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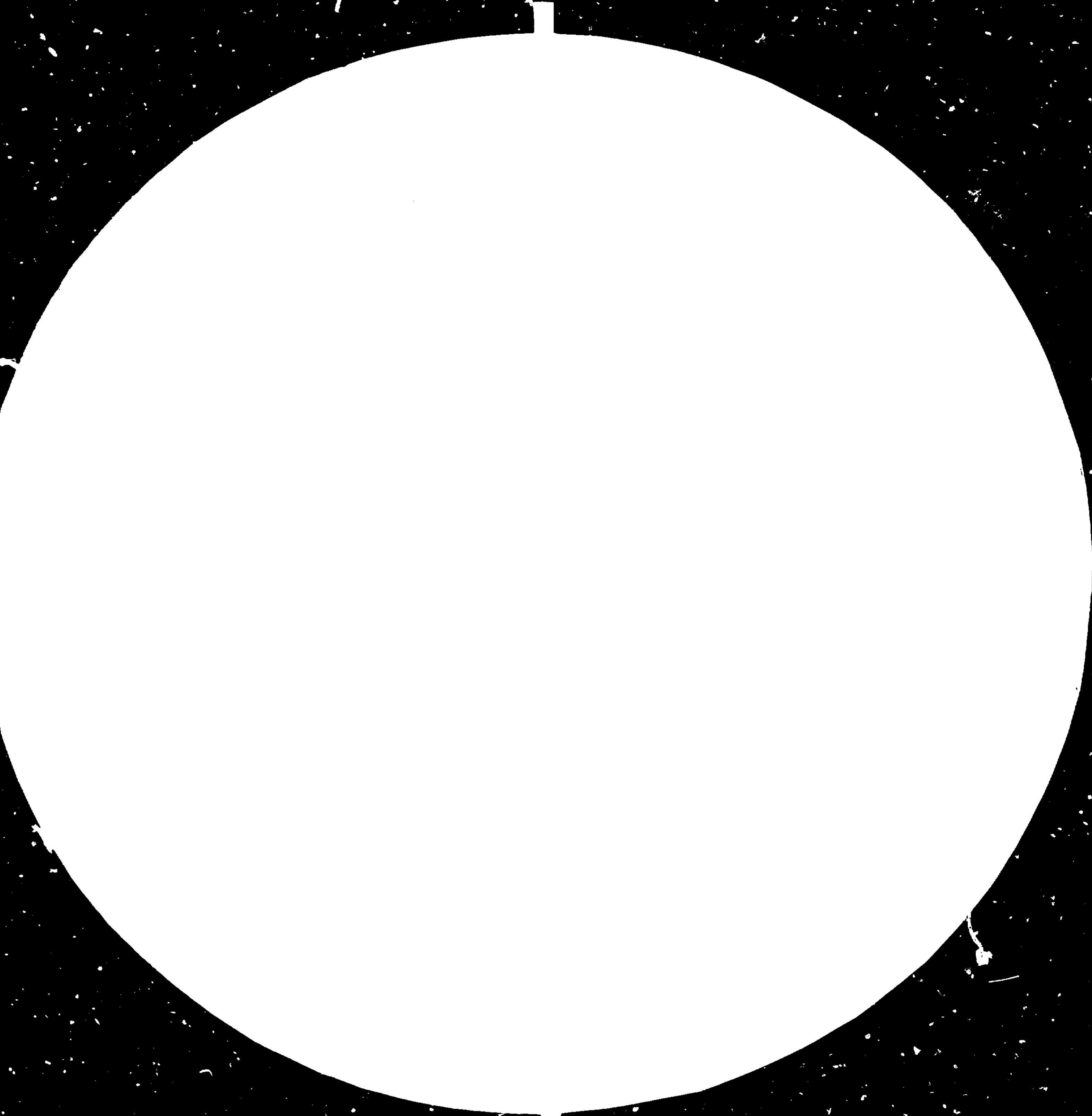

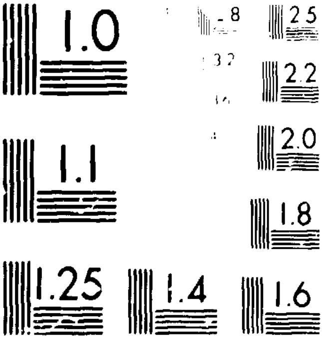
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CAPITAL GOODS FOR THE PRODUCTION AND DISTRIBUTION OF ELECTRICAL ENERGY

November 1979

INSTITUT DE RECHERCHE ECONOMIQUE ET PLANIFICATION DU DEVELOPPEMENT
UNIVERSITE DES SCIENCES SOCIALES DE GRENOBLE

C O N T E N T S

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INTRODUCTION

The sector covering equipment for the production and distribution of electrical energy is of great importance in the industrialized countries. Despite the very long delivery dates and the very high level of technology this sector must be able to meet the demand for electrical energy at any time by supplying equipment. The conditions necessary for the production of such equipment also require the implementation of major resources.

