible for the manufacturing department to inform design of any difficulties which arise in relation to the designs for new products. As a result of this system there are frequent design changes based upon the advise of the manufacturing shop floor. Closer examination of the relationship with the JE General Research Laboratory shows that the test models which it develops are frequently budgeted for and mass produced at the Fukiage Factory. There are also, however, cases whereby the Fukiage Factory receives the basic technologies from the JE General Research Laboratry and develops it's own test models.

In this manner it can be seen therefore that development on the factory level represents a process of integrating new technologies and test models from the operating divisions and the JE General Research Laboratory with existing technologies in order to produce model changes rather than developing entirely new products based on new technologies. The Fifth Design Section, however, has virtually no relationship with the JE General Research Laboratory. Because the products which the Fifth Design Section are responsible for, breakers, switches and fuses, are all mature technologies, sufficient know-how for modifications and improvements are available and the engineers are responsible for the whole process form development through to production.

Fukiage Factory's design department is connect with the JE General

Research Laboratory for JE Control in the manner described above, but the connections within the factory between the design and production departments are very close. Upon transfer designs produced by the design department sent off to mass production after being subjected to performance evaluation by a tester in the production department but there are frequent cases of design changes being made because of the suggestions of the production department. Such information exchange is supported by the "improvement suggestion system". This system promotes the exchange of information from production to design in cases where design are seen to be difficult to make by the actual production personnel. This results in the frequent exchange of information between the two departments and numerous cases of design changes.

Sggestions for design modifications continue even after products enter manufacturing. This closes relationship between design and manufacturing was formed after 1965. The reason for this lies in the moves starting in 1965 to allocate high school graduates to manufacturing, and because of efforts to improve quality by the introduction of QC circle programs at the same time. Before that period the design and manufacturing functions were totally isolated form each other and suggestions for modifications originating from the manufacturing shop floor level were rarely ever heeded.

e. Work system and workforce composition of the Fifth Design Section

The Fifth Design Section is part of the equipment design department. The equipment design department is comprised of five design sections, a development and testing section in charge of making test models prior to mass production, and a materials research section in charge of metallic and materials research.

The Fifth Design Section is manned by eleven male engineers. Personnel within the section are divided into a breaker, a switch and a fuse group. The former has seven members and the latter four. The section manager in charge of the breaker group is also the line administrator in charge of the whole section. The managers in charge of the switch and fuse groups are technical professionals of senmonshoku and are thus staff kacho. The assistant section managers are responsible for a leadership role as well as a performing operations within the section. In the switch and fuse groups, which are in charge of peripheral parts for the breaker group, can be found high school graduates who have reached the equivalent of administrative posts. Apart from the engineers there are also two female part time workers performing routinized peripheral work and CAD operation (see figure2-15).

Figure 2-15 Workforce Composition of the Fifth Design Section

Breaker Group (7 peoples)
- --Kacho
- --Assistant Section Manager
- --Engineer

Fuse Group (4 peoples)
- --Staff Kacho
- --Assistant Section Manager
- --Engineer

The main functions of the Fifth Design Section are :

1. Development work including the review of previous technical references, and drawing and checking designs.

2. Consultant work including the performance of surveys and reference checks and the writing of reports at the request of marketing and of clients.

3. Discussions and meetings with other departments and organizations.

Design work is comprised of the steps of conception, basic design, fine design, test modelling and design for mass production. Based on the differences in products design can be divided into development and modification design. Development design is the design of a product for a full model change -it is not made in order to accommodate a clients request but in order to develop a standard component which will become a standard product. Development design take place in three to five year cycle in the same product range and the product teams working on them usually follow the cycles from conception to mass production design as a part of their work.

In contrast modification design is a design made in order to effect a minor or partial change in a design. After a product has entered the mass production stage changes are made in order to introduce new technologies or materials in order to effect cost reductions - partial design changes are usually made for these reasons. modifications are also necessary to include the option demands of clients into products as standard products. In the past, in a time when the volume of work was relatively small, work was performed individually, but with the increase in the volume of design work project teams became the norm.

At Fkiage Factory neither development or modification design work is commissioned outside. This is because there is relatively little volume of design work. In concrete terms design work actually involves drawing a concept and parts designs - the concept design is drawn by the assistant section manager and core engineers while the designs for the parts are drawn by the younger engineers. In the event that the needed design is relatively straight forward, younger engineers will often take the lead in designing with the assistant manager and core engineers checking and correcting their work afterwards.

The distribution of work and performance of new product development in the Fifth Design Section takes the following form. In terms of development and modification designing, the assistant section manager and core engineers usually take responsibility for development designs leaving the younger engineers with the responsibility for development designs. This is not, however, a rigid division, and in fact there are cases of personnel who perform both types of design in parallel. Rigid divisions between the two types of design lead to shortcomings in the ability formation of the modification designers and gives rise to development designers who are not competent in modification design. Because of this the core engineers in charge of the breaker group and the assistant section manager in charge of the switch and fuse groups perform both types of design. Furthermore, in all groups some aspect of development design is made the responsibility of younger personnel.

In the case of development design for a new product project teams are formed including personnel from sections other than the normally related departments. Because products run at a cycle of between three to five years, and because a number of teams are in formation at any single time on some product line, development designers are continuously involved in some project. Leadership of project meeting is in the hands of the design section and meeting are called at each step of the development design enabling a design check to be performed at each stage via the "design evaluation system". The four stapes in development design are as follows.

1. Sales form head office, factory production department, manufacturing department and the quality control department participate in producing the conception design. Representatives from head office sales and the operating division participate in order to determine costs based on predictions of customer needs. The costs decided here are used to control the development process to follow.

2. The basic design is drawn up and after being assessed it is used to drawn the detailed designs. Although this is mostly the work of the design section, other related departments are also involved in order to check the drawings.

3. A test model is built in order to determine whether or not the functions written into the design can actually be attained. The design section is also involved in this process but the work itself is performed by the development and testing section.

4. Mass production test. In this stage the manufacturing department also participates and the design is tested to determine whether or not it lends itself to easy manufacturing. Alterations to the design are sometimes made at this point. With the completion of the final mass production design the test model stage is completed.

The above is the outline of the development design project - these project usually last from between one to two years in duration. During this time the projects is the responsibility of the development and testing section which takes charges of meeting and administrative tasks. Of course actual leadership rests with the design section. The members who participate in these projects are comprised of one person form each section - it is common for section managers or assistant section managers to participate. However, depending upon the level of the new product under development core engineers and at times younger personnel may also participate. Project teams are also sometimes formed in VA meetings not concerning new product development. Apart from the design section, production, testing and production technology also participate in VA meetings. The members are not selected from any particular them. These projects frequently last for a year.

The problem that arises in such a project system for the development designs is that of selecting the members. Should and engineer be chosen for a project in which they have little interest, then they cannot be expected to participate enthusiastically and it is highly likely that the project will not progress efficiently.

Because of this the section managers who are responsible for selecting team members are expected to be aware of the interests of each of their subordinates. Recently, however, growing labor shortages, reductions in development times, increases in the development loads of core and administrative engineers has lead to the emergence of workplace environments in which such careful management and adequate education and training is becoming difficult to accomplish. This is a problem which could very well undermine the project system of new product development.

f. Networks with other departments

The Fifth Design Section and the sales department are related in the following manner. Although the sales representative responsible for the respective product being developed by the design section is in daily touch with the Fifth Design Section once every three months a regular meeting is held. At this meeting information is exchanged about customer needs, about whether or not the product as envisaged by the Fifth Design Section will sell or not, and about technical information not included in the catalogues and product manuals. The Fifth Design Section is in charge of preparing literature in response to customer enquiries which come to them via the sales department - this is a time consuming process. Of late an increasing number of inquiries are arriving from clients directly by fax thus increasing the volume of work for the Fifth Design Section. These enquiries are initially handled by the assistant section manager or core engineers and, depending on the content of the enquiry, can be delegated to the younger engineers.

