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QUALITY ASSURANCE PROGRAMME AND QUALITY CONTROL.

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ABSTRACT

The objective of this paper is to analyze the most relevant roles related to quality control and assurance corresponding to the participants in nuclear power projects in order to achieve reliable, safe and economical plants.

The paper begins by analyzing the bases for the establishment of a nuclear program on a national level and the participation corresponding to the different organizations carrying out activities in a nuclear project, following up with the study of a specific case.

The author intends to transmit his own experience in connection with the Spanish nuclear programme, with which he has been linked since its beginning. An experience of this kind is felt to be useful for those attending this seminar for the following reasons: 1) When the programma began, the country's industrial substructure was still very slightly developed; 2) the programme's specific aims were to obtain a source for the national energy supply and to be "the driving force" of technological development; 3) in Spain the owners of the plants are largely private, and the choice of the plant type and the execution of the project have been governed by a competitive market on an international level; 4) the Government has determined the minimum percentage of national participation for each project and 5) presently the are three plants in operation in the country, seven in an advanced phase of construction and seven more in an initial stage, which makes it possible to reach some conclusions which can serve as a means of comparison for countries initiating a nuclear programme. The author wishes to emphasize the fact that the programme has been developed in accordance with the codes, standards and recommendations of the International Atomic Energy Agency, on the basis of which we are setting up specific technical regulations. This is a circumstance which has allowed us to create a substructure according to internationally accepted principles.

FIRST PART

1. BASES FOR THE STRUCTURE OF AN ORGANIZATION FOR THE MANAGEMENT OF A NUCLEAR POWER PROJECT

The effort required of a country in order to build its first nuclear power plant can be put forth successfully, if one of the necessary important conditions (although not sufficient by itself) exists - that is, there must be an awareness on a national level of the magnitude, the complexity and responsibility involved; that means, as a first stage, an adequate framework and the organizations which will allow it to progress must be structured, ensuring health and public safety at the same time.

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On the other hand, the construction of a nuclear power plant has a multiplying effect on the technology of the country, in the sense that if the nuclear plan is well established, the quality level of the industry and the experience of the engineering and technical staffs will improve. The plan has to show consideration for the construction of a whole plant and not an isolated unit.

In the past decade, it was frequent practice to contract a power plant on a turnkey basis, which means that the main supplier or architect-engineer carried out the entire management of the project up until the moment of commercial operation of the power plant. In that way, a very limited transfer of technology is effected to the engineering companies and domestic manufacturers, except the constructors of public works and some fitters who participate to a very slight extent. For these reasons, and because of the higher costs of the power plant, this approach has been practically abandoned and it seems advisable to create an organization for the management of the project, which will subcontract the necessary services, but will always maintain the direction and responsibility of the management.

It is a fact that for the progress of the construction of a nuclear power plant to be reliable, safe and economical, it is necessary to begin with the establishment of an adequate organization which eventually will have to incorporate professional engineers who will carry out the different missions which such a project requires, with competence and responsibility. The structure of the organization has to be set up as soon as the objectives are defined and as early as possible in advance, because it is foreseeable that numerous trained or specialized engineers and technicians will not be found in a developing country. However, with an adequate framework and time, one can encounter them, but without that, final success is always doubtful; there is a principle which says: where an organization with clear lines of authority is lacking, there is no responsibility, and without responsibility there is no quality.

In figure 1 is shown the basic management organigram for the planning and implementation of a nuclear power plant project. It is assumed that the venture is established by means of an association of public and private companies, such as electric utilities, promoting entities, and so on. It is considered that the best way to make a project of such importance successful is to bring together the available sources, which do not normally have supplies in a developing country.

In the first stage, when the organization is already structured, it is only necessary to cover certain positions in order to study the project feasibility, necessity of the nuclear power plant, capacity of the grid and the size of the power plant; sites selection; financing, etc. Such positions should include that of the manager or executive director, project manager, legal and financial advisers and the quality assurance manager of the organization. This team will have recourse to the collaboration of consultants outside of the organization, who can advise about specific questions. Afterwards, when the stages of the project are defined, the remaining positions of the chart in figure 1 will be covered.

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2. APPLICATION OF THE CRITERIA OF QUALITY ASSURANCE TO A NUCLEAR POWER PROJECT

Once the organization for the management of the project has been established and the site selected, the particular characteristics of which will be known, the preparation stage of the technical specifications begins, for the subsequent petition of offers from the main suppliers of the different parts of the power plant (nuclear island, turbo-generator, etc.). At the same time it will be necessary to research the domestic market in order to determine in principle the participation to be expected of the engineering companies, manufacturers, public works builders and installers of the country, who will all have to participate in proportion to what they will be able to show objectively, so that their services or products will have the required level of quality. The project management organization, and most concretely the quality assurance department, have an arduous task in identifying all of the existing industrial activities in the country, which because of its lack of development, will not be abundant, and in determining what each activity can contribute to the project. At the same time, a technical information task should be performed in order to point out the quality requirements of the nuclear project which, although always requiring an initial effort of reorganization and equipment, will have the advantage that any one who has been manufacturing quality products, generally will find the economical incentives to maintain this level. Experience always confirms that manufacturers who understand how to obtain and to prove the quality of their products with objective evidence and who remodel their factories adequately, are completely successful.

