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DEVELOPING ENGINEERING CAPABILITIES

AS A SUPPORT TO A NUCLEAR PROGRAM

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The purpose of this presentation is to provide an analysis of the engineering capabilities needed for the development of a commercial nuclear program, its possible interrelation with research and development centers and the spin-off effect that a sound approach can have on the industry as a whole.

In the first place, it is worth noting that generating electricity by means of fission of the uranium nucleus is not merely one option among many others; it is also a very important decision for any country. I am referring to the fact that the nuclear alternative brings with it other consequences, among which is the need to create a minimal technological and industrial infrastructure within the country that will allow for the following activities: Supervising the program, licensing the installations, operating them safely, supporting postulated emergency plans, managing radiological protection for potentially exposed personnel, training the required scientists, engineers and technicians, handling and storing radioactive waste, etc.

In practice, there are other factors that make it necessary to go beyond this minimal required infrastructure. Balance of payment considerations, local industry workload and transfer of advanced technology will induce an urge to search for maximum local participation.

From an economic point of view, nuclear power plants allow the obtainment of electrical energy at a Kwh cost which - overlooking the cost of O & M - is distributed in 70%, corresponding to the capital needed for the first installation and 30% relative to fuel. The same concepts, in a coal fired power plant are in a reverse situation, that is to say, 30% for capital costs and 70% corresponding to coal.

Based on these data let us consider the case of a country which looks at the alternative of building either electric nuclear power plants or coal fired plants burning imported coal. We start from the assumption that the final Kwh cost will be the same in both cases. With the idea of basing our comparison on the most specific data possible, let me take the case of Spain at the beginning of the 60's as a reference model. This also allows us to suppose that the development of this model in the next 25 years will be similar to that of Spain up to this date.

(SLIDE 1)

In the slide, which represents the initial situation of the reference model corresponding to 1961, we can see the following: With the option of coal being chosen, we would obtain a local participation equivalent to 15% of the final cost of each Kwh produced, while in the nuclear alternative this percentage rises to 40.5%. These figures are obtained, after considering a potential local participation of 50% in the cost of the first installation in the case of coal and 45% for the same concept if the power plant were nuclear. In fact, the figures correspond to real data from the plants built in Spain during those years. Also, a participation of 30% in the nuclear fuel has been considered, referring to supplies of uranium concentrate from a local source.

(SLIDE 2)

In the slide, we can see the evolution that the reference country has experienced so far. The participation in the final Kwh cost, in the imported coal option, is now 27% on the basis of a local content of 90% in the cost of the first installation. In the nuclear alternative, the participation has now reached 77.5% as a result of 85% of local content in the capital cost of the plant, and present contribution of not only uranium concentrate but also fuel manufacture.

With the aim of quantifying these results, let us now suppose that, around 1980, the country had considered the choice of one of these two options, imported coal or nuclear, in order to cover 50% of the growth of global demand - 120,000 x 10^6 Kwh in 1986 - from 1986 to 1996. That is to say, in 1980 we were planning an addition of electric power from 1986 to 1996 to reach, on this last date, a total increment of 60,000 x 10^6 Kwh.

(SLIDE 3)

On the basis of a Kwh cost - excluding O & M - of the order of 50 mills US$, equal for both cases, 60,000 x 10^6 Kwh would represent some 3,000 million US$ in annual cost for both options in 1996. Of this figure, the alternative of imported coal would imply the equivalent of 810 million dollars annually, as a result of services and supplies offered by local industry, while the remaining 2,190 million of the cost would correspond to payment in foreign currency, mainly for the purchase of coal. This means dedicating a large sum to payments abroad, with hardly any other benefits than the production of energy itself. In the nuclear case, local services and supplies would profit from considerable investments with a total annual cost equivalent to 2,325 million dollars, almost triple that of the coal option. On the other hand, payments abroad are reduced to the equivalent of 675 million dollars. Also, these payments are made for supplies and services from foreign companies dealing with high technology which would, undoubtedly, lead to the added advantage of keeping the way open for technology transfer to local industry.