In the developing countries the demand for equipment for the production and distribution of electrical energy is considerable; some of these countries direct their investments as a priority and to a very large extent into the electricity production sector; for others the implementation of basic industries such as iron and steel and petrochemicals, which are major consumers of electrical energy, creates a demand for equipment for the production and distribution of electricity. At the present time, and with the exception of some countries which have some productive capacity in this sector, most of the developing countries are obliged to import all the equipment needed for the production and distribution of electricity.

It seems therefore to be an opportune time to see how the developing countries could create the bases for an electrical engineering industry capable of producing these equipment goods, either independently of or with technological support from outside. In order to do this an attempt will be made to analyse each type of item of equipment as a function of its degree of technological complexity, to examine technical development in such equipment and to determine which companies hold the know-how and how the technological transfer for each category of equipment goods can be effected.

Initially the first part of the analysis will cover the technico-economic structures of the sector covering equipment for the production and distribution of electrical energy[1] and the methods and possibilities for the transfer of production, taking the complexity of the products into account.

The second part will give a brief summary of the present situation regarding world production and international trading in this equipment, the actors at a worldwide level and the market powers in this sector.

Finally the third part will set out an analysis of the experience of certain developing countries in producing energy equipment goods.

(1) This analysis covering the field of equipment for the production of electricity will be mainly directed towards equipment for conventional power stations; nuclear power stations are excluded from this study, as are also items of equipment used with renewable energy supplies (solar, wind, geothermal, etc.).

CHAPTER I

ANALYSIS OF EQUIPMENT FOR THE PRODUCTION AND DISTRIBUTION OF ELECTRICAL ENERGY AND THE TECHNICO-ECONOMIC CONDITIONS FOR ITS PRODUCTION

1 - Analysis of the technological routes and of the complexity of equipment

A - Equipment for the production of electrical energy

Electrical energy can be produced in four types of installation:

- conventional thermal power stations[1],
- power stations with gas turbines,
- diesel power stations,
- hydroelectric power stations.

Each of these installations can be characterized by the nature of the primary energy used, the electrical power produced, the efficiency of the installation (in relation to the primary energy used), the degree of complexity of the installations, etc.

The implementation of a given installation is determined by an economic study based on fixed costs and variable costs. Each of these installations can be connected to the network for distributing electrical energy. According to the quantity to be produced use is made of:

- diesel power stations for powers from 100 kW to 10/20 MW. The cost is of the order of 3,500 FF per kW installed,

- gas turbine power stations for powers of the order of 5 to 50 MW. The cost is 1,500 to 2,500 FF per kW installed.

- thermal power stations for powers varying between 10 and 1,000 MW. The cost per kW installed is 3,000 FF.