To ensure the participation of the greatest number of domestic companies, engineers and technicians in the project, however small the contribution of each may be, should be que of the main goals of the project, for it is here where the transfer of technology will take place, affecting the future national development. The equilibrium between the objective of domestic participation and the quality of that participation must be established and supervised by the department of quality assurance which, as you can understand, must be made up by a staff which experience in their work and with a vocation and conviction of the necessity of quality assurance, which essentially have as their aim the fact that things will go well according to the state of the art as can ben evidenced in an objective way.

3. THE REFERENCE PLANT CONCEPT

To achieve the goal of building a power plant which will be reliable and safe (this means, that it will produce the projected quantities of energy without unacceptable risks for the public) and economical besides, it seems to be most wise and conservative to keep in mind that one power plant is practically the same as another, which has succeeded in fulfilling these objective, with no changes other than those which are derived from the characteristics of the new site (seismic, geotechnical, etc.). However, considering that projects will evolve, with improvements in every new construction, the use as a reference plant of a power plant already in operation for some time, has the drawback that the improvements introduced in the most recent ones are lost; this is the reason why we should take as a reference plant an

established prototype, whose definitive power plant is under construction and has some advancement of the date take advantage of the experience of the construction and of its start-up phases.

Once the reference plant has been defined and specified with no innovations, in principle, other than those derived from the characteristics of the new siting, a part of the objective is assured.There remains the very important aspect of quality, as the above-mentioned concept would worthless, if measures were not taken to reasonably ensure that the power plant will be built with the same quality requirements as those of the reference plant. Because the developing country does not have advanced technical codes and standards available, the wisest thing to do is to take as mandatory the ones applied in the reference plant, even for those parts of the project which are manufactured in the country, for you cannot forget the axiom that the whole can not be of better quality than any one of its compenents which has less.

SECOND PART

4. MAIN PHASES AND ACTIVITIES OF THE PLANNING AND CONSTRUCTION OF A NUCLEAR POWER PLANT.

In the development of a nuclear project, there are essentially three phases with specific characteristics:

- Preconstruction phase.
- Construction phase.
- Operation phase.

Below, the most significant activities in each phase, which are shown in figure 2, are commented upon:

a) The preconstruction phase. As a first stage you have to structure the preliminary organization of the project, on the basis of the criteria described in the First Part.

The executive board with the executive director and appropiate consultants must define the organization objectives and the basic effort. Likewise, they have to decide which contract type they will set up in principle (turnkey, partial turnkey, by packages etc.). The next step after such a decision is the selection and nomination of the department managers of the organization by the executive director. Among these, there must be the quality assurance manager, whose first job is to prepare the basic quality assurance programme for the project, which will prepare the way for a coordinated and homogeneous development of the project activities.

- Activities planning and scheduling. Once the activities mentioned in the preceding paragraph have been concluded, you should go on to a study of the site, which will lead to the selection of one or several locations which, in principle, fulfil the required characteristics. In such studies you must rely on the participation of domestic experts in geology, seismology, hydrography, metereology, ecology, etc. for whom the owner organization will define the objectives and specifications, which

have to be fulfilled. It is always advisable and necessary in some cases, to contract the services of foreign consultants, although these consultants should not be contracted for the realization of the full study, as you should take advantage of national resources to the highest degree possible and generally nobody will know the country better than the domestic experts. The following organization task is to investigate the feasibility of the project and, in consequence, if the case warrants it, the preparation for the call for bids which must include concrete technical specifications. The next activities should be the application for the site licence to the proper authority, selection of the NSSS, the balance of the power plant (BOP) suppliers and finally the development of the quality assurance programme.

- The development of the project. Once the main suppliers have been chosen, you will have to perfect the owner organization so that it will be able to realize its own activities and at the same time to decide and check those which are contracted with the architect-engineer and the specialized consultants. It is essential to define the codes and standards applicable to the project, how and by whom the design review will be carried out, and to establish which departments within the organization are to prepare the preliminary safety report and other documents which serve as a support for the construction permit application.

b) The construction phase. In this phase, that of the construction itself, one may distinguish fundamentally:

- Procurements or purchases. The prequalification of all the suppliers, especially that of the domestic ones, is an important task in order to obtain the desired technological transfer. Generally, they will have to be advised and encouraged, in order to make possible the fulfilment of the quality assurance requirements.