To sum up the above, it can be said that, apart from the conventional aspects which lead to the choice of one of various power alternatives, such as cost, diversification of supplies, etc., the nuclear option also involves other factors, favorable and unfavorable, such as the sociological impact, balance of payments, availability of capital, technology transfer and industrial development. We are, then, dealing with a complex option which, when shrewdly approached, and diminishing the negative aspects, could be of great interest for the economy and the industrial development of many countries.

Nevertheless, it is worth noting that the promotion of a nuclear program is an ambitious and complex task and that there is no guarantee that the decision to undertake it is going to produce the benefits that have been described so far. It frequently happens that problems of various kinds finally result in higher investment costs than those anticipated, as well as lower proportions of local participation and technology transfer. This means a reduction in the initial objectives that should be avoided.

As the potential importance that the choice of the nuclear option may have for the industry has been quantified, I am now going to deal with one of the means which have contributed, in Spain, to a reasonably successful development of the program: The creation of strong engineering organizations.

I would also like to deal with the role that certain institutions and research and development centers can play in the implementation of the nuclear program by means of their interrelation with the engineering companies.

ARCHITECT/ENGINEER ROLE (SLIDE 4)

There are various different systems of managing projects that go from "turnkey" to "management by components", passing through intermediate organizational schemes, by islands or, more frequently, "turnkey" with the take-out of some supply and service packages.

In principle, any formula reasonably set out and well-managed may produce the desired result, although it is frequently admitted that the system of "management by components" favors local participation and, therefore, technology transfer. Nevertheless, even with pure "turnkey" systems, it is possible to achieve a considerable level of local participation. In fact, this formula, or a variation of the same, may be the best when a country lacks sufficient previous experience in this sort of project.

In any event, and whatever the formula adopted, it is worth promoting the creation of local engineering organizations to participate actively in the nuclear program from the beginning.

I am now going to concentrate on the analysis of the role of the A/E organization in a project "managed by components". I am going to deal with it in this manner, because I feel that, for the most part, the results will be of general validity, independent of the management formula chosen for the project: "By components", "turnkey", or "mixed".

(SLIDE 5)

In a project managed by components, the process would be developed in the following way:

In the first place, the electrical utility owner appoints a consultant or an A/E to collaborate on the preliminary studies and selection of the site. The A/E normally also participates in the bid evaluation of the Main Supplier: NSSS, TG and NF.

The Main Supplier, once selected, provides the basic and interface information so that the A/E can develop the engineering and design of the power plant as a whole. The Main Supplier locally subcontracts those supplies and services to be developed by local industry in this area, as agreed on previously.

Based on the A/E's definitions and specifications, the BOP equipment is purchased directly by the electrical utility owner, as are the services of civil works and erection companies that have to build the power plant.

The A/E, acting as an agent for the electrical company, is responsible for coordination, supervision and follow-up of the work awarded to the various manufacturers and construction contractors.

On a rough estimate, it can be noted that the Main Supplier's portion represents about 20% of the overall investment in the power plant. So, there remains an 80% that the electrical company manages directly with full cooperation from the A/E.

(SLIDE 6)

To summarize, it can be said that the A/E carries out the following activities during the project:

First, it develops the preliminary and site studies. Subsequently, it prepares the NSSS and TG specifications and participates in the selection of the Main Supplier. After this, it develops the engineering and design of the power plant as a whole. By means of an engineering organization at site, it is responsible for field detail design and the solution of technical problems that might come up during construction. The A/E may also assume the function of construction management, plant testing and startup.

As the electrical utility owner's agent, the A/E can perform procurement activities, including inspection and expediting of supplies.

In view of their volume and complexity, it seems evident that the performance of all these functions requires that the A/E have available an experienced project management team to orientate, supervise, coordinate and control the activities as a whole.

The formula described, with variations and exceptions, is the one normally applied in the USA, and has also been the one adopted in Spain from 1972, when the second generation of nuclear power plants was initiated. Nevertheless, it is worth noting that, regardless of the project organization, it is necessary to develop the aforementioned activities completely and in an orderly fashion and to assign the necessary resources. In this sense, if the figure of the A/E did not exist as such, the "turnkey" suppliers and the various subcontracted organizations would have to share all the work indicated above in the most complete, homogenous and coordinated manner possible.