The relation between the Fifth Design section and the manufacturing department is not simply one of the former being of higher status and the latter following it's orders. Suggestions for product and design improvement frequently arise from the manufacturing department even after new products have entered the mass production stage and have attained some stability. Mass production is often meet with a host of problems which were not foreseen in the test model stage and which cannot be resolved without the input of the manufacturing department. At the Fukiage Factory a "modifications system" is used whereby the quality control department collects these suggestions from the manufacturing department. These suggestions are discussed and evaluated at a regular monthly meeting attended by all related departments. This is not something particular to the Fukiage Factory - most Japanese workplace have long established QC circle activities which permit engineering personnel to obtain feedback from the shop floor.

Among the products handled by the Fifth Design Section are included some which do not include standardized parts. These products are frequently modified upon the basis of suggestions from the manufacturing department. Suggestions for product modification are even exchanged with parts suppliers outside JE Company and design modifications are made through the VA meeting.

g. Rotation and human resource development of design engineers

Excluding those rotated to factories in the immediate vicinity of Fukiage Factory, the fact that only twenty percent of all factory workers have experience of rotation attests to the low level of personnel movement. The reasons behind this are :

1. high school graduates are recruited directly by the divisions themselves and therefore rarely ever move to different divisions,

2. university graduates hired by Head Quarters and assigned to divisions usually work as specialists in customized orders and tend therefore not to move. Movement within the design department and between other departments is however, frequent.

Although the movement of engineers between the three design departments is scarce, there are many cases of engineers changing themes and design areas within their department and going on to forming their careers in this manner. This form of career course is in fact quite frequent. There are also cases of engineers moving out of design to other departments, one finds frequent movement to Testing, Sales Technology and Quality Control departments. Sales Technology is a section responsible for technical backup of the sales force, customer education and surveying customer needs.

There are two main methods for the human resource development of design engineers.

1. Reading the work manual under the supervision of an experienced designer.

2. On the Job Training.

The work manual outlines the required performance and functions of products and components and is studied under the guidance of an experienced superior or senior engineer. On the Job Training is a highly important form of human resource development because of the need to grasp the use of interfaces which, unlike mass marketed standardized component circuits, have to be mastered by experience.

Close examination of the OJT system shows that new personnel are assigned to modification design for two to three years after which they are assigned to development design. Because modification design is performed as a set of smaller tasks as broken down by experienced personnel it offers great scope for applying new engineers. Young personnel are usually given relatively easy tasks to commence with, and are given more advanced tasks to perform as their abilities develop.

Training in design technology begins with studying references and documents related to one's current task. Veterans teach the new recruits the methods for locating references and reading drawings. When actual design work commences, new people are paired of with experienced workers and work in teams. Experienced workers show considerable interest in the training of young recruits because part of their evaluation is based upon their ability to develop their subordinates and because of their awareness that incompetent subordinates mean an increase in their own workloads in the future.

Apart from this there are also, technical presentations, exchanges of ideas with engineers from other departments, and attendance at conferences at the research center or outside the company. With the growing importance of incorporating electronic technology into products a need has arisen for training engineers with a grasp of electronic technology as well as mechanical. At present there are very few engineers with a grasp of both fields.

2-3-2. PERSONNEL MANATSGEMENT OF MATURE PRODUCT "IMPROVEMENT INNOVATION"DEPARTMENT

a. Product composition

Kobe Factory began operation in 1968 as a factory of the K Denki Seizo Co, currently knows as the K Jukogyo Co. At that time the factory produced electric generators and motors for trains and ships. Since then the product range has changed with the discontinuation of motor production and introduction of products such as electricity distribution boards and CAD/CAM systems. In 19083, a new factory was completed.

The present composition of sales by product areas is : 43 % electric distributors, 17 % rail carriages, 24 % inverters, 20 % electricity supply equipment. Of these electricity supply equipment and inverters are showing the greatest levels of growth, while previously main products of which in the past comprised 55 % of sales have fallen off dramatically. Weakening international competitiveness due to the appreciation of the yen has led to reduction in production in some areas. All of these products are innovation products. While products consist of both mass-produced and customized, customized comprise the greater share.

On the one hand the Kobe Factory is faced with maintaining a range of products in matured areas such as electrical distributors while trying to maintain it's growth by means of developing new products such as the inverter and anti-failure power sourcing systems using new technologies with potential for growth.

b. Organization

Kobe Factory is organized into the five departments of Administration, Sales Technology, Design, Production and Quality Assurance (see figure 2-14). The roles of these respective departments are as follows. Sales Technology Department, is responsible for taking the technology orders of Head Quarters and the divisions and acting as an intermediary between customer and factory. This department takes responsibility for taking orders, scheduling, and costing and is therefore in a position to control production schedules of both the design and production departments. It follows therefore that Sales Technology Department is staffed with veteran employees with a firm grasp of the workings of the whole factory. Moreover, reflecting this operational content there are a considerable number of technological people deployed in the marketing and technical service department.

The Design Department is responsible for the development and design of products. Because the main product, the electrical distributor, is a customized product and specifications vary by customer, the design department divided into groups for specific customers. Because of this structure the design department is manned by more personnel than the other departments.

The Production Department previously had an organization based vertically upon products but is now organized horizontally by section in order to give the needed flexibility for production and technological change. The subsections within the sections are vertically organized upon products giving a combination of vertical and horizontal organizations.

Quality Assurance Department works to test and maintain product quality. As a custom device the electrical distributor requires high levels of reliability, and quality checks are therefore carried out on all the individual products. For this reason there is also a large number of personnel deployed in the testing department - all of whom are engineers.

The Administration Department deals with product budget costing, management of materials and parts and personnel management

Figure 2-16 Organization of Kobe Factory

- Factory Manager
  - Administration Department
    - General Affairs Section
    - Accounting Section
    - Materials Section
  - Sales Technology Department
    - Control Equipment Section
    - Electrical Distributor Section
  - Design Department
    - First Design Office
    - Second Design Office
    - Third Design Office
    - Technology Administration Section
  - Production Department
    - Production Control Section
    - Industrial Engineering Section
    - Manufacturing Section
    - Purchase Control Section
  - Quality Assurance Department
    - Quality Control Section
    - First Inspection Section
    - Second Inspection Section

c. Workforce deployment

Of the total 401 employees of Kobe Factory, 59 are located in Administration (14.7 %), 33 in Sales Technology (8.2 %), 95 in Design (23.7 %), 130 in Production (32.4 %) and 84 in Quality Assurance (20.9 %). The average age of workers is 37 and there are 42 female employees, most of whom are clerical workers. The recent trend has been a decrease in numbers, particularly in the production department. As is indicated by the fact that manufacturing employs no more than 30 % of the total workforce, Kobe Factory has a stronger character as a technical center than as simply a manufactory.

The reduction in the number of workers was due to discontinuing the production of motors and the increase in order made products. The manufacturing department used to employ 500 people when it produced motors. Apart from this there has also been a decrease in the numbers of skilled workers as a result of ongoing automation.

It follows, therefore, that of the 200 employees presently classified as engineers, all members of the Design and Testing Departments along with a portion of those persons employed in sales Technology and engineers. Most of these 200 engineers are high school graduates, only a few being university graduates. Up until 1972 all high school graduates were employed as engineers, but after 1973 high school graduates also came to be employed as skilled workers. At present new recruits are evaluated upon the basis of academic accordingly. At present almost all managerial posts are held b y high school graduates, and all section leaders at present are high school graduates.