- Manufacturing. In order to have a reliable and safe power plant, it is necessary for the domestic as well as for the foreign manufacturers to fulfil the requirements which are called for in the project country. You will have to pay special attention to and adequately control the domestic manufacturers who do not have previous experience in this activity. The realization of non-destructive tests (NDT) and the review of non-conformance parts must be followed with special attention.

- The plant erection. This activity begins by the excavation of the site to which the established criteria of the quality assurance must be applied. In the same way, such criteria and structures which arrive at the site, while the entry of those which do not exhibit release for shipment and package data are not accepted ("hold").

During the construction itself, which several years, it is necessary to train the operation staff and the industrial security team of the power plant, to prepare the final safety report and, of course, to inform the public adequately.

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- The preoperational tests and start-up of the plant

The owner organization must prepare the programmes of preoperational tests, the operation manuals, the technical specifications and the emergency plans, which are going to regulate the operation of the power plant.

THIRD PART

5. THE SPANISH EXPERIENCE

Presently, three nuclear power plants are in operation, seven units are in different phases of construction, another three will initiale their construction soon and, probably, at the end of the present decade, additional units will do so (Figure 3). The power plants are usually classified into three groups or generations, as each group has been directed by specific criteria.

a) First generation plants. This group includes the three plants presently in operation, which were contracted under the turn-key system and whose national participation was on the order of 40% of the total plant costs, that means, interest during the construction, land values, etc. are included. In this form of contracting, the transfer of technology was small, but it was the only way to make a start in a new field which presented so many uncertainties.

b) Second generation plants. This group includes the seven units under construction and whose management and technical direction is carried out by the owner companies, which contract the necessary services (consultants, engineering, etc.) and whose first activity is the preparation of the technical specifications related to the biddings for the NSSS, turbo-generator etc.

In figure 4, the plants'construction costs are broken down and listed, so that it can be stated that, the national participation is over 65% of the real construction value. To achieve this figure, the electric companies have contributed by encouraging the participation of Spanish technology (whenever in light of the required quality this would be warranted, even though at the expense of a higher cost than for international technology), the engineering companies have acted as the "driving force" of the development and the Administration has promulgated the legal, technical and administrative standards channeling and giving the necessary fluency to the structural development. Mention can also be made of the tariff and fiscal deductions which are offered to the domestic manufacturers, who are to manufacture some parts of the components for the nuclear power plants in collaboration with other foreign companies, whenever the domestic percentage would surpass the established minima in any case. This policy has made it possible for components of great technical responsibility to be constructed in Spain (pressurizers, parts of the emergency refrigeration system, valves, pipes, etc.), and the firm "Equipos Nucleares S.A." is beginning to manufacture vessels and other components of the nuclear steam supply system.

c) Third generation plants. In accordance with the National Energy Plan, several 1000 Mwe units will make up the third generation and will go into service between 1980 and 1990. In these units the domestic participation will be consolidated, surpassing 80% of the real value of each, thus contributing to adjust the commercial balance and at the same time promoting Spanish industrial and technological development. The objective is to eventually bring about the creation of a company integrating the firms "Equipos Nucleares S.A.", " Empresa Nacional de Uranio S.A." and others, which could obtain the NSSS supplier licence.

6. SPANISH PARTICIPATION IN THE NUCLEAR PROGRAMME

Below, we are analyzing the most significant activities of the participation in the present-day construction of the so-called "second generation plants".

a) Organization of the project. In contrast to what was established in the first nuclear power plants, where the organization of the project mainly depended on the main supplier, this is carried out by organizations formed by the owner companies themselves at the present time. The experience achieved in this field is truly important, especially with regard to those activities which are not included in the main supplier's contract. In almost all cases, programming and follow-up methods for the projects are applied through the utilization of computers.

b) Design engineering. The design engineering of the NSSS is carried out completely by the main supplier. The design engineering of the BOP, including the design of the buildings, is carried out by associated Spanish engineering companies, which have foreign engineering firms, mainly from the United States, as consultants.

c) Manufacturing. The greater part of the mechanical components of a nuclear class are being manufactured in Spain. In the case of the NSSS, the manufacturing is normally carried out under a foreign license, while the situation is very different for the mechanical components of BOP.

The manufacturing of electrical equipment is basically domestic, except for the emergency diesel generators which are imported. On the other hand, the situation of the manufacturing of the instrumentation and control equipment is quite diverse according to each particular case. Some NSSS suppliers have set up factories for assembling this equipment in Spain, but the field of the manufacturing of instrumentation and control equipment is less developed in the Spanish nuclear industry.

d) Erection and civil work. The erection of the plant, both mechanical as well as electrical, is carried out almost entirely by Spanish companies. The civil work is likewise carried out by Spanish companies with extensive experience in the field.