(SLIDE 7)

The total volume of the A/E's technical manhours, according to all the functions defined above, is approximately 9,000,000 for a non-standardized project, with the distribution shown in the slide. Of this figure, approximately half corresponds to engineers or university graduates and the rest to design technicians and construction supervision staff.

The Spanish experience shows that, even for the first nuclear projects, a great proportion of these manhours can be provided by local personnel, if adequate training programs are set up.

(SLIDE 8)

The slide shows data of an actual engineering services proposal for a country with little previous nuclear experience in which a significant local participation can be seen.

At this point, it is worth considering the following conclusions:

- The services that I have described so far as being A/E's responsibility, regardless of which organizations perform them, are of great importance for smooth development of the project. Nevertheless the percentage of financial costs within the whole investment is not very high. The figure may vary according to the cost of technical personnel, but in Spain is around 10%.

- Within the total services of the A/E, the engineering and design of the installation as a whole is what most conditions the project This activity requires approximately half of the manhours indicated above, i.e. 4,000,000. A correct development of this work would require timely preparation of good basic engineering which is not subjected later to frequent changes. This circumstance allows the on-schedule development of a quality project and detail engineering in such a way, that equipment manufacture, construction and erection of the power plant can be undertaken in an orderly and efficient manner.

- The large number of engineers and technicians participating in a nuclear project - of the order of 1,200 or more at the peak - gives an idea of the opportunities and difficulties involved. On the one hand, it allows for the training of a large number of local engineers and technicians during various years with a potential spin-off effect on other industrial activities. On the other hand, it determines that it is not only the purely technical problems that have to be solved and overcome, it is necessary to manage efficiently a very large group of people who must participate in a coordinated way in the same project.

- Irrespective of the fact that one sole engineering organization should be responsible for the basic engineering work and the overall technical coordination, there is room for collaboration in specialized areas of other companies and institutions. To be specific, certain research and development organizations, suitably coordinated, can contribute their technical expertise to the project, while benefitting from the experience of participating in it.

LOCAL INDUSTRY PROMOTION (SLIDE 9)

We have seen how the development of a nuclear program allows and requires the creation of large local engineering organizations in which a great number of engineers and technicians are integrated and quickly trained. These organizations rapidly constitute technological nuclei capable of assimilating very diverse areas of knowledge, applicable to their own assignments and which can also be channelled into local industry.

It can be interesting to see how this multiplying effect on industry has occurred in Spain.

Preselection and Information

First, industries with sufficient interest and capability were selected by the A/E to participate in the program. They were advised of the possibilities and the requirements early enough for them to prepare themselves, and also informed of possible foreign partners with proven experience in their respective fields.

Specification Preparation

Following this, the A/E prepared the specifications of the equipment taking into account the capabilities of local industry, the most frequently used techniques and the availability of materials. In this respect, rather than issuing complex packages for bids, these were divided into smaller packages, simpler to deal with by the local industry.

Engineering Support

In third place, the A/E directly developed the detail engineering that created important coordination problems or which required techniques that were not within the capabilities or experience of local manufacturers.

(SLIDE 10)

A specific example is the manufacture, in Spain, of dynamically designed equipment, right from the beginning of the second generation of nuclear power plants in 1972. As a solution, the A/E performed, on its own, the calculations and drew up the detail dimensions of some of the equipment.

(SLIDE 11)

Another successful example was the manufacturing of the steel containment and penetrations. In this case, it was the A/E that took on the task of developing the complex calculations required. As regards the mechanical penetrations, they were calculated and designed by the A/E in such a way, that the local supplier could manufacture them directly, based on the detail drawings received.

(SLIDE 12)

(SLIDE 13)

In other cases, modern design techniques (CAD/CAE) make it possible to go easily and without any discontinuity problems from basic to detail designs.