In this manner high school graduates are promoted in the Kobe Factory to managerial posts such as factory manager and department manager. There are two reasons as to why such personnel management is possible. One is that the Kobe Factory does not deal with advanced technology product development but with the modification and improvement of mature technologies. The other is that the time when most of the people that are now advancing to higher managerial posts within the factory joined the company levels of affluence and the number of people who advanced to higher education were not comparable with the present with the effect that many good personnel hold only high school qualifications. At present bachelor level university graduates are the main source of engineering recruits at present.

d. Organization of the design department

The design department consists of three design sections divided according to products, each containing two design groups. In cases of Large scale orders, however, the organization of design is sometimes adapted to better suit the scale of the work. The hierarchy of each section is Section Manager - Assistant to Section Manager - Group Leader - Engineer. According to the scale and importance of the work a group leader can also discharge the role of section manager or assistant section manager, or in some cases be established independently. Although the members of sections and groups are frequently changed, no engineers are ever allocated to two groups at the same time.

The work of engineers in design is divided into product development and system integration. The division of functions between Kobe Factory and the General Research Laboratory is as follows; While the research laboratory is responsible for the development of single function equipment, the factory performs innovative type modifications to products in terms of costing, schedules, and market functions. It follows therefore that there are relatively no close connections with the research laboratory.

As discussed above, although the Kobe Factory does not undertake the development of new products based on new technologies it does perform improvements on existing products by the development and use of peripheral technologies. For example in order to improve the performance of electrical distributors oil was replaced by vacuum and inert gas as a means of insulation. This technological innovation was undertaken as a joint project with a manufacturer of electrical equipment from outside the corporation. Other important parts used in insulation are purchased form external manufacturers. The tendency for Japan's manufacturers of finished goods to produce all required parts within house is rather weak, instead they use external suppliers and concentrate their own efforts on improving development and production.

The work of the design department includes administration, alteration, instruction, rough design, detailed design, data production, information gathering, blueprint production, estimate production and customer service. These operation are performed by the section manager, deputy section manager, planning specialist and regular employees (young and newly recruited personnel). Apart from these personnel designers from related and other companies as well as part time staff are also present. The reason for using designers from outside stems from the fact that although the volume of design work is increasing from custom orders, poor economic performance in the early 1980's has restricted recruitment and left the department with very few personnel around the twenty year age bracket. In short, in order to perform the detailed design which requires considerable manpower while avoiding large payroll overheads people from outside are being deployed in the process. The deployment of personnel in the design department take the following form :

Table 2-15 Workforce composition of the Design Department

Regular employee	
Fifties	1
Forties	2
Thirties	13
Twenties	2
Teens	1
Related/other company engineer Part time staff	

The respective ranks of personnel are responsible for the following duties. The section manager is responsible for administration, co-ordination and instruction, and although he is not directly involved in the actual design process he is responsible for producing the overall policy behind the process. With regular meetings concerning development, combined with frequent consultations with other departments, the section manager's time is mostly consumed in meetings and the preparations for them. Apart from this every day management another important part of the section managers function is the preparation of short and long term business plans.

The deputy section manager is largely responsible for shop floor operations such as design specifications, instruction, preparing estimates and interacting with customers, rarely does he ever perform actual design work. The deputy section manager also takes responsibility for some of the section managers functions such as personnel management. Profit and loss management, new technology introduction, progress management, and developing new clients.

Core engineers are mainly responsible for basic design. The basic design is a rough sketch based upon the specifications which is used to draw the detailed designs - these detailed designs are drawn by younger designers with about five years of experience or by the external personnel. Design takes up about half the time of these core engineers with the remainder being spent on scheduling within the section, instruction for out ordering and trouble shooting.

Young engineers perform detailed design land support work under the supervision and instruction of the core engineers. After about three years of experience their duties are expanded and they come to take on external roles such as sales. The personnel form other companies also perform detailed design, and the part time workers perform support tasks such as taking copies.

An important aspect of the design of electrical distributors is to effectively combine the existing parts. Wide knowledge of the structure and components of an electrical distributor technology is necessary in order to be able to draw a sequence diagram. One core engineer had the following to say about the design of electrical distributors.

"An electrical distributor is made up of relays and the circuits which operate them. At this factory we just make the basic framed, most of the circuits and components are purchased from outside. We make a part of the high voltage component but we purchase the majority from the Fukiage factory. Because we don't have an electronics division we are unable to design and order our own components so we buy them from other companies. In this situation our work consists of putting together the components, the better we design the components together the better the product."

Because the design department is related to all the other departments within the factory, performing design gives a good grasp of the whole company. In the first place production departments must be consulted in order to determine whether or not the designs produced are actually manufacturable. Discussion between the work research section and the external orders administration section within the production department are held in order to determine whether or not the product can be manufactured in order to meet the delivery date, and in some cases the production engineers or workers may request some modifications to the designs.

With regards to the marketing and technical service department it must be determined whether or not it is possible to design a product that meets both the customer's specifications and the marketing section's estimates. At times personnel from the design department accompany the staff from marketing to meetings with customers. The design department also works with the quality control section in order to test quality. In the event of faults personnel form the quality control section consult with personnel from design .

The design department participates along with other departments at head office meetings regarding such topics as business and sales plans and product advertisement. Where components are purchased from other factories the trading takes place at cost. Because not all four of the factories are producing electrical distributors, the head office co-ordinates activity between them.

There is relatively little contact with the General Research Laboratory because of the mature nature of the technology being used at the Kobe Factory. The development department of the Tokyo Factory is in charge of making innovations to these products. It then distributes the results of it's development work and technical information to the relevant factories from there.

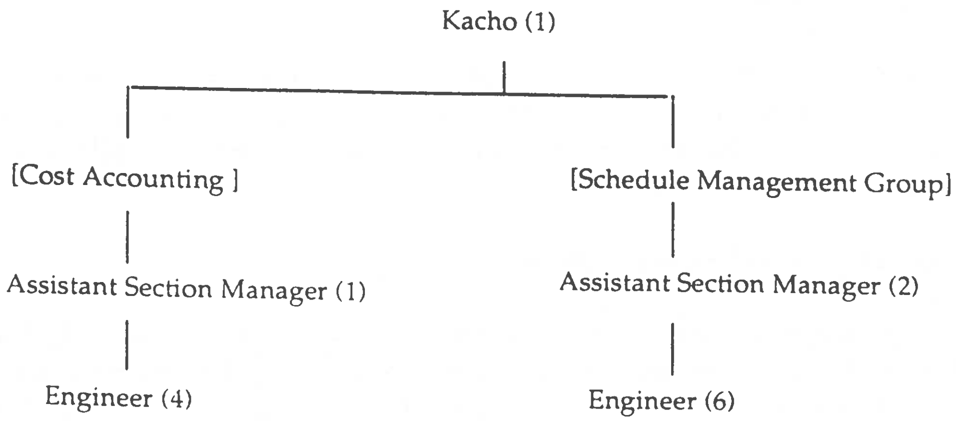
e. Organization of the Sales Technology Department

Working in play with the technology department of the head office and the sales outlets, the sales technology department is responsible for taking orders for the factory, and managing delivery schedules and costs. Cost management had previously been performed by the design and production departments but the function was transferred two years previously to the marketing department, thus giving rise to the sales technology department. The reason for giving the sales technology department, instead of the design or production departments, responsibility for cost management was to make cross the board cost management possible.