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7. PROBLEMS RELATED TO QUALITY ASSURANCE WHICH AROSE DURING THE CONSTRUCTION OF NUCLEAR POWER PLANTS IN SPAIN

Experience shows that in many cases, deviations arose which could have been avoided, if the quality assurance techniques had been applied in a more strict manner from the beginning of the project. In other cases, in contrast, there were foreseeable deviations in the development of a project which could be easily controlled, or others caused by unforeseen technological situations, difficult to avoid in any case; however, these should appear very rarely, as the reference plant concept is used.

a) Problems related to the organization of the project

Among the typical problems found in Spain regarding the organization of the project, we can point out the following:

- The lack of definition in the lines of responsibility of the project organization. In some cases, problems have arisen between the organization of quality assurance and other organizations.

- Lack of experience of the staff of the organization of the project with regard to the tasks assigned, together with the little-defined situations brought by a staff which is not highly specialized and tends to different tasks indifferently, and changes in the staff occupying positions of great responsibility, due to the great demand for nuclear engineers. In some cases, persons with little experience can hold positions of great responsibility.

- Lack of definition and procedure in the relationship between different organizations (interphases), thus creating poorly defined areas giving rise to problems occuring a posteriori which are very difficult to solve.

b) Problems regarding the site studies. The deviations occurred during the site studies stage, are those which have given rise to the most important problems involved in the construction of Spain's nuclear power plants. Many of these problems are derived from a lack of application of the quality assurance techniques during this stage of the project.

The repercussions of these failures in some cases have been important, both from an economic point of view as well as regards execution deadlines, while occasionally costly studies, changes in design and repetitions of work in conditions much inferior than initially have been necessary.

We are going to mention the following cases:

- Modification of the seismic acceleration of the ground after making the dynamic design of building and structures.

- Inadequate planning of geotechnical drilling campaigns.

- Incomplete or inadequate topographical following of differential movements of the ground and the buildings.

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c) Design engineering. The main problems arising in the design engineering are derived from the lack of capacity and preparation of the project organizations in order to carry out an adequate follow up and control of the activities of the engineering firms, and very especially as regards the main suppliers. In some cases modifications have been introduced in the design without being properly verified and controlled, and thus these verifications were required after the manufacturing of the equipment, which brings about an undesirable situation from a quality assurance point of view.

Among the most typical cases in which this situation tends to occur, we can mention the antiseismic design of structures or components and the modifications of the pressure and temperature transitory values as well as the modifications in the specifications to prevent certain problems found in the plants in operation.

To avoid or reduce such situations, the project organizations tend to contract consulting firms in the field of design quality assurance.

d) Problems arising during manufacturing. The problems arising during the manufacturing of the mechanical nuclear equipment do not differ from those which tend to appear in other countries. The application of the systematic inspection plans has made it possible to detect typical deviations such as oxidations, contamination of the stainless steel, rejected pieces mainly of cast steel, sizing errors, incomplete quality assurance documentation, as well as the discovery of non-conformities in pump prototype tests, hydrostatic tests on equipment having parts from different factories assembled for the first time in the field, etc.

Which regard to the manufacture of electrical equipment, mention should be made of the difficulties in the application of the standards of environmental qualifications of electrical cables and the problems derived from the prototype tests on motors manufactured in the United States with a frecuency different from that used in Spain.

The problems of the manufacture of instrumentation and control equipment deserve special interest, as this is an area which usually received little attention in the quality assurance programmes, mainly due to the complexity and disperse nature of the pertinent standards and regulations.

e) Problems arising during transportation of the nuclear components. A large part of the deviations of highest significance in quality assurance of the nuclear components have been produced during transportation, mainly due to the failure of applying the quality assurance standards in this stage. This fact should be blamed mainly on the circumstance that the transportation of these components is a typical interphase problem in which situations difficult to control arise.

Among the most typical deviations produced in this phase, the following deserve being pointed out: oxidation occuring in large components due to insufficient protection during sea transport or to the use of inadequate vessels, damage caused

by defective handling in ports, losses of identification and documentation, temporary storage in places with contraindicated ambients, etc.

f) Problems occuring during erection. The problems occuring during the mechanical erection are the normal ones in this type of activity, Some unforeseen problems have arisen regarding the welding in the field of large components and with inadequate erection sequences of large tanks and structures, especially in cases of changes in design with insufficient experience on the part of the erection engineering.

Problems have been encountered insofar as the laying of cables and their identification, with the antiseismic design of the cable pallets and with the introduction of modifications which were not revised for all of the parts involved.

g) Problems involved with the civil work. The main problems involved in the civil work are due to settlements greater than those foreseen in the filler supporting the building, which has made it necessary in some cases to alter the design of the slabs supporting them. Also, problems now solved arose due to the fact that Spanish standards, quite well developed in this field, are noticeably different in some cases from those of the country of origin of the plant referred to.