(SLIDE 14)

(SLIDE 15)

A specific example is piping design. The process begins from computer-designed flow diagrams, from which piping specialities, lines, valves, equipment and electric consumers lists are obtained automatically.

Taking these flow diagrams as reference, the piping arrangement drawings by buildings are prepared and, subsequently, piping master isometrics are derived. From these, fabrication drawings such as piping supports, piping spools and isometrics are automatically obtained. In addition, support material, structural steel and piping material lists are obtained through the computer. The following slides show examples of some of these applications:

(SLIDE 16)

(SLIDE 17)

(SLIDE 18)

This increasingly computerized process not only improves productivity and the technical coordination of engineering, but also provides the manufacturers and erectors with detailed information which favours the participation of local suppliers.

A/E CAPABILITIES PROMOTION (SLIDE 19)

If the A/E's role is so important and, as we have seen, its consequences are so significant, we might ask ourselves "What does one have to do in order to successfully develop one's own engineering capabilities?".

The circumstances of each country and each project may be different and, sometimes, very different. In this sense, it is difficult to provide detailed formulas which are universally valid. And yet, we could say that the complexity of modern-day nuclear projects requires that engineering be developed in the most integrated way possible, independent of the general management scheme adopted for the project. This means that, in any case, there should be a technical nucleus responsible for engineering as a whole and for management of the common project data bank; that the collaboration of consultants and specialist organizations should be channelled through said nucleus and also that certain linked activities cannot be split up and assigned partially to other organizations.

I dealt with the specific subject of how to set about developing A/E capabilities on the basis of the Spanish experience, during the celebration of ICONTT III in Madrid last October. (Copies of the paper are available for those interested.) I am not going to repeat myself now in detail, although I would like to sum up some of the aspects that I consider more important.

Selecting a Qualified Partner

It is necessary, although not sufficient, to appoint a technically qualified organization with proven experience in the field of technology transfer.

Establishing a Suitable Agreement

It is vitally important that, right from the start, a clear agreement exists in which assignments and objectives are described. The organization which transfers technology must admit that this can, and must, be made compatible with the harmonious development of the project.

Access to other Consultants

The possibility of using other consultants, local or foreign, must be kept open if the organization which receives the technology acts as an independent contractor. Later on, I shall deal with the topic of the possible technological contribution of local R & D institutions and organizations.

Assignment of Company Staff

It is important to select and assign the company's own personnel qualified to carry out the functions involved. It is not so important for this personnel to have a great deal of experience; it is more necessary for them to have had a sound basic training and a good attitude towards assimilating new techniques.

Organization

Owing to the volume and complexity of these projects, the problems of documentation or organization and information management are just as important as technical points. For this reason, it is necessary to place special emphasis on this area.

Assuming Responsibilities

This is an important aspect that will condition the whole process of technology transfer. It is vitally important to assume firm responsibility as soon as a minimal basis for this exists. This is true both at an individual and organizational level. It must be pointed out that the major portion of technology is transferred by means of on-the-job training.

Personnel Training

This is an important asset to on-the-job training. Personnel training can be prior to on-the-job training, simultaneous with it, or a combination of both, depending on the circumstances.

TECHNOLOGY SUPPORT CENTERS (SLIDE 20)

We will now briefly analyze in which areas certain institutions and development centers (R & D) can collaborate with local engineering companies and contribute towards enhancement of their capabilities.

We are going to center our attention on the activities of the A/E itself, as defined before, without entering into other areas also pertaining to the nuclear field but which belong to the Main Supplier (NSSS, TG and NF), and in connection with which collaboration of R & D centers is also possible.

First, training activities. A nuclear program such as the Spanish one, with 6,000 MWe in operation and four groups of 1,000 MWe each under construction entails the need for some 8,000 technicians, about half of whom work in engineering and design activities. Of this half, about 2,500 are university graduates.

The figures quoted give an idea of the need for collaboration with universities in order to orientate basic training and with universities and other R & D institutions to promote post-graduate training. This is not an exclusive need for A/E companies since other areas of industry also require it. Nevertheless, the comparatively high weight of these organizations is obvious.