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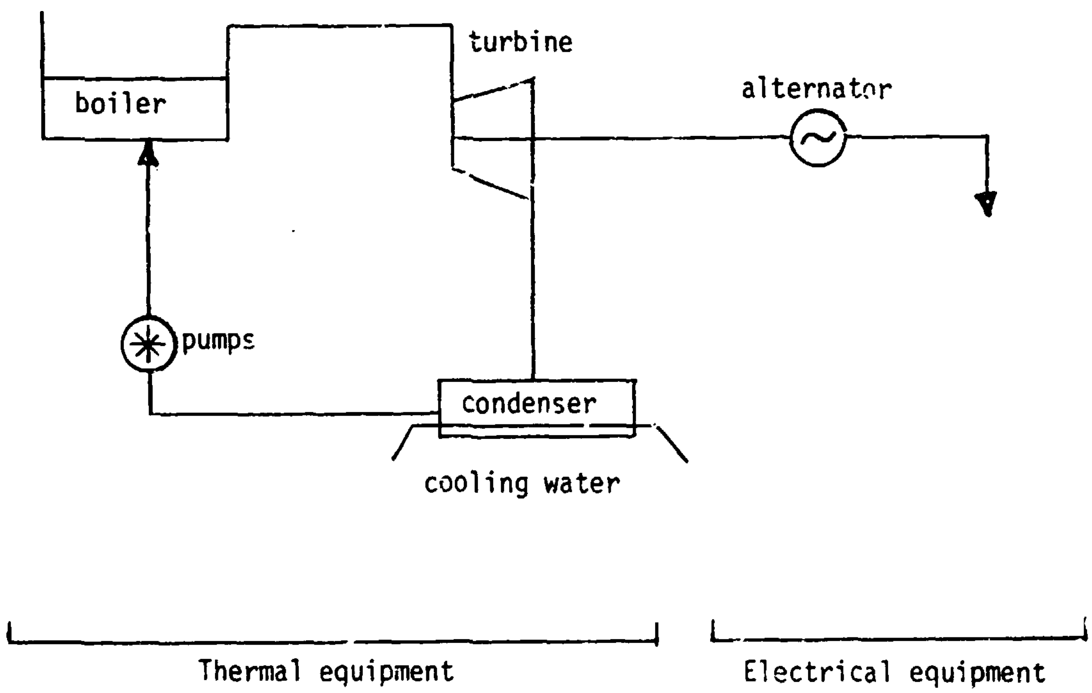
(1) Electricity from nuclear energy is excluded from this study.

1.1 - Conventional thermal power stations

By conventional power station is meant a power station using, as the source of primary energy, fossil fuels such as coal, fuel oil, natural gas, etc. Most of these power stations are adapted to burn one type of fuel, but some of them may be designed to burn two types of fuel (mixed power stations).

Thermal power stations of the conventional type have an efficiency of the order of 30%, and are of a very high level of complexity.

The following diagram shows the principal equipment in a thermal power station:



- The thermal equipment comprises:

  . the steam generator (boiler)
  . the turbine and condenser, including also all pumps and compressors in the steam circuit
  . the pipework and valvework.

- The electrical part comprises:

  . the alternator
  . the control, regulation and motor supply panels
  . the electrical installation of the power station (minor electrical equipment, cables, etc.).

The breakdown of the equipment of a power station as a function of cost shows that equipment counts for half the value of a power station (Table 1).

In the sector manufacturing heavy equipment for thermal power stations the technical barrier is particularly high. Whilst such a sector will undoubtedly have to carry out further fundamental research the discovery of new principles in its own field or any basic technological change seems to be excluded; its development and mastery will depend closely on an increasingly detailed knowledge of the equipment.

Apart from a relatively small part of the equipment which is less complex (general pipework, control panels, electrical installations), equipment for conventional thermal power stations is characterized by products of high quality which must operate for 20 to 30 years without any serious failures; the confidence inspired by many previous installations and the credibility and the quality of the brand image are essential factors in competition; the technology is of a high level, and ongoing R & D effort must be carried out, particularly in the field of the materials used.

The products are large in size, of constantly increasing unit power, and require considerable production and manpower resources for their manufacture.

TABLE 1 - Breakdown of the cost of a thermal power station

. Studies and supervision	= 10%	
. Civil engineering	= 25%	
. Thermal equipment	= 32.5%	
of which: steam generator:		13%
turbine and condenser:		9.5%
pipework and valvework:		6%
structural steelwork and boilerwork		[illegible]%
. Electrical equipment	= 17.5%	
of which: alternator:		5.5%
auxiliary control:		6%
electrical equipment:		6%
. Installation	= 15%	
Total:	100%	

1.1.1 - The steam generator

. Level of complexity

The steam generator in a thermal power station is a boiler; its design does not differ from an industrial boiler apart from the fact that, for the production of electrical energy, the very accurate regulation constraints and the greater reliability necessitate greater complexity than in the production of industrial boilers.

A boiler consists of tubes assembled together. The pressures and temperatures involved necessitate recourse to alloy steels and heat treatment, together with complex welding methods, whilst quality controls are extremely detailed.

The "burner" part is, itself, extremely complex.

The steam generator integrates sub-assemblies which call on general boilerwork (tank and collectors), but these components represent only a tiny part of the whole (1 to 2%). An easily accessible operation is the thermal insulation of the boiler.

. Necessary production apparatus and technological evolution

The production apparatus needed is that for heavy boilerwork: this is generally reasonably multi-purpose, it being possible to produce other equipment using the same production resources (in particular equipment for the petrochemicals industry).