Other questions which initially gave rise to frequent deviations are: laying of concrete in cold and in hot weather, the pouring of concrete in very dense reinforcement structures and the qualification of "Cadweld" welding procedures. In some cases, the complexity of the geometric arrangement of the bars, orifices and post-tensioned sheaths has made it necessary to carry out a modelling in order to solve problems of erection sequence.

FOURTH PART

8. IMPLANTATION OF THE QUALITY ASSURANCE IN SPAIN

As pointed out earlier the first generation power plants (fig. 3) were contracted under the turnkey concept. In this type of contracting the capacity of management and action on the part of the owner company was reduced essentially to a certain supervision of the project and the construction of the plant. On the other hand, the participation of domestic manufacturers and engineering was also limited, except for that of civil works construction. However, when taking into account that such plants were contracted in the first half of the sixties, probably the turnkey contracting was the most prudent form of entering into the nuclear field for a country which at that time was just initiating its development. In reality, three plants were obtained which have operated satisfactorily, however, the transfer of technology was very sparse.

Spain's nuclear program had two well-defined objectives,

a) to make available sources for the electric power supply and

b) to contribute to the technological development of the country by means of a true and real transfer of advanced technology. With reference to the latter aspect, it was evident that in order to significantly increase domestic participation, it was necessary to abandon turnkey contracting and to substitute it by contracting by packages, managed by the owner company, which would strive to achieve maximum domestic participation. The limit of the domestic participation had to be set by the quality to be demanded of the different components and services, and to a lesser degree by the price and even the delivery dates. The quality assurance techniques have been the instrument which provides the due equilibrium between the two members of the domestic participation-quality binomial.

After having studied in each era the possibilities of domestic participation, the Spanish Administration has been setting a minimum for this participation in each construction authorization. For the second generation plants presently under construction, a minimum of 60% of the total cost of the plant was established. From available data it can be concluded that the real technological participation or added value will surpass 50% of the total. The fact that six of the seven units making up the second generation have the same supplier for the "NSSS" (fig. 3) has contributed to the achievement of these values. This was an incentive for domestic industry, which saw the possibility of obtaining on a short-term basis an acceptable number of orders which would compensate for the economic and technical efforts required for entering into the nuclear field. It was necessary to convince the domestic suppliers of goods and services that they had to demonstrate clearly and objectively the quality they were committing themselves to incorporate into their products -a quality which would later have to be accredited in the data packages. The manufacturers with experience and prestige in the country did not react very favourably, alleging that over the years they given sufficient evidence of their quality and that the only intention now was to produce written documentation which would add nothing to the quality. On the other hand, the small manufacturers or those who were starting their activities were more receptive and accepted the challenge involved in preparing their respective quality assurance and procedure manuals.

The regulatory body required the electric companies to organize their own quality assurance departments, with a capacity for prequalifying the domestic industry, which in no case could manufacture components for a plant unless explicitly authorized to do so by the Administration. At the present time, approximately 120 authorizations for the manufacture and assembly of mechanical, electrical and civil work components of a nuclear type have been granted.

Insofar as the components manufactured outside of Spain, they must necessarity be designed and manufactured in accordance with the codes, standards and guidelines required in the country of origin of the project for each plant. Both in the case of domestic as well as foreign manufacture, it is the

responsibility of the electric company to check that the standards established are fulfilled, before allowing any shipment to enter the site. Since the plants under construction are all of a U.S. origin, the standards of that country are to be applied. Some problems have arisen when certain components were manufactured in European countries which do not apply U.S. standards. These have been solved by requiring that objective proof be given that these standards, as a minimum, are fulfilled.

9. FORMS OF ESTABLISHING A QUALITY ASSURANCE ORGANIZATION

Spain's development involved an increase in the electric power demand, which was met, as from the fifties, by building conventional thermal and hydroelectric power plants. The electric companies at that time organized quality control services which used the non-destructive testing (NDT) techniques, among others. These services and other independent services which worked in the industrial field had competent, well-qualified personnel. The quality assurance deparments of the companies which constructed nuclear power plants drew on this personnel. Nevertheless, it was necessary to "indoctrinate" this personnel in the new philosophy of an integral control of the quality or "quality assurance", which arose as a result of the failures and low availability of the plants which had been constructed in the United States and other countries. The indoctrination consisted of making these persons aware of the objective pursued of reaching a determined level of quality, for which purpose it did not suffice to merely apply the quality control, which is a part -a really important part- of the quality assurance . Later, persons selected as quality assurance department heads were sent to U.S. organizations which applied the quality assurance techniques, where their training was completed during stays of six months to one year. Thus, a nucleus of professional persons in quality assurance trained on the job was achieved. At the present time, the training of professionals takes place in the country itself, where courses for graduates are given in the technical universities.