In Spain, it is worth highlighting the role of the polytechnic universities, specially those of Madrid and Barcelona, that have updated and extended their ~~post~~ under-graduate programs in the nuclear field. Also, the Instituto de Estudios Nucleares which belongs to the Junta de Energía Nuclear, the Polytechnic and the Comillas Universities of Madrid have collaborated with engineering companies, and with other institutions in post-graduate training. In the area of operating personnel training, we can point out the contributions of, again, the Junta de Energía Nuclear and the TECNATOM company. In the field of design and maintenance support, the contribution of the Instituto Politécnico Salesianos de Atocha, Madrid, in collaboration with engineering companies, is notable.

In site study activities, institutions in the areas of geology, soil mechanics, hydrology, seismology, meteorology, etc. can act as consultants. These organizations can contribute towards improving the capabilities of engineering organizations and, at the same time, benefit from specialized works and investigations arising from the needs of the nuclear program. At the same time, through this participation, information and technological knowledge of major interest for other industrial activities can be obtained. In Spain, we should mention the participation of the Servicio Geológico of the Ministry of Public Works, the Instituto Geológico y Minero de España, the Laboratorio del Transporte y Mecánica del Suelo, the Centro de Estudios Hidrográficos, the Instituto Meterológico Nacional and the Instituto Eduardo Torroja de la Construcción y del Cemento.

In the field of materials and manufacturing processes - specially metallurgy and welding - there can be a considerable contribution from universities and R & D centers to project engineering and industry in general. In this respect we may mention, among other centers, the Junta de Energía Nuclear, the Centro Nacional de Investigaciones Metalúrgicas (CENIM), the metallurgical department of the Madrid Higher Technical College of Industrial Engineering, etc.

In the area of environmental and seismic qualification, there are also possibilities for collaboration by centers that have the appropriate specializations. Qualification under ionizing radiations, extreme humidity and temperature conditions and aging, in general, are usual techniques in the nuclear field. On the other hand, there is the area of seismic qualifications by means of advanced calculations and/or tests on vibrating tables. In Spain, the following have collaborated in these activities within the scope of their installations: The Junta de Energía Nuclear, test laboratories of the Polytechnic University and other laboratories and companies that have installed equipment according to the growing necessities and requirements.

In the area of advanced calculations, we can identify technologies such as dynamic structural calculations, thermohydraulic calculations, mechanical system modelling for transient analyses, electrical stability studies, safety studies, radiation protection and risk analysis, etc. It frequently happens that the basic techniques and the calculation programs needed for the development of many of these activities are mastered by some universities and R & D institutions. In this event, these centers can contribute to improving the capabilities of local engineering and at the same time, take advantage of the opportunity to experiment and use their resources in cases of real application at an industrial level.

Computer programs like NASTRAN, ANSYS, SAP for structural analysis, RELAP and RETRAN for transient analysis, WHAM for transients in fluid systems, QUAD, MORSE, CORRAL for shielding and dose calculations, SETS and PREP/KITT for reliability analysis and many others provide opportunities for such collaboration.

It is clear that mutual interfacing between engineering and many of these institutions may be beneficial to both parties, and also to the nuclear program. The only thing that has to be preserved, and which at times is not so easy, is the consistency of objectives and criteria and, above all, maintaining coordination in conformance with the actual needs of the projects.

REFERENCE MODEL-1961

OPTION	Kwh COST (O & M EXCLUDED)		
	INVESTMENT	FUEL	TOTAL
COAL	30%	70%	100%
LOCAL PARTIC.	50%	–	15%
FOREIGN PARTIC.	50%	100%	85%
NUCLEAR	70%	30%	100%
LOCAL PARTIC.	45%	30%	40,5%
FOREIGN PARTIC.	55%	70%	59,5%