The size of the sub-assemblies for a boiler necessitates adequate resources (dimensions of the furnaces for heat treatment, possibility of handling heavy loads).

Technological developments in boilers for power stations relate both to pressures and temperatures. The rise in power outputs leads to recourse to equipment which is increasingly large in volume, whilst finally regulation and reliability involve extremely complex regulating systems.

1.1.2 - The steam turbine and condenser

. Degree of complexity

The level of complexity of these two items of equipment is very high. There is no difference, at a technological level, between a 100 MW turbine and one of 1,000 MW since it is the efficiency which is determinant. Irrespective of the power the search for maximum efficiency necessitates a highly developed technology.

The stator parts of the turbines are cast from alloy steel.

The rotor is the most complex part of a thermal turbine (axle and fins) and requires the use of high alloy steels; most of the rotor sub-assemblies are forged.

. The production apparatus

The production of thermal turbines necessitates a forging unit and a foundry unit; these units are specific inasfar as the grades of the steels which are forged or cast are very special. The present evolution towards thermal turbines with powers of more than 1,000 MW necessitates very large installations. The Creusot-Loire company has installed a cast iron unit of unequalled capacity in Europe (9,000 to 11,000 tonnes). The power of the turbines remains dependent on the capacities for forging and casting.

The resources needed for lifting and handling are also considerable; for the most powerful turbines these must allow for lifting and moving parts weighing 200 tonnes.

. Technological developments

There are no technological mutations in this type of equipment. However two trends can be seen:

- the search for maximum efficiency
- the increase in the unit powers of turbines (by increasing temperatures and pressures, amongst other techniques).

These trends force manufacturers to carry out ongoing research on materials, in particular very special steels.

1.1.3 - Pipework, valvework and pumps

For these items of equipment the degree of complexity is lower than for the previous items. Pipework is fairly important in a conventional thermal power station. The pipework, valvework and pumps are not specific to thermal power stations, such equipment also being found in the petrochemicals industry.

1.1.4 - The alternator

. Degree of complexity and production apparatus needed

The operating principle of an alternator remains simple, but the manufacture of such equipment is relatively complex, mainly because of the increasing unit power output of the equipment. Despite its large size the alternator requires an accuracy in its production and assembly which, in the case of certain sub-assemblies, can be as high as 0.1 mm.

The rotor of the alternator is a forging; every increase in the unit power output involves an increase in the mass of the rotor and its dimensions. As an example an alternator of 700 to 900 MVA requires, for its manufacture, a single forging of 120 to 150 tonnes and a steel ingot of 300 tonnes. Machining of the rotor therefore becomes of extreme importance and machining equipment (lathes of very considerable length, etc.) and highly skilled labour are necessary.

. Technological development

The manufacture of high power alternators will probably continue to be based on the same technology up to the end of the century. Study of the introduction of new techniques, such as the application of cryogenics, is nevertheless being undertaken so as to allow considerable unit increases.

1.1.5 - Control and regulation equipment

These items of equipment are at the crossroads of several techniques, so that it is difficult to approach this subject in the same way as for the previous items of equipment.

The manufacture of control and regulation equipment for thermal power stations calls on assemblers, companies producing automation equipment, control desks for the control rooms and the general installation, sometimes including the civil engineering and connecting up, and these are therefore generally large companies. However companies which originally specialized in the problems of electrical distribution (control panel manufacturers and installers) are increasingly incorporating control desks and the production of automation equipment in their activities. Finally installers (general companies) may also be involved in the final phase of connecting and general installation. The latter types of companies are generally small and medium-size organizations of average technicity.

Generally speaking the production of control and regulation equipment calls on control and regulation equipment for the control systems, for analytical instrumentation and processors (relays, programmable automation, etc.).

Such control systems allow control by cabled sequencing units, adjustment of the load and supervision (generally a mini-computer is responsible for indicating faults); start-ups and shut-downs are controlled by the controller, but his orders are carried out in a more general manner using cabled or programmed sequencing units.

. The production apparatus

The production of control and regulation systems remains an activity requiring limited resources: assembly, cabling and locking (for control panels) are essential operations. The great majority of the components (electromechanical, electronic and pneumatic, etc.) such as relays, mini-computers, sensors, etc. w. are used in the control systems for a power station are not specific to this field but cover other markets; these components are supplied by large firms such as IBM, Siemens, Schlumberger, Foxbo", etc.