The electric company which decides to build a nuclear power plant establishes its quality assurance deparment as from the first stages of the project, following an organization diagram similar to that shown in Fig. 1. It essentially consists of a department head and six or eight experts in the activities listed. These experts generally have experience in earlier projects, either foreign or Spanish, and hold diplomas awarded by the universities. The department also has assistants for these experts and a team of from four to six persons specialized in the different quality control techniques. Consequently the department is made up by approximately twenty experts. This staff prepares its own quality assurance and procedures manual, and contracts the services of inspection and control firms which act in specific activities, by delegation, whenever this may be considered advisable. In order to give an idea of domestic capacity in the specific field of the END's by X-ray and gammagraphy techniques, there are presently 3 linear accelerators of 8 Mev each, 150 sets of X-ray equipment and approximately 200 gammagraphs with a total maximum activity of 18,000 Ci.

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10. COST OF A QUALITY ASSURANCE PROGRAMME

It is estimated that the owner of a power plant, insofar as the goods and services purchased, will pay more than 10% of the cost of same for the quality assurance in all of its aspects, as applied specifically to what is purchased. Taking into account the fact that the quality is something which should be incorporated in the item or service, it is of primary interest for the owner to verify that it is constructed with the quality required, checked by the necessary quality controls which will identify deviations whenever they occur.

As a result, it is necessary to specify that insofar as the quality, there are two aspects a) what the owner pays the supplier for the control and integral management of the quality of the goods and services supplied, which is on the order of an average value of 7%-10% and b) what the owner's own quality assurance department costs him, which will prove in an objective and direct manner whether the goods and services purchased have the quality specified in the respective purchase contracts. Without a doubt, it is difficult to estimate this latter cost, but it can be indicated as being on the order of 1 to 3% of the cost of the plant.

FINAL REMARKS

From what can ben concluded from the above, and from the author's own experience, it can be deduced that, in order to construct a power plant, you must take the following considerations, among others into account:

a) The signing of any contract with the main suppliers, engineering companies or consultants, should only take place, once the technical points have been determined and the corresponding specifications have been determined. A contract that is not well prepared sometimes causes irremediable problems. The main contract should stipulate that the project is based on an established prototype in the country of origin (reference plant). Concerning this, only very justified innovations should be accepted besides those which are conditioned by the characteristics of the chosen site. The reference project should be available to the project management organization and, of course, for the government of the developing country, without restrictions.

b) The organization of the Government to safeguard public health and safety controlling the project, and the organization for the proyect management should be independent and adequately structured, both relying on a suitable, responsible and experienced staff.

c) It is necessary to apply realistic criteria regarding the quality requirements of each "package" of the contract (nuclear island, turbo-generator etc.) bearing well in mind that the quality of each "package" must be homogeneous.

d) The application of the quality assurance criteria, which is necessary in all countries, has vital importance in developing countries undertaking the construction of nuclear power plants. The quality assurance is the tool of the management by which objective and documentary knowledge is had concerning the quality with which each component is going to be manufactured and set up and, therefore, it makes it possible to take corrective action at the moment when foreseeable quality deviations take place.

e) The domestic manufacturers and constructors, who participate in the project, not only must think of improving their factories with new equipment, but also of making the decision, along with all of its consequences, to direct the introduction of the quality assurance techniques.