SL–1

REFERENCE MODEL-1986

OPTION	Kwh COST (O & M EXCLUDED)		
	INVESTMENT	FUEL	TOTAL
COAL	30%	70%	100%
LOCAL PARTIC.	90%	–	27%
FOREIGN PARTIC.	10%	100%	73%
NUCLEAR	70%	30%	100%
LOCAL PARTIC.	85%	60%	77,5%
FOREIGN PARTIC.	15%	40%	22,5%

SL–2

REFERENCE MODEL-1996 (1986 US dollars)

OPTION	COST OF 60,000 x 10^6 Kwh (x 10^6 US $)		
	INVESTMENT	FUEL	TOTAL
COAL 50 Mills US $ Kwh	(30%) 900	(70%) 2,100	3,000
LOCAL CONTRIBUTION	(27%) 810	–	(27%) 810
FOREIGN CONTRIBUT.	(3%) 90	(70%) 2,100	(73%) 2,190
NUCLEAR 50 Mills US $ Kwh	(70%) 2,100	(30%) 900	3,000
LOCAL CONTRIBUTION	(59,5%) 1,785	(18%) 540	(77,5%) 2,325
FOREIGN CONTRIBUT	(10,5%) 315	(12%) 360	(22.5%) 675

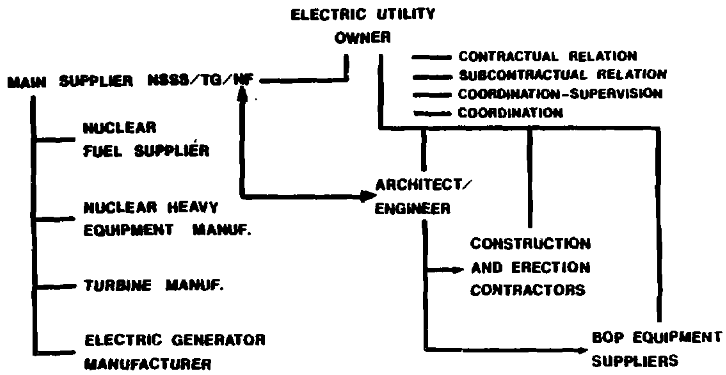
SL–3

ARCHITECT/ENGINEER

RÔLE

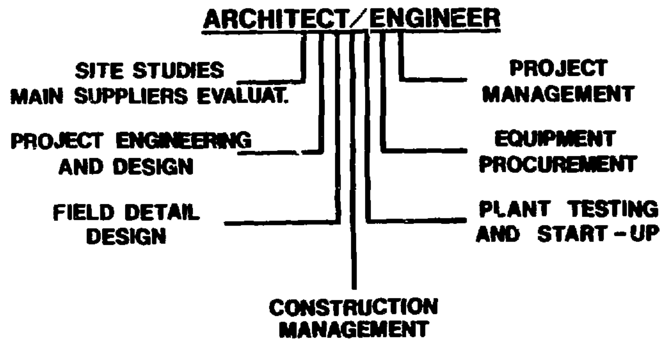
SL–4

PROJECT MANAGEMENT ORGANIZATION BY COMPONENTS



SL-5

SCOPE OF SERVICES OF THE A/E IN NUCLEAR PROJECTS



SL-6

A/E VOLUME OF WORK (man-hours)

PROJECT ENGINEERING	4,000,000
PROCUREMENT	400,000
FIELD DETAIL DESIGN	1,600,000
CONSTRUCTION MANAGEMENT	2,500,000
TESTING & START-UP	500,000
TOTAL	9,000,000

SL-7

A/E SERVICES - EXAMPLE (man-hours x 10^3)