The essential activity is the design and engineering work on the automated systems.

. Technological developments

The design of control rooms is changing very little; trials on centralized control by computer have generally created more problems than they have solved. In the conventional instrumentation few major developments are appearing in the field of sensors and actuators, apart from improvements made by the instrumentation component manufacturers. In the processors relays are of considerable importance in an electrical power station and are present in all stages of control; their number is generally several thousand, and they remain largely electromechanical; the same also applies to most of the 600 MW power stations, and programmable automation will only come into effect for powers of 1,300 MW.

1.1.6 - Grouping of thermal power station equipment by route and by degree of complexity

The equipment for a thermal power station calls on a number of technical production routes.

These are:

- The boilerwork and structural metalwork route
- The forging, casting, machining and heat treatment route
- The electronic route
- The pipework route

Each item belongs principally to one production route, and each route can be broken down into the degrees of difficulty involved in mastering production (easy, fairly difficult, difficult and very difficult).

TABLE 2 - Complexity of equipment goods for thermal power stations and installation work by principal manufacturing route

	%	%	Sheet metal and profile working, structural metalwork, boilerwork					Casting - Forging - Machining					Other routes					Installation and civil engineering				
			1	2	3	4	Total	1	2	3	4	Total	1	2	3	4	Total	1	2	3	4	Total
- Study and supervision	10																					
- Design		40																				
- Execution		40																				
- Supervision		20																				
- Civil engineering	25	100																80	20			100
- Equipment	50																					
- Structural metalwork		4	3	1			4															
- Boilerwork		4	3	1			4															
- Boiler		26			26		26															
- Turbines and condensers		19								5	14	19										
- Alternators		11								5	6	11										
- Pipework		8													2	6	8					
- Valves		4							1	3		4										
- Control equipment		12													2	10	12					
- Electrical equipment		12												1	2	9						
		100	6	2	26		34		1	13	20	34		1	6	25	32					
- Installation	15																					
- Structure		10																10				10
- Pipework		30																20	10			30
- Painting and lagging		10																10				10
- Cabling and instrumentation		30																10	10	10		30
- Equipment		20																15				15
	100	100																65	25	10		100

Table 2 sets out, in the form of a summary table, the various items of equipment grouped according to the principal route and the level of complexity. This table gives an idea of the relative importance of each of the routes: the "boilerwork" route and the "forging, casting" route represent two thirds of the equipment and, generally speaking, all the equipment is either complex or very complex.

1.2 - Gas turbine power stations

Since the end of the Second World War gas turbines have been progressively more widely used in land-based applications: they have occupied specific sectors such as pipeline compressor or pump drives, but their development over the last ten years has been most rapid in the production of electricity. In this field their fairly low efficiency (25%) and the requirements of cleanliness, and hence of the cost of the fuel, together with the investment charges which are relatively light, have favoured their use, essentially in the supply of peak or stand-by electrical energy.

The rapid increase in requirements for electrical energy in the developing countries, particularly for producers of hydrocarbons as a cheap form of fuel, encourages them to prefer the gas turbine to other forms of production of electrical energy. In this case the gas turbine constitutes the basic power unit for producing electrical energy.

The simultaneous production of electricity and heat, without having recourse to abundant cooling water, makes it possible for gas turbine power stations to provide an appropriate solution in the fields of sea water desalination, town heating systems, etc.

The sale of a gas turbine is carried out on a turnkey basis: the company carries out the manufacture, assembly and commissioning of the turbine itself and also the ancillary equipment which comprises:

- the fuel oil storage tanks in the case of turbines operating on fuel oil
- the building
- the system for removing the energy
- the connection to the network.

The approximate ex works cost of a gas turbine alternator set is:

- 25 MW size = approximately 15 million FF
- 90 MW size = approximately 50 million FF

The breakdown of the costs as a percentage of the total cost of the gas turbine/alternator set is as follows:

	25 MW size	90 MW size
Compressor	14.5	13.5
Turbine	16	20
Combustion system	2.5	3
Accessories for the compressor turbine unit	22	20
Mechanical and electrical ancillaries (inlet, exhaust, air cooling, etc.)	19.5	18.5
Alternator + excitation	25.5	25
	100	100

For turbines of the order of 25 MW the production cycle is about 60 weeks for the static parts and 72 weeks for the rotors.