The technical department of the head office is consulted when it is difficult to establish the costs of ordering a component from outside the factory. The sales technology department supports the retail outlets which are manned by sales and repair personnel in matters concerning pricing and delivery by supplying information or sitting in on meetings with customers. The sales technology department is also responsible for drawing up schedules and estimating costs upon the basis of the design department's basic designs. Following that the sales technology department co-ordinates with the production, materials, external orders, and testing departments in order to produce a viable estimate. The sales technology department the department which schedules the work of the other departments so that their combined activity meets with the customer's needs. This co-ordination takes place in the weekly production meeting. At the present average delivery time is from two to five months, this represents a reduction of fifty percent of the times ten years ago, and demands for further reductions are strong. After production is complete the sales technology department calculates profits and losses and verities the validity of the original estimate.

The above is an outline of the overall work content, but in actual practice the work is performed by two different groups, one for cost accounting and another for schedule management which is also responsible for dealing with complaints from customers and services. Because cost accounting requires considerable technical knowledge over half of the group's personnel are engineers and some are designers. Despite this, within the factory the status of the design department appears to be higher. The present manager is an white collar employee with experience of production. The scheduling group is mainly concerned with production management and therefore contains many white collar employees. The workforce composition of the section is as follows :

Figure 2-17 Workforce Composition of Electrical Distributor Section



Examination of the actual work content reveals that there are cases of estimation work both with and without designs. Estimates for work with designs are relatively easy because the necessary components and parts are already indicated. Jobs without designs are difficult unless one has technical knowledge of planning and the technologies involved. Because of this, this work is usually performed by staff with technical experience. The following is a comment from an engineer responsible for cost accounting :

"The first stage is to look at the customer's specifications and determine the product layout and external dimensions, from then on you think of how the product would be best built and from there you estimate the costs. When the job is not certain and actually drawing a design costs money that may not eventuate you just have to circumvent that stage and make the estimation without it. In these cases it really helps to have technical and design knowledge - it makes the work a lot easier. This is the reason why technical people are allocated to perform cost accounting."

The functions of the different positions are as follows. The section manager is responsible for managing orders, trouble shooting, and instruction. Of this the most important function is managing sales objectives against orders. Managers also check the estimates of their workers and instruct them in their work, a large proportion of their work is taken up in co-ordination between departments upon the basis of the schedules drawn up by the marketing and technical service department.

Although on occasion the deputy section manager also participates in estimate work, the major part of their function is the supervision of subordinate's work and checking the estimates against costs. In terms of marketing the deputy visits the technical department of the head office and the larger sales outlets along with the section manager where they provide information of the factory's performance and income - by this they perform a qualitative as well as a quantitative role in promoting orders for the factory.

The core members of staff write estimate for jobs without designs, leaving the jobs with designs for the younger staff members. Where there are no designs the staff makes rough sketches for which experience is necessary. These core members of staff are also responsible for the instruction of the younger staff. Work is divided according to customers, some work is performed by groups while others can be handled by individuals.

Apart from these members of staff there are some retired veteran employees and women who work as part time workers - the women perform support work such as word processing, drawing graphs and organizing documents while the veteran workers assist on the estimates.

f. Education and training of engineers

Education and training of engineers at the kobe Factory takes the following form. Firstly in the case of electrical distributor design, the whole process of design is one large applied learning experience where by engineers gain a wide if somewhat shallow grasp of the technologies involved. As well as learning from experienced designers by OJT, the designs and applications of existing distributors are studied and related data is analyzed in order to promote ability development.

Training as an engineer takes the form of new recruits working along with experienced engineers and being taught about aspects of design and finally total design. Such one on one forms of training are centred around OJT and in the first year usually involve learning the basics of design and the technologies involved, in the second year taking responsibility for parts of design work and in the third year working with experienced workers in adapting the demands of customers into designs and doing advanced work.

After this basic education full scale ability development commences and involves the absorption analysis and accumulation of a wide range of information from both within the various departments within the factory and from outside the factory in such places as the JE General Research Laboratory, head office and even from the customers. Experienced engineers in such positions as section manager and assistant manager are responsible for training new recruits. In order to train engineers along with OJT and self development it is also important to promote information exchange and the development of human information networks between organizations. The co-operation between departments within JE Company makes this inter-departmental networking possible.

Because there is a lot of operating and clerical work in the sales technology department, ability development there differs somewhat from that as seen in the design department. In this department work is divided up upon the basis of clients and personnel are trained to perform their own work as well as to perform as members of a group responsible for a certain job. Because experienced personnel have to cover for younger engineers when they are unable to perform their own duties a pair system is used whereby the senior personnel direct the junior.

In the case of estimating work the pattern of educating new recruits is to have them work one on one with experienced personnel for a year in order to learn the basics. In the second year young personnel are expected to use this first year's experience and widen the scope of their activity, until in the third year of service they are made responsible for drawing up estimates on their own and for maintaining the prices stated in them. Beyond this the level of their work increases as they are put in charge of higher voltage equipment of a more advanced nature. The above is the pattern of education for new personnel.

Within Sales and Technical work cost calculation work is particularly close to design work. The section manager responsible for that function made the following remark about the need for human resource development.

"One needs a wide ranging and shallow knowledge of orders, design and production. Even though you can't draw a design yourself, one has to be able to calculate costs, scheduling and personnel deployment."

Because of the nature of this work the cost calculation group contains a large number of engineering staff. As well as numerous technical personnel from production and clerical personnel form administration. Although these personnel receive the training as described above they are also expected to visit other departments on their own initiative and make efforts to develop the knowledge necessary for their duties. In both the design and the sales and technical department personnel the internal formation of technical personnel is accomplished by OJT and interdepartmental information exchange.

In the Kobe Factory there is little personnel rotation. There is virtually no rotation in the design department. Although a minority there are cases of people working in design in their early years and moving to the sales and technical department in their mid career. These cases are the result of personnel administration policies rather than an outcome of human resource development policies.

CONCLUSION

The characteristics of R&D personnel and R&D management in JE Company

JE Company performs R&D across a wide range of fields ranging from heavy electrical equipment to semi-conductors, information and instrumentation, considerable differences can be seen between the administration of R&D and R&D personnel between the existing mature technology fields of heavy electric and the newer technical areas of strategic high growth.

In the first place because of the absence of rapid technological change in the mature technology fields the development of R&D personnel takes place within relatively stable organizations in these departments. In these departments where personnel rotation between organizations is uncommon the education of R&D

personnel takes the form of OJT as the central mechanism of education the borders between engineers and between engineers and skilled workers are flexible and not rigidly defined. In other words there is an overlap between the functions and abilities of the personnel in the workplace. Beyond this the emphasis placed on evaluating experienced personnel by their contribution the development of their juniors, combined with the fact that experienced personnel realize that if their subordinates are not capable of full scale work that his only adds to their own responsibilities and work loads, OJT oriented ability development is readily promoted.

Over time the personnel within these stable work organisations achieve wide reaching communication networks, both informal and formal, which enable them to exchange information in order to promote effective improvements in existing products and the development of new ones. Flexible work design structures and stable educational systems without rotation promote the accumulation of know-how regarding design and development. In this environment accumulation of know-how and ability development is readily promoted and even high school graduates are capable of achieving promotion relatively high positions.

In contrast to this, in the areas of strategic growth where technological development leads to rapid technological changes the R&D organization is correspondingly dynamic. In order to develop new technologies and products within this environment of rapid technological change it is essential that technological transfer form basic research to production is conducted efficiently. To this purpose organizations are relocated from research centers to the operating divisions and engineers are rotated along with new technologies in order to promote smooth and rapid transfers.