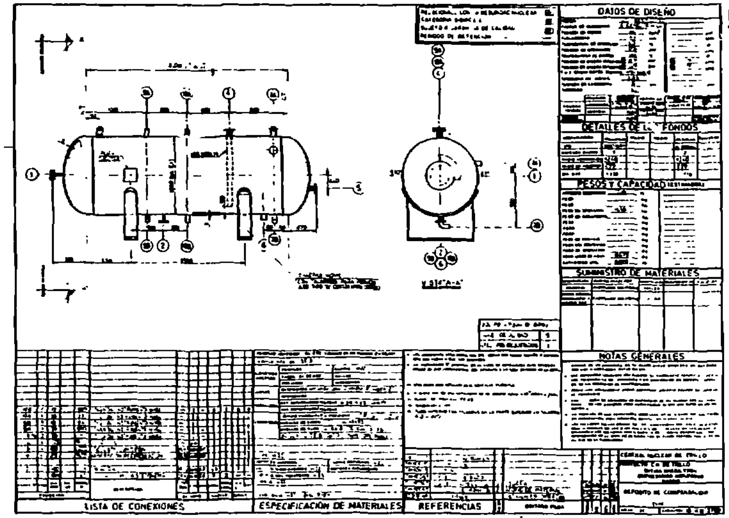
	FOREIGN	LOCAL	TOTAL
Project engineering	1,500	2,400	3,900
Procurement	210	240	450
Field detail design	200	1,400	1,600
Construction management	270	2,300	2,570
Testing & start-up	130	450	580
TOTALS	2.310	6,790	9,100

SL-8

LOCAL INDUSTRY PROMOTION

* PRESELECTION AND INFORMATION
* SPECIFICATION PREPARATION
* ENGINEERING SUPPORT

SL-9



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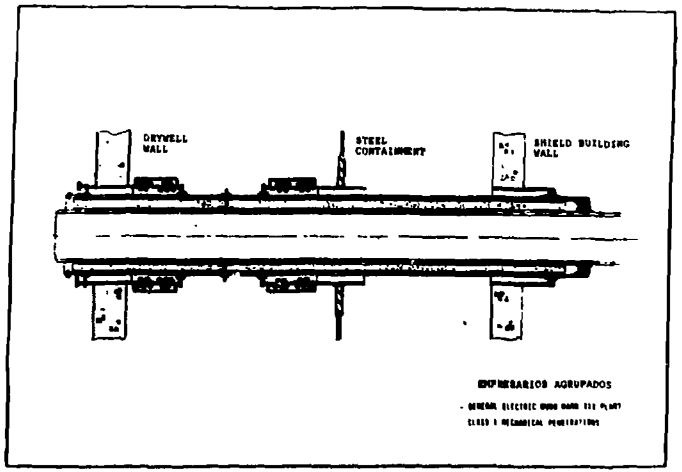

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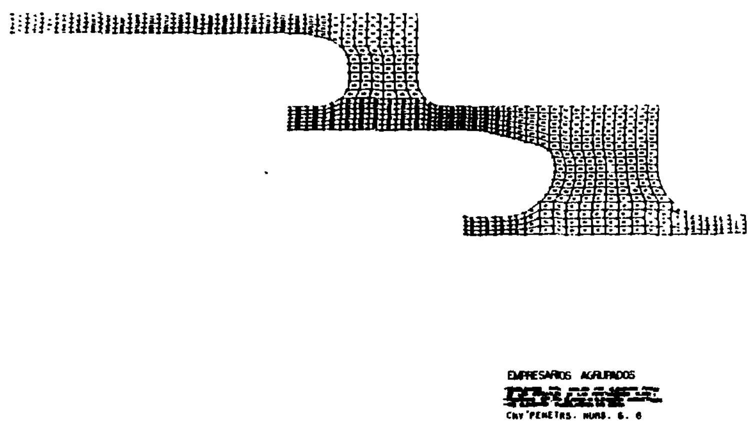

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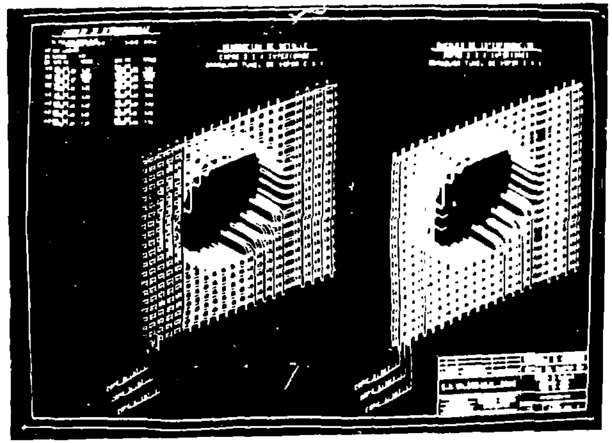
SL-13