Gas turbine sets are frequently of the package type, requiring only a minimum of civil engineering, essentially the solid foundation for the set. They are generally delivered as 3 or 4 units, entirely assembled at the works, and their installation on the site requires limited labour and time.

. Degree of complexity

With their highly sophisticated technology gas turbines necessitate the mastery of many production techniques. The controlling part of the turbine being the turbine compressor rotor assembly this part necessitates major forging facilities for the rotor and precision casting facilities for the fins of the turbine. The machining of the various parts of the turbine compressor rotor assembly necessitate large machine tools and skilled labour. Since the parts are heavy - the turbine compressor rotor weighs 50 tonnes in the largest gas turbines - heavy lifting equipment is also necessary.

The production of gas turbines is carried out in runs of the order of 10 to 20 turbines per year. It is not therefore an item of equipment designed and produced according to the client's specification but equipment sold from the catalogue. Most companies are capable of offering several ranges of powers; Alsthom-Atlantique (France) offers turbines of 10 MW, 20/25 MW, 60/65 MW and 90/100 MW.

. Technological development

Research carried out in the field of gas turbines has made it possible to increase the unit power considerably. In 1956 of the 400 gas turbines in service only 22 were of more than 20 MW, but at the present time power outputs of the order of 100 MW have been reached. These results have been obtained as a result of the progress made by engine manufacturers in improving the performance of turbo-jets, and that carried out in the technology of refractory steels, making it possible to improve the thermal efficiency of the turbines by raising the temperature of the gas on entering the turbine. Such research work can only be carried out by very large companies, so at the present time only a few companies have developed turbines using their own technology, the others being licensees.

1.3 - Diesel power stations

Diesel power stations have powers of 100 kW to 10 MW. Their use is highly developed in regions which are not very accessible (power stations in the bush) or for industrial requirements (autonomous production of electricity or stand-by power stations). The cost of such a power station is about 3,000 FF per kW installed.

A diesel power station consists of a diesel engine coupled to an alternator. The breakdown of the components of the power station as a function of cost is as follows:

- Study, design		10%
- Civil engineering		20%
- Installation		15%
- Equipment		55%
of which:	Engine	31%
	Alternator	9%
	Electrical equipment and instrumentation	10%
	Fuel storage	5%

The determinant factor is the diesel engine. Diesel engines used for the production of electrical energy do not differ from other diesel engines used in the industrial or transport sector; only the power of the engine determines the power of the power station. Diesel engines for trucks can be adapted for small diesel power stations, and in this field DEUTZ in West Germany, DORMAN in Britain and BERLIET in France manufacture diesel engines which can be used in a diesel power station. At the top of the range marine engines are used from CHANTIERS DE L'ATLANTIQUE in France, from SULZER in Switzerland, from VOIGT in West Germany, etc. for diesel power stations.

The complex part of a diesel power station is, above all, the diesel engine; the relatively modest alternator does not present any special technical problems. For large electrical sets one finds mainly the major companies in the mechanical engineering industry which design and produce generating sets on the basis of their engines, the alternators being bought from electrical engineering companies.

Grouping of the equipment by route and by level of complexity (Table 3), which has been carried out on the basis of meetings with some manufacturers, shows that the "Casting, forging, machining" route is the most important in the production of this equipment, and that the level of complexity of manufacture for all these routes is either complex or very complex except for the "boilerwork" route.

1.4 - Equipment for hydroelectric power stations

1.4.1 - The turbine

The essential part of the hydraulic equipment is the turbine.

TABLE 3 - Complexity of equipment goods for diesel power stations and installation work by principal manufacturing routes

			Structural metalwork - Boilerwork					Casting - Forging - Machining					Other routes (pipe-work, electronics, electrical equipment)					Installation				
	%	%	1	2	3	4	Total	1	2	3	4	Total	1	2	3	4	Total	1	2	3	4	Total
- Study	10																					
- Civil engineering	20																					
- Installation:																						
- Cabling		40																20	10	10		40
- Equipment		60																40	20			60
																		60	30	10		100
- Equipment	55																					
of which: - Storage		9		9			9															
- Engine		56								50	6	56										
- Alternator		17								17		17										
- Electrical equipment and instrumentation		18													6	12	18					
		100	0	9	0	0	9			67	6	73			6	12	18					
	100																					

Except in special cases a hydraulic turbine comprises three characteristic components:

. a distributor
. a rotor
. a diffuser.