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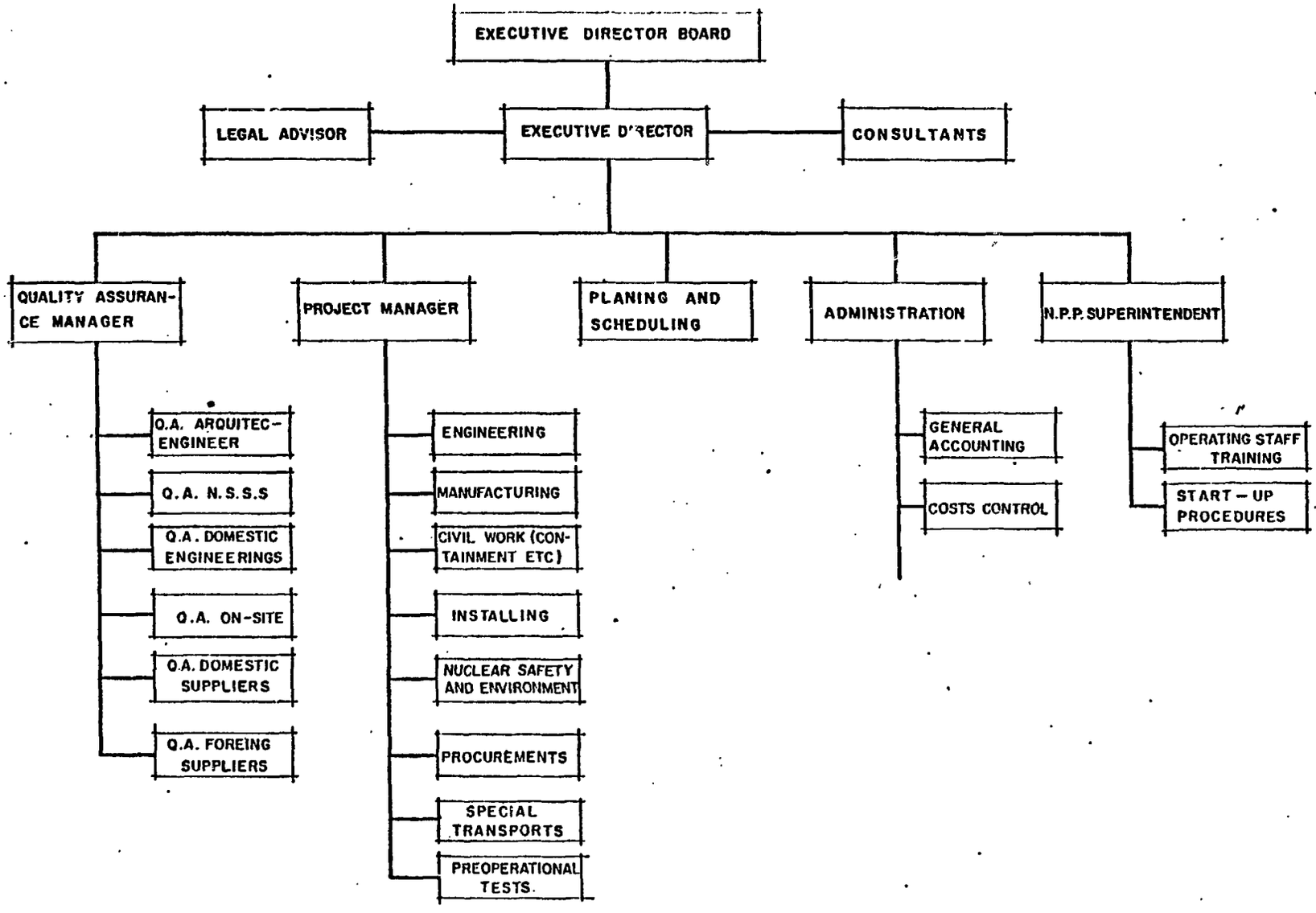

FIG. 1.– BASIC NUCLEAR POWER PROJECT PLANNING AND CONSTRUCTION ORGANIZATION CHART.