Here too technological boundaries are not rigidly defined but are loosely defined in order to provide an overlap. The flexible organizations resulting from these overlapping structures facilitate the smooth transfer of new technologies and products by creating common functional areas between researchers, engineers and skilled workers. In contrast to areas of mature technology, it is difficult to provide sufficient ability development using only long term and stable OJT mechanisms in an environment of such technological change and advancement. Because of this a variety of techniques including recruiting from post graduate schools and initiating programmes of off-JT have been initiated. Compared with organizations dealing primarily with matured technologies these organizations tend to display considerable differences in the educational qualifications and education and training experiences of their workforces.

GENERAL CONCLUSION

This concluding section will be divided into three parts.

- an introductory section given over to short assessments of the comparisons of pairs of firms, firstly the electromechanical engineering companies and then the chemical firms;

- a more general summary highlighting the broad outlines of national trends in each country;

- a brief look back at the opportunities opened up by an international comparison carried out in accordance with the societal approach, high lighting its heuristic potential and the questions it raises as much as the answers it provides.

1. SOME LESSONS TO BE DRAWN FROM THE COMPARISONSOF PAIRS OF FIRMS

We will examine the electromechanical engineering companies and then the chemical firms. The points to be made are not necessarily the same in both cases: the information collected was not identical and the basic questions raised by the comparisons may vary, depending on the economic, technological and social context.

1-1. THE TWO ELECTROMECHANICAL ENGINEERING COMPANIES

There are five points to be tackled in succession.

1-1-1. COMPARISON OF THE TWO COMPANIES' FINANCIAL ACCOUNTS REVEALS TWO BASIC TRENDS

Firstly, the accounting "performance" of the FE company measured here by the share of net profits relative to turnover is clearly superior to that of its Japanese counterpart. For the past 5 years, the former has constantly achieved a net profit rate in excess of 3% of turnover. In contrast, the equivalent figure for the Japanese JE company has fluctuated between the rather low figures of 1 and 1.5%, although its turnover is almost three times greater than that of FE company. This difference in results seems to arise from several factors. FE company is very much more open to international trade (50% of turnover) than JE company, where foreign earnings account for only 15% of turnover; in other words, FE company enjoys better international competitiveness. Furthermore, the market for electromechanical products is oligopolistic in France and highly competitive in Japan. FE company, with its specialization in circuit breakers, operates in a relativ ly stabilized market, but one which ensures a certain level of profits, while the Japanese company, whose strategy is oriented towards product diversification, is involved in a number of technologically promising activities offering little immediate prospect of profits.

Secondly, it is interesting to note that, despite such a disparity in profitability, the Japanese JE company devotes the same level of financial resources (5 to 6% of turnover) to technical costs (R & D, pilot studies) as its French counterpart. As for industrial investment, the Japanese company devotes 4 to 6% of annual turnover to the formation of fixed capital. In this respect, FE company is rather cautious, devoting 2 to 3% of turnover to the same end, whereas it has no hesitation in embarking from time to time upon largescale financial operations, such as takeovers. These two different patterns of behavior are of course part of an already familiar distinction between a policy based on internal growth and one based on external growth. More fundamentally, however, they reflect the difference in the strategic time scales adopted by these two companies.

1-1-2. THE CONTRASTING TECHNOLOGICAL TRAJECTORIES OF TWO COMPANIES DURING THE 1980's

Circuit breakers, FE company's original specialty, still form the core of the company's business, accounting for more than 80% of turnover. This specialization is not changing, even though the flagship products are increasingly low voltage devices for use in final distribution. Taking into account its strong association with this specialty, which has a decisive influence on its management strategy, technical learning processes and human resources, and despite a certain strategic inclination, the company seems to have experienced some difficulty in diversifying its product range and appropriating new technologies, particularly in the field of electronics. However, from the point of view of the FE group, the company has undoubtedly succeeded, through purchasing companies, in establishing another hub of activity in the field of industrial automation.

Like FE company, the Japanese JE company was founded in the 1920s, starting out as an importer of Siemens products. With its historical links with Siemens, it is an archetypal electromechanical engineering company. Indeed it is one of the Japanese companies most strongly committed to the sector. Nevertheless, it has for the past 15 years been constantly reducing the share of electromechanical activities (turbines, motors, circuit breakers, transformers, etc...), which accounted for 50% of turnover in 1980 but for only 36% in 1989. At the same time, it has been building up two new activities, one based on electronics (computer control systems, components, automatic control systems etc...) and the other on new energy technologies (new means of generating energy, solar powered batteries, new materials etc...). The competencies required for the development of these new activities have been acquired mainly at the central laboratory level, as well as through a variety of technical associations, even joint ventures with other Japanese or foreign companies.

1-1-3. It is possible to make a rough estimate of the proportion of technical management staff in each company. FE company has 1,300 engineers 900 graduate engineers and 400 promoted within the company and 2,600 technicians out of a total work force of 8,000 (1987 figures). The Japanese company classifies 5,900 of its

13,900 employees as "guijutsusha", or engineers. This categorization for internal use only is used to define, particularly in relation to the manual worker category, "a body of technical employees" with the same status and pay. Of these 5,900 engineers, 2,900 have 4 or more years of further or higher education, 300 have two years of further or higher education and 2,700 are high school graduates in technical subjects (198 figures). In comparative terms, there are three points to be made.

The proportion of technical management staff (engineers and technicians) is higher at FE company (49%) than in the Japanese company (42%).

The proportion of engineers to technicians is 1 to 2 at FE company, whereas if this French distinction is applied to the Japanese company, there are just as many "engineers" (four or more years of further or higher education) as "technicians" (high school graduation certificate or two years of further or higher education).

The proportion of "engineers" with four or more years of higher education is twice as high in the Japanese company (21%) as at FE company (11%).

1-1-4. In addition to this quantitative comparison, the way in which technical personnel (engineers and technicians) are distributed seems to illustrate the organization of technical creativity.

In general, FE company distributes its engineers and technicians fairly equitably among the various departments, unlike the Japanese JE company, which clearly reveals its priorities by concentrating its technical staff in new activities. This contrast is particularly striking in the case of general research. The Japanese company allocates 9% of its technical staff (13% of those with four or more years' higher education) to general research (central laboratories), while the corresponding figure for FE company is less than 1.5%. This difference, which cannot be dissociated from the strategic orientation of each firm, reveals two methods of organizing technological innovation. In the Japanese company, the general research department has the clearly defined functions endogenising technical potential, of conducting research into applications and serving as a "nursery" for new activities. Thus the organization of general research plays a vital role in product diversification. In contrast, the status of general research at FE company is ambiguous. Trapped between a very favorable external environment (with public institutions playing a considerable role in basic research) and the autonomy of individual departments, each seeking to innovate as part of its strategy of specialization, the general research department has difficulty in defining its objectives. As a result, and with the exception of a few very specific areas of study, it is often confined to the role of "technological lookout". It plays an essentially passive role in the development of new technologies.

1-1-5. THIS LEADS US DIRECTLY TO CONSIDER TWO UNDERLYING PHENOMENA

Firstly, the style of technological management, despite some aspects that are formally very similar (budgeting of technical costs, contract between general research and departments etc.), seems different. FE company basically devolves responsibility for technical innovation technological choices, project management etc to a decentralized level.. Central management does not supervise research programs, nor does it intervene directly in project management. On the other hand, it does check the results a posterior, by examining the overall profitability of each department. It is as if a decentralized system of technological management can be given overall coherence only through centralized budgetary control. There is little evidence ofstrictly technological dialogue between the central and decentralized levels. In the Japanese company, which has to manage the technological complexity arising out of its range of activities and, above all, the diversification of its technological potential, technological management turned out to be organized at a high level. Indeed central management seems directly to monitor, evaluate and coordinate innovation programs. In particular, it intervenes in the management of general research. Such control at central level certainly does not exclude "hierarchical" aspects or a sort of "dirigisme" in the management of the company's technical dynamic. At the same time, however, it brings into play a mechanism for negotiation between central management, middle management and engineers, and a mechanism for continuous review of the company's technological and strategic orientation.