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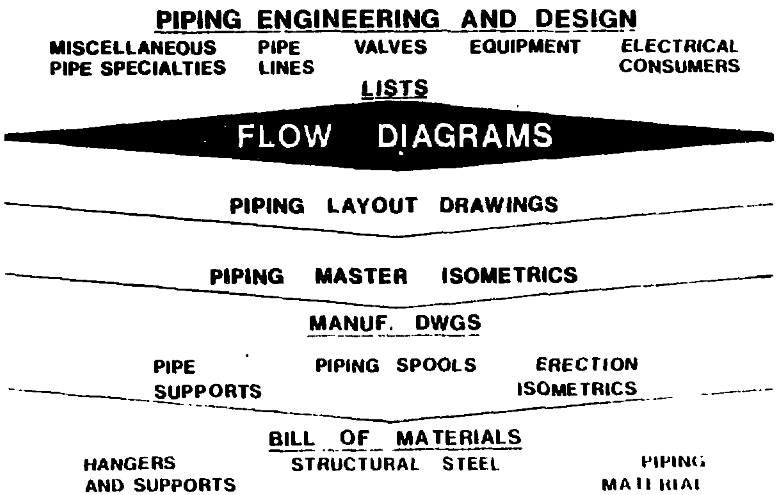

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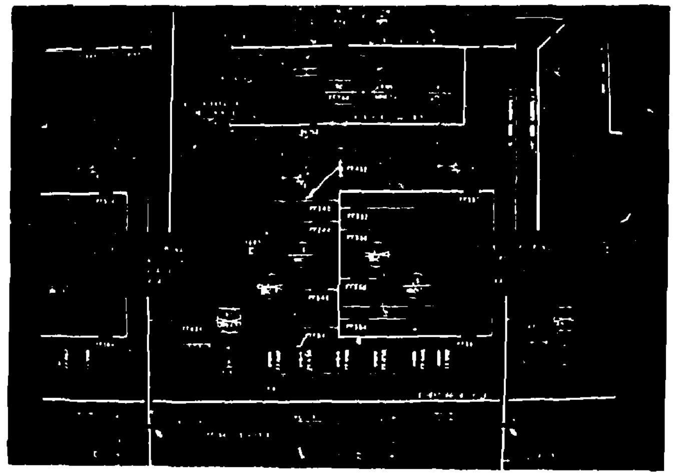

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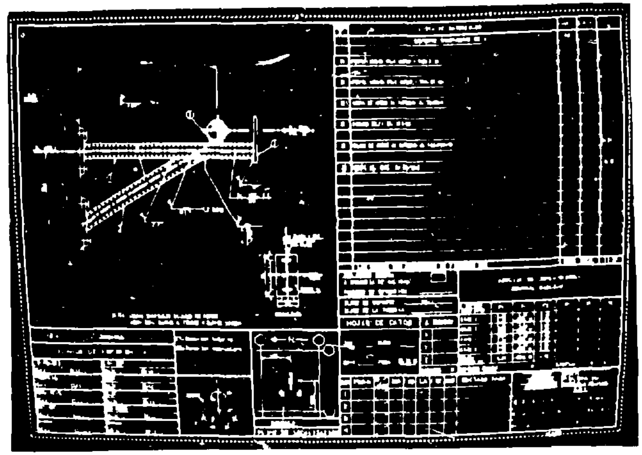
SL-17



SL-18

A / E CAPABILITIES PROMOTION

* SELECTING A QUALIFIED PARTNER
* ESTABLISHING A SUITABLE AGREEMENT
* ACCESS TO OTHER CONSULTANTS
* ASSIGNMENT OF COMPANY STAFF
* ORGANIZATION
* ASSUMING RESPONSIBILITIES
* PERSONNEL TRAINING

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TECHNOLOGY SUPPORT CENTERS

SL-20