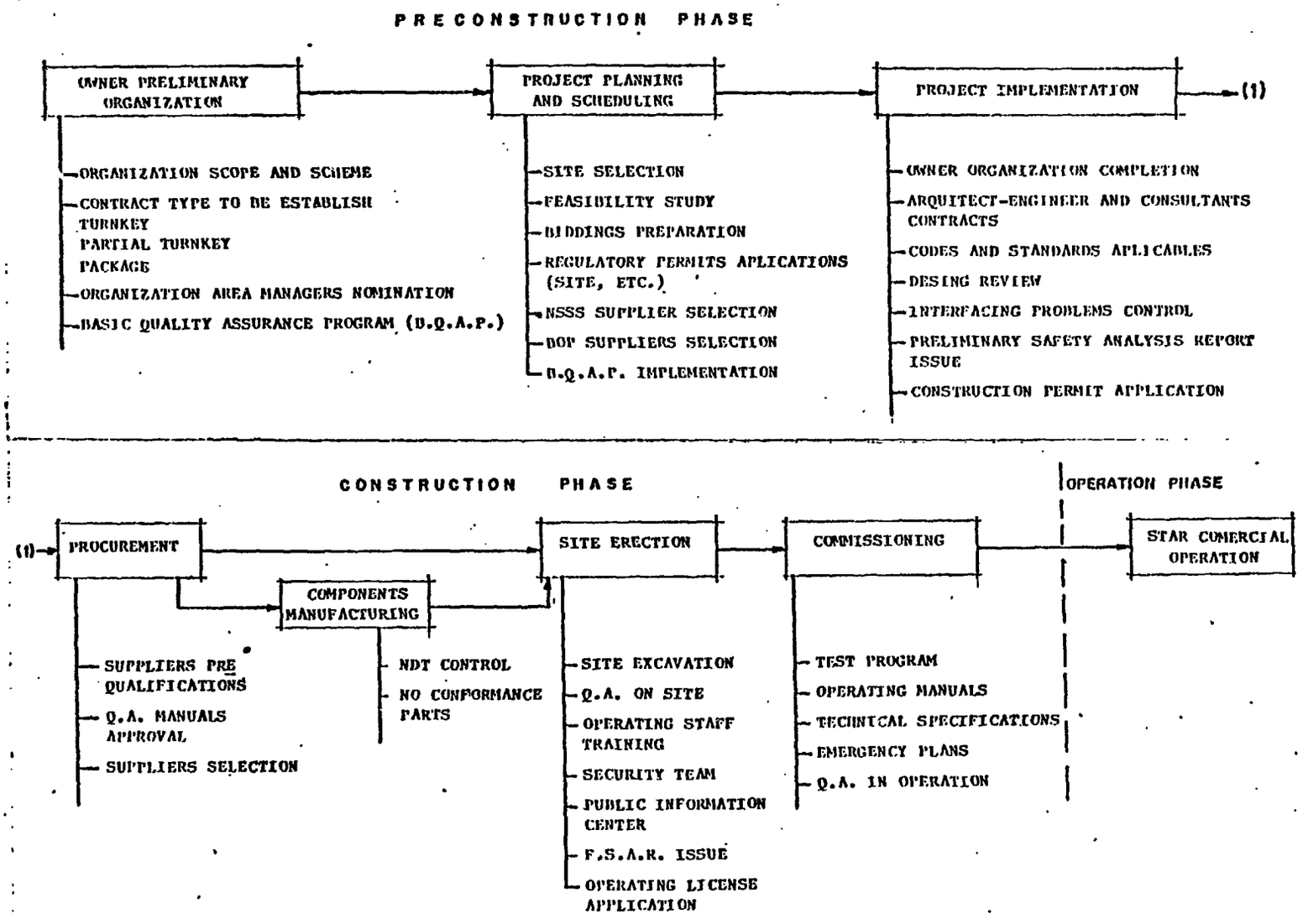

FIG. 2.- NUCLEAR POWER PROJECT PLANNING AND CONSTRUTION MAIN PHASES.

	POWER (Mwe)	PLANT TYPE AND NSSS SUPPLIER	PLANT DENOMINATION	CONSTRUCTION STARTS, YEAR	COMERCIAL OPERATION YEAR
FIRST GENERATION PLANTS	160	PWR(W)	JOSE CABRERA	1965	1965
	460	BWR(G.E.)	Stª Mª GAROÑA	1966	1971
	500	GCR(France)	VANDELLOS I	1967	1972
SECOND GENERATION PLANTS	930	PWR(W)	ALMARAZ I	1972	1979
	930	PWR(W)	ALMARAZ II	1973	1980
	930	PWR(W)	LEMONIZ I	1972	1981
	930	PWR(W)	LEMONIZ II	1973	1982
	930	PWR(W)	ASCO I	1974	1980
	930	PWR(W)	ASCO II	1974	1981
	975	BWR(G.E.)	COFRENTES	1975	1982
THIRD GENERATION PLANTS	1000	BWR(G.E.)	VALDECABALLEROS I		
	1000	BWR(G.E.)	VALDECABALLEROS II		
	1000	PWR(W)	SAYAGO		
	1000	PWR(KWU)	TRILLO		
	1000	PWR(W)	VANDELLOS II		
	1000	-	VANDELLOS III		
	1000	-	REGODOLA		
TOTAL	15000				

FIG. 3.—ESTIMATED NUCLEOELECTRIC POWER INSTALLED IN SPAIN (1990)

CONCEPTS	PLANT CONSTRUCTION COSTS BREAK DOWN (*) %	PLANTS IN OPERATION (1st generation). DOMESTIC PARTICIPATION IN %		PLANTS UNDER CONSTRUCTION (2nd generation) DOMESTIC PARTICIPATION IN %		CONSTRUCTION PLANNED PLANTS (3rd generation) DOMESTIC PARTICIPATION	
		IN EACH CONCEPT	IN THE TOTAL	IN EACH CONCEP	IN THE TOTAL	IN EACH CONCEPT	IN THE TOTAL
1. CIVIL WORK	16	81	13.0	100	16	100	16
2. EQUIPMENT	61	25	15.0	50	30.5	71	43.3
2.1. NSSS	(19)	-	-	(34)	(6.4)	(60)	(11.4)
2.2. TURBO-GENERATOR	(13)	-	-	(29)	(3.8)	(45)	(5.8)
2.3. BOP	(29)	-	-	(70)	(20.3)	(90)	(26.1)
3. INSTALLING	6	66	4.0	100	6	100	6
4. ENGINEERING	8	50	4.0	70	5.6	90	7.2
5. STAFF TRAINING	1	50	0.5	80	0.8	100	1
6. PROJECT MANAGEMENT	6	33	2.0	80	4.8	90	5.4
7. MISCELLANEOUS	2	-	2.0	70	1.4	90	1.8
TOTAL	100		40.5		65.0		~ 81.0

(*) The financial and land costs, etc, are not included,

(**) Not very represantive as the costs breakdown is referred to LWR of 1000 MWe

FIG.4.-DOMESTIC INDUSTRY AND ENGINEERING PARTICIPATION IN THE CONSTRUCTION OF NUCLEAR POWER PLANTS IN SPAIN