Secondly, it goes without saying that these two types of technological management cannot be independent of the method of managing technical staff and, finally, the form taken by their professionality.

In the case of French company, the management of engineers particularly of graduate engineers sits uneasily with the technological dynamic. Social management is somewhat at odds with technical management. A decentralized system of technological management must constantly deal with the manifestations of the engineers' professional strategy that focuses principally on their own career strategy. In other words, the engineers have the autonomy to implement their strategy both in the technical sphere performing technical feats and in the hierarchical or managerial sphere. In this context, mobility is often the principal. Immobility, in contrast, is interpreted as a sign of inability to develop professionality, means for engineers to prove their ability to adapt to a succession of different jobs. It does not necessarily lead to an accumulation of technical knowledge, either on the individual or collective level. The fact that the essence of their professionality is constructed outside the firm before they join it provides little incentive to strengthen the mechanisms through which learning takes place or technical knowledge is accumulated within the industrial environment.

In the Japanese company, the "centralized" coordination of technological management goes hand in hand with the form taken by the management of technical staff. Personnel policy including the management of "engineers" plays an important role in articulating technological management with the professional development of employees. This attempt to link the company's technical dynamic and the acquisition of competencies is made necessary, or at least encouraged by the fact that the education system produces only people with potential that needs to be shaped, even though standards of general education are improving all the time. Engineers' professionality has to be constructed gradually within the company, in accordance with both the accumulation of industrial knowhow and the slow and controlled process of promotion through the hierarchical structures by which work is organized. This method of constructing skills, together with the relatively centralized policy of allocating "engineers" to the various departments, minimizes but does not totally eliminate their room for strategic maneuvering in developing their own careers. In this case, the mobility of engineers tends to be closely regulated by the nature of the technology with which they are involved and its rate of development.

For example, there seems to be a great deal of mobility between research, development and production in a new activity such as electronics, while there is a high level of stability among "engineers" in technologies that have already reached maturity, such as electromechanical engineering, or in specific research projects in which the process of technological maturation is of necessity slow. In this last case, stability (or lack of mobility) is by no means considered as an indication of a lack of ability.

In other words, their mobility or lack of it is determined by the trajectory of the technology or the product they are dealing with. It is without doubt this deliberate synchronization of technical and professional trajectories that constitutes the driving force behind the endogenisation of new activities within the organization.

1-2. THE CHEMICAL COMPANIES

The points to be stressed here are either those specific to the sector, or those that are more particularly evident in the chemical industry and the chemical companies than in the general differences observed between France and Japan.

1-2-1. The two companies JC company and FC company have different positions relative to their markets. Although both companies face a particularly difficult market, considerable competition and problems arising out by the fluctuating prices of raw materials, leading to instability in the production of basic chemicals and specialities alike, the structures they have adopted in responding to the same difficult conditions are very different.

FC company is a nationalized company, the product of a whole series of restructuring exercises; it includes production units with very different histories and was set up in order to complement other nationalized companies in the products market, in accordance with a national policy of specializing in those same products. The chemical sector as a whole is more significant than the company: it is the sector as a whole that competes with other chemical companies on the European or world markets. The opening up of FC company to the world market is one element in this sectional policy. In order that FC compny may compete effectively, it forms part of a large oil group E, a link that is intended to soften the effects of fluctuations in the chemical products market. In return, the activities of FC company are to be subjected to a policy of strictly economic rationalization. Each product line will have to be profitable, noncompetitive production plants will be rapidly closed down and jobs will be lost. However, the rigors of this rationalization will be softened to some extent by the company's presence in the nationalized sector.

JC company is an older company, built up in the face of competition from other companies in the Japanese market for chemical products. Subject to the same fluctuations as French company, its product diversification policy is more considered and less hurried than that of the French company; it develops this policy under the impetus of competition, whereas FC company is directed by the state towards certain technical paths. This policy seems to give rise to greater short-term financial difficulties than those experienced by FC company and to exclude any opening up to markets other than the Japanese one.

In terms of short term performance, the French company seems to produce the more satisfactory results, due in part to its position within group E. And yet the Japanese company probably has greater dominance over its own market, and maintains a high level of investment.

1-2-2. The two firms have different relationships to their "environment". One of the characteristics of the chemical industry is the particular link between research, development and production and the construction of the skills of the actors involved in this process.

The innovation space, as thus defined, is not identical in the two countries.

JC company constructs its own research space, although of course it uses the fruits of national and international research. It utilizes the competencies of graduates of the Japanese education system but trains them itself. Its innovation space is self contained, and it organizes the confronting of ideas and knowledge, mobility and information flows internally, in such a way as to produce innovation from the actors in the process. Although it does offer some encouragement, it seems to leave relations with the outside world (conferences, trips abroad) up to individuals, while managing with great care the internal skills market . French company is engaged with other bodies (public research institutions, colleges, etc.) in an innovation space , in which all the parties benefit from the contributions made by the others. Thus the engineers are trained and assessed in the external market, innovations are realized in collaboration with partners in the public sector and information flows crisscross the innovation space, with each participant being a part of the same dynamic and taking what he needs from the information available. FC company carefully manages its participation in this space, but allows the individual engineer the latitude he needs to build a successful career for himself within it.

1-2-3. The process of innovation forces itself upon the two chemical companies, despite the different paths they follow. Similarly, JC company andFC company find themselves facing the same constraints when it comes to man management. Nevertheless, faced with these determining factors, they do not organize their various units or the phases of the innovation process in the same way.

Thus for JC company the various phases of the innovation process and the organization of units are interdependent and interlocking. This framework is supported and dynamited by cooperation between the various hierarchies, i.e. the various units, the various elements in the whole, and by the fact that the actors' skills are constructed as they make short moves between closely related parts of the process.

For FC company, the innovation process is segmented between the various phases, and the different units (pilot laboratory, production plant, etc.) are organized so that they function well in isolation, each with their own territory, rather than maximizing their relationships with each other. Thus each centre's traditional hierarchy has to be supplemented by a project type organization that provides a means of coordinating all the actors in the process and the impetus for the central strategic purpose, namely cooperation between the actors involved. This management strategy comes up against the various territories or "empires" within the company, individuals' career strategies and weak human resource management.

Other actors make appearances in the course of the process: some, like process or development engineers, mediate between the various "empires", while others, notably project managers, are the driving force behind cooperation. The organization supports or creates actors whose task it is to combat its own misdeeds. This in turn creates duplication within the organization, leading probably to a certain degree of confusion bordering on disorder

1-2-4. Taking as a starting point the initial training received in the same specialisms, an engineer's competence and career will be constructed differently in the two firms.

In FC company, a separate profession is employed in each "empire": researchers work in the laboratories, production engineers in the manufacturing plants, and so on. Only process engineers, by virtue of the technical nature of their profession, have access to more than one "empire", including the pilot service and the process services in the technical center and the production plants. Engineers in managerial positions, who often have a production background, achieve recognition through their ability to change rapidly from one territory to another along routes that mobilize their managerial and relational abilities rather than their technical skills, with the result that their technical specialism is left behind or forgotten. They entered the company as "finished products" from the technical point of view, and are recognized as such by the innovative space; as future managers, they construct their careers and competencies in an individual and voluntarist way within a system of interrelationships between individuals in the company. Human resource management in FC company consists of encouraging and channelling these individual ambitions and increasing interrelationships between individuals.