The purpose of the distributor is to direct the water to the rotor; this constitutes the regulating component of the turbine. The distributor is generally preceded by a spiral chute which carries the water to the entry point of the turbine and ensures its symmetrical distribution over the entire inlet surface of the distributor.

The rotor is the essential component of the turbine; it has blades which convert the energy of the water into mechanical energy.

The diffuser collects the water as it leaves the rotor so as to lead it to the outlet section of the turbine at a given speed.

These three components vary in configuration according to the type of hydraulic turbine; there are several types of hydraulic turbine, the choice of which is determined by the height and flow rate of the water.

Classification of turbines

- Pelton turbines are suitable for heads of water above 400 metres; the diameter of the wheel can be up to 4 metres; the available flow rates with high heads of water being generally modest the most powerful of these are of the order of 200 to 250 MW.

- Francis turbines are suitable for medium heads of between 400 and 40 metres. Using very considerable flow rates they make it possible to rise to greater powers of up to 700 MW; the wheels can be up to 8 metres in diameter and may weigh 200 tonnes.

- Kaplan turbines operate on low heads of water, normally between 15 and 40 metres. Their power can be more than 100 MW in the case of the most powerful or down to 6 MW for the smallest. The wheels can be up to 8 metres in diameter in the case of the most powerful units.

- Sets of the totally immersed type, adapted to low heads of water (on average lower than the Kaplan turbines) have a fairly extensive power range of the order of 1 MW in the case of micro-power stations (heads of 10 metres, wheel diameters 2 to 2.5 metres), of 10 MW in the case of "river bulbs" (10 metres head and wheels of 3 to 4.5 metres) or 50 MW for the most powerful on large rivers or tidal power stations (wheels 8 metres in diameter).

Finally we should mention the turbine pumps which are reversible machines used for power stations with pumping storage.

Technical aspects specific to the production of turbines

In order to solve the problems which are presented according to the dimensions, the weight and the transport possibilities, various production techniques are used.

- For the wheels

The alternative techniques used for producing wheels are casting or heat welding;

. casting in a single piece is used for wheels up to a certain size and weight (up to 6 metres in diameter and 100 tonnes in the case of Francis wheels);

. wheels with welded components, completely finished in the workshop: only if the transport conditions allow the despatch of wheels of such size as a single unit. The limits are of the order of 8 metres diameter and 200 tonnes, and transport can only be by water;

. wheels with components which are partly completed in the workshop, in those cases where the transport conditions do not allow the despatch of wheels in a single unit. Produced in two parts the final assembly by welding and then the final machining are carried out on site;

. wheels with welded components, completely produced on site (such as Francis wheels of 9.50 metres diameter and 500 tonnes weight). The production of these very large wheels frequently involves this technique. Complete production on site with welding and machining presents serious problems and the need to establish welding and machining workshops on the site.

- For the penstocks

Problems are presented by the large sizes (Francis turbines) or the use of high heads of water. The technique used remains heat welding, but the use of ordinary construction for the very large sizes requires very considerable thicknesses of plate leading to a search for other solutions such as:

. the use of high elastic strength steel
. the use of penstocks with a multilayer wall
. the use of penstocks of a double walled type, the space between the walls being filled with concrete.

The manufacture of the various components of the turbine necessitates both major production resources and highly skilled labour. The constraints imposed by the use of turbines (problems of erosion and cavitation, vibration, shafts, etc.) necessitate the utilization of highly sophisticated manufacturing techniques (shaping by explosion, welding under gases or by electronic bombardment, etc.); furthermore the machining and handling involves major resources (boring machines with very long travels, parallel lathes with a space of 8 metres between the stocks, etc.).

Design, calculations, tests and quality control are also important. Unit production of hydraulic turbines[1] necessitates major design and calculation resources: the design of a turbine depends above all on two variables, the head and the flow rate of the water, these two variables rarely being identical from one hydroelectric scheme to another; the search for optimum efficiency in the turbine implies considerable design and calculation work.

In the majority of cases the construction of the reduced scale model makes it possible to carry out trials so as to test the problems of efficiency, cavitation, vibration, etc. The actual manufacture of the turbine is commenced when all the tests on the model have been satisfactory.

All the design operations, the trials on the model, the manufacture and the actual installation involve long periods of time:

- for a turbine of 200 to 300 MW 4 to 5 years elapse between the time of ordering and the time of commissioning,

- for a turbine of 50 MW the time required is 3 years.