In the Japanese JC company, the early, voluntary, phases of the construction of the careers of engineers with specialized competencies take place in a specific unit within the company. Then, taking these same specialisms as a starting point, their competencies are gradually extended along routes that take them into a series of closely connected technical areas. The training of "generalist" engineers, who may go into managerial positions, is a slow process that takes as its starting point technical and specialized knowledge that is gradually extended to other specialisms and to the management of men and technologies. Japanese engineers in managerial posts remain closer than their French counterparts to their original technical competencies.

2. THE HIGHLIGHTING OF SOME NATIONAL DIFFERENCES

The company monographs and statistical analyses form the basis of this comparison. In this second part of our conclusion, we will draw some very general results based on these documents and on the deliberations that have taken place both within the French and Japanese teams as well between those teams. These results are provisional and will be the subject of further debate and refinement.

The first result relates to the status of engineers in the two societies. In France, this professional and social status is clearly identified. The education system creates the rank of engineer, recognition of which precedes the entry of engineers into companies. This rank or title is a guarantee of both general knowledge and technical competence. In that respect, it cuts across all productive activities and is not directly and exclusively linked to manufacturing industry in the strict sense of the term. Indeed, within the state functions that it has had since it was first introduced, this is its greatest strength. This strength goes hand in hand with its scarcity value and its close association with the category of advanced technician, which is numerically larger and classified differently within the social and professional hierarchy. This is the origin of the heterogeneity of advanced technical staff that is a basic notion for firms. To which must be added the fact that the engineering schools are themselves socially and professionality hierarchised... In Japan, the rank of engineer does not exist as a basic notion imposed upon firms.

The identification between university science graduates and manufacturing companies particularly the larger ones is constructed over time on the basis of these companies' power of attraction and their ability to integrate these graduates into a specific management structure. Advanced technical staff constitute a population that is, a priori, undifferentiated and the "loose" management structure into which they are integrated stands in contrast to the French style of stratified management. It is true that hierarchies are eventually constructed in Japanese firms, but the methods of differentiation are developed over a long period of time.

As soon as they acquire recognition through their formal qualifications, highlevel technical staff in France, particularly engineers, are allocated tasks around which they construct a territory that concretizes their professional status. The a priori stratification between engineers (who are "managers") and technicians (who are not) means that engineers' jobs have an element of command and responsibility right from the outset. The occupation of their territory has a managerial dimension to it that conflicts with the technical dimension. The need for cooperation in technical spheres is not well served to say the least by two forms of compartmentalization, that arising out of the difference in status between engineers and technicians and that linked to the exercise of specific responsibilities (project leadership from the beginning of engineers' careers). In the case of Japan, a science graduate is not, as in France, a "finished product" which is realized immediately, within limitations but in its entirety. On the contrary, engineers are formed through a slow process of professional socialization characterized by the exploration, through continuous moves, of a zone of competencies. This process of exploration begins with a number of limited tasks that are effective in developing cooperation between the various actors in the technical function.

The way in which they are conceived means that these zones of competence overlap. Young, highlevel graduates in the early stages of their careers perform tasks that are the sole province of technicians in France and that never form part of the experience of engineers in French companies. Unlike the French case, Japanese management is characterized by the looseness and imprecision of organizational forms. Personal status is certainly less clearly defined and less certain, but work groups establish themselves on the basis of the cohesion and cooperation that are "natural" to them.

Thus mobility has a different significance in the two countries. In Japan, mobility is based on a succession of short moves which constitute a gradual, controlled extension of what we have termed the zone of competencies. This type of mobility sustains the capacity for cooperation and a high level of collectivization of productive activities. This mobility, which extends the zone of competence of each individual, may also be considered highly organized and managed. It is not solely the result of individual career strategies, even if it does go hand in hand with the increases in salary with seniority that are traditional in Japanese companies. In France, individuals move between functions that are organized as we have already said as territories or "empires". It is in each individual's interest to be mobile, in order to show that he is capable of understanding and mastering a variety of tasks, thus proving his adaptability. As a result, the career paths of engineers in particular constitute a series of breaks between areas of responsibility. Instead of leading to the accumulation of individual knowledge in symbiosis with a collective competence, they in fact constitute a series of experiences that make it difficult to determine the extent to which the demands of the most recent cancel out the benefits of those that went before. In contrast to the situation in Japan, the high status of engineers in France means they can adopt career paths driven for the most part by the opportunities they create for themselves,

Moreover, this state of affairs reinforces the distinction between engineers, who manage their own mobility and are encouraged to do so, and technicians, who are much more stable team members.,. Senior management plays little part in the management of mobility, except in superficial matters such as laying down the maximum number of years an individual may spend in the same job. Here as elsewhere, the high status of engineers is an obstacle to the collectivization of accumulated experience, particularly in the technical sphere. This then raises the question, particularly in the case of France, of the structures through which the various territories, functions and statuses are linked and enter into synergy. These structures are ad hoc fabrications whose role is to forge links between the different professional constructions that define the actors' territories. Thus the anticipation of future trends is the province of highlevel engineers, design that of engineers and technicians organized into teams and industrialization that of technicians and highly skilled manual workers. In Japan, these three types of technical professionalities are organized around the knowledge each one from engineers to manual workers has acquired of a science of production. One characteristic of this science is that the professionality of the production plant rises upwards to permeate those of research and design, or more accurately, to create a permanent link between these different types of technical professionality. This has disadvantages as well as advantages, and may make research less flexible and creative. In the case of France, the various actors identify with a sphere of competence and the relative power of their statuses from engineers at the top via technicians in the middle to manual workers at the bottom most definitely encourages communication from the top down.

In France, the way of thwarting the sequential nature of the design and industrialization process is to systematize and formalize the work by means of the project system. The existence of project groups blurs territorial boundaries and establishes the principle of cooperative synergy. The challenge then becomes one of building a continuous, consolidated process on ephemeral structures whose success depends on the strength of personality of those managing it. In Japan, it is the work group constructed as we have already stressed around the realities of the production process and of the actors involved in it that ensures that innovation processes proceed effectively. The social construction of engineers' status and the organizational functioning of firms serve to reveal provisionally some differences in the operation of the technical function and of the innovation space in the two countries. Technological trajectories are managed differently in the two countries. In France, they rely simultaneously on external growth (takeovers; use of the fruits of publicsector and university research) and a tendency to maintain profitable specialization's. This type of dynamic coincides with a concept of central management that is more business than technology oriented and gives a great deal of autonomy to the exercise of those occupations associated with the powerful status of engineers.

In Japan, the centralized management of technology and the decentralized mobilization of human resources are more closely integrated. The central laboratories are powerful. They provide the impetus for diversification strategies, and human resources are committed unevenly in accordance with the priorities of the innovation process. This is made possible by the breadth and continuous extension of each individual's zones of competence. The capacity for flexibility that characterizes the innovation space in Japan is in symbiosis with the homogeneity of the technical function, where the resources for innovation are more widely distributed, whereas in France they are concentrated on engineers, who are very much a minority relative to technicians.

This difference reflects the different ways in which the professionalities of technicians who lie midway between design and industrialization are constructed in the two countries. The greater stratification of the technical function in France leads firms in that country to produce intermediate actors and to a tendency for the organization to duplicate itself This state of affairs may give rise to unnecessary costs, losses of information and the wasting of time.

Finally, these two forms of technical professionality go hand in hand with differences in the processes by which knowledge is accumulated and elites are selected. In the case of Japan, he accumulation of knowledge is based on close cooperation and a system of mobility that guarantee the continuity and compactness of the innovation space. The selection of elites is based on recognition of effective participation in this process of collectivization. This may well lead to a certain degree of difficulty in giving birth to innovations characterized by discontinuity and favor the gradual shifts that characterize the true nature of the production of innovation in that country. In the case of France, competencies are accumulated through individual adaptation within a strategic mobility space. The selection of elites concretizes this process, which is characterized by discontinuity and the polyvalence embodied in each individual. The dangers of a loss of competence, knowledge and recall are obvious, even if in certain cases localized successes may be highly profitable. It would be inaccurate to give the impression that a clear distinction can be made between the strongly technical orientation of Japanese engineers and the more managerial, even administrative strategy adopted by engineers in France. In both countries, in fact, and particularly in hightechnology companies, engineers place great value on what might be called a successful technical venture. It is just that, in the case of Japan, technical creativity and the commitment of actors arise out of the need that each has of the other, of his specialization and competencies which, though only partly formed, foster the development of effective forms of hybridization. In the case of France, technical creativity lies in the modification of the trajectories adopted by occupations or specialties. These occupations or specialties are conceived as so many areas of excellence that constitute what we have called the innovation space.

3. INNOVATION, ACTORS AND ORGANIZATION: THE HEURISTIC VALUE OF THE SOCIETAL APPROACH

The preceding analyses have highlighted the most significant results of the case studies carried out in France and Japan, together with the national trends that emerge from them. Returning here to the societal approach outlined in the introduction, we shall discuss the contribution it may make to better understanding of the phenomenon of innovation. We shall make a distinction between methodological contributions and those involving the social actors, notably decisionmakers and managers working in R & D in public institutions and firms. In other words, in so far as the societal approach offers a new way of looking at the processes of innovation, it may also be of value for those who, on various accounts, are responsible for the organization and management of innovation.

3-1. THE SOCIETAL APPROACH TO INNOVATION: THE METHODOLOGICAL BENEFITS

Economists and sociologists have long been interested in analysis of this phenomenon, which is now considered one of the major issues of the next decade.

Economists have attempted to measure various parameters of innovation by using econometric approaches. They have been able in this way to compare different countries' capacity for innovation. In this case, innovation is considered essentially from the point of view of its scientific and technical content, in terms of inputoutput, and human resources are evaluated as so many units that can be posted in terms of stocks and flows. Similarly, each country's investment in R & D is measured in terms of expenditure and results. This is a quantitative approach, in which innovation is a static concept and the actors are reduced to units that are equivalent across countries.

For their part, sociologists have usually regarded innovation as a particular case of technical "change", and have attempted to measure the effects of it on work and workers ("before" and "after"). They have also analyzed the intensity and speed at which innovation is diffused, in the manner of epidemiologists. More recently, in the field of the sociology of science, innovation has been analyzed through the networks of actors who produce it and their strategies and interactions, or their competitive or cooperative relationships.

These last approaches, which are more qualitative than the preceding ones, do not, however, deal with the interdependencies that exist between firms, as innovation spaces, and society, or with the endogenisation of innovation in spaces socialized by the relationships between actors.

The societal approach to innovation attempts to fill the gaps in the approaches outlined above, both economic and sociological, but from a completely different point of view; it is more qualitative, more comprehensive and more dynamic.

It is qualitative in that it is not restricted to quantifiable phenomena. It seeks rather to go beyond quantitative data in order to reveal the social forces at work and the logics that guide them.

It is comprehensive, because it analyses the interdependencies between micro and macro phenomena and the effects of these interdependencies on the quality of the innovation space and the professionality of actors.

Finally, it is dynamic because it examines closely the various processes that help to produce innovation, as well as the learning and socialization processes through which the actors' creative capacities are developed and organized.

Thus innovation emerges as a complex social phenomenon, the various components of which are arranged by each society in its own way (although within the limits of its own resources and capacities).

Comparison of the processes of innovation in French and Japanese companies consists, in this approach, of identifying similar elements in a basic structure which, nevertheless, has its own logic in each society. The heuristic effect of the societal approach is to highlight both the relevant elements in this basic structure and the social logic's at work in each country. This in turn reveals the forms of innovation specific to each country, together with their capacity for innovation.

3-2. THE CONTRIBUTION OF THE SOCIETAL APPROACH TO THE MANAGEMENT AND ORGANIZATION OF INNOVATION

The capacity of a country (or of its firms) to innovate is constructed and developed over time, and we are now witnessing an acceleration in the pace of innovation, and in particular a shortening of the time that elapses between the development and production of a new product and its market launch.

Each of the elements that help to produce the innovation space (higher education, investment in R & D, the social links between actors in firms and between firms, the construction of a market, etc.) has its own time scale, and in each country these various time scales are not necessarily the same. This may give rise in each case to competitive advantages or disadvantages.

As we have seen, the transition from R & D to production, and the various processes of "feedback" involved in the internal transfer of technology, proceed more or less rapidly and more or less efficiently, depending in particular on the "social construction" of the actors (engineers, researchers and technicians). The issues in this sphere cannot be analyzed solely in quantitative terms.

There is no doubt, for example, that the shortage of engineers is similar in France and Japan. And it may be (although this still needs to be verified) that the training provided by the universities for physicists and chemists is similar in both cases.

However, the forms of socialization, both professional and social, are different, and this will undoubtedly have effects on the competitive advantages of the same sector of activity in the two countries. Many more examples taken from our case studies could be provided.

However, it is not our purpose directly to assess such advantages. Rather, the societal approach makes it possible to identify the elements in the basic structure mentioned above, and to assess their contribution to the collective process of innovation or creativity when they enter into relationships of interdependence with other elements in the same basic structure.

Thus in France, for example, the stratification of technical jobs (between engineers and technicians, which is reinforced by the new engineers, the socalled "technologues"), is such that it might give rise to rigidities in their relationships and communications. In order to counter these "risks", firms have to make certain nontangible investments in order to improve the circulation and accumulation of knowledge and knowhow.

Such investments seem less necessary in Japanese companies, which undoubtedly make different choices by devoting greater resources to the internal socialization and training of their university graduates, notably through the management of their career mobility. The resultant endogenisation of professional competencies probably more than compensates for the effects that can be expected from the intangible investments made by French firms.

On the other hand, at a time when Japanese companies are concerned more than ever before with the development of their basic research capacity and with fostering the creativity of their engineers and researchers (in collaboration with other employees), it might be wondered whether French companies do not in fact enjoy certain comparative advantages. Making use of a relatively more extensive system of publicly funded research (universities, CNRS), they have also been able recently to improve their cooperation with organizations and institutions in that system, and have undoubtedly made more effective use of such cooperation than their Japanese counterparts. However, this has not necessarily improved one of their weaknesses, namely the industrial development and marketing of new products.

Similarly, it might be that the more autonomous career strategies of French engineers or researchers strengthen their individual creative abilities, although in some cases this may be to the detriment of the collective accumulation of competencies.

However, could it be the case that what has hitherto been the strength of Japanese companies, namely the science of production and development, is the weakness of French companies, and vice versa? We do not think this is necessarily so, since changes are taking place in both countries. And the debate on the merits (or demerits) of individual or collective creativity is still going on. In the societal approach, the form taken by creativity cannot be considered as an independent reality. Rather, it is the result of a set of relationships between the professionality of actors and the quality of the innovation space. It is in this sense that we speak of "organized creativity" (a term inspired by our observations in Japan).

Thus the societal approach is not necessarily being used here to assess the merits or demerits of the French or Japanese "model" of innovation. The value of this type of approach seems to us to lie rather in the way in which we formulate the questions specific to our research (in this case, how the professionality of engineers and researchers and the innovation space are constructed). However, to pose these questions in new terms is also to give new answers.