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(1) Each hydroelectric scheme necessitates the study and production of a specific turbine. A hydroelectric unit rarely includes more than 10 sets, so the production of these sets can involve very small production runs.

1.4.2 - Other hydraulic equipment

The turbine is the central unit of a hydroelectric power station, but nevertheless a number of other items of hydraulic equipment are needed to supplement the turbine and to allow it to operate. This is primarily equipment for bringing in the water and the positioning equipment.

The equipment for bringing in the water

Upstream of the turbine three units equip the turbine; these are:

- the head valve
- the penstock or collector
- the safety valve:
  . spherical valve for high heads
  . butterfly valve for medium heads

These units, produced by heat welding, are in most cases designed and manufactured by the constructor of the hydraulic turbine. Of less sophisticated technology than the turbine itself certain of the units (the head valve and the check valve) are of impressive size and weight. For example the spherical valve supplying certain turbines can be 2.5 metres in diameter and may weigh 130 tonnes; in the case of butterfly valves the diameter can sometimes be more than 6 metres and the weight more than 200 tonnes.

The head valves and the other valves include control units for opening and closing them (servo-motors).

Positioning equipment

The turbine and alternator assembly is positioned by pivots or thrust bearings. This heat welded unit transmits the total load of the rotating parts to the foundations. Guide bearings arranged on each side of the alternator serve as suspension and guide for the shaft. All these bearings are designed and produced by the suppliers of the equipment.

The positioning equipment consists of parts of high technicity (machining to 0.1 or 0.01 mm) and uses sophisticated techniques for babitting and measuring the parts.

1.4.3 - Regulation and control equipment

Regulation of the speed of hydroelectric sets is effected by a group of regulation components comprising detection and stabilization instruments (electronics and hydroelectronics).

All the operations of starting, stopping and controlling the hydroelectronic sets are carried out from a general control panel in the power station.

In most cases all the regulation and control equipment is supplied by the company producing the turbine.

1.4.4 - Grouping of hydroelectric equipment by route and by degree of complexity

In hydroelectric equipment one finds a certain number of production routes with which a number of items of equipment are associated:

- "sheet metal and heat welding" route
  - Chute
  - Distributor
  - Head valve
  - Penstock, collector
  - Safety valve, diffuser

- "Casting, forging, machining" route	- Wheel and shaft
- "Precision engineering" route	- Positioning equipment
- "Electronic and electrohydraulic" route	- Regulation and control equipment

The grouping of this equipment by route and level of complexity (Table 4) shows that the "metalworking, heat welding" route accounts for half the value of the equipment; this route is easy or not very complex; by contrast the "casting, forging, machining" route is more complex and accounts for 30% of the value of the equipment; finally the "precision engineering" and "electrohydraulic" routes, which account for 20% of the equipment, are very complex.

1.4.5 - The alternator

To each hydroelectric turbine is coupled an alternator, the function of which is to convert the mechanical energy into electrical energy by rotating a rotor within a stator.

The speed of rotation of the turbine-alternator assembly being low in hydroelectric units (less than 1,000 rpm) the size of the alternators is very considerable(1).

As in the case of the turbine the alternator also requires, despite its impressive dimensions, an accuracy in manufacture and assembly which, in the case of certain components, may reach 0.1 mm.

Production of the alternator necessitates major machining resources and also highly skilled labour for carrying out the mechanical machining of the components (magnetic sheets, etc.) and assembly.

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(1) In the case of the Churchill Falls hydroelectric power station the alternators, of which there are 11, weigh 178 tonnes and measure 7.6 x 4.4 x 6.2 metres.

TABLE 4 - Grouping of hydraulic equipment by routes and level of complexity

	%	Boilerwork Heat welding				Casting-forging-machining				Precision engineering Electrohydraulics			
		1	2	3	4	1	2	3	4	1	2	3	4
Water inlet equipment Chute Distributor Diffuser	50	25	25 to 30										
Wheel and shaft	30							30					
Positioning equipment Control equipment	15 to 20												15 to 20
Total	100	25	25 to 30					30					15 to 20

As in the case of the turbines the production of the alternators for a hydro-electroc power station is carried out in single units - or possibly in very short series. The design and study work constitutes a major initial phase in the production of alternators. Furthermore relationships with the design office of the manufacturer of the turbine during the design phase must be established to deal with problems relating to the coupling of the alternators to the turbine, as also at the assembly phase.

B - Equipment for the transmission and distribution of electrical energy

Electrical energy is produced in power stations, but this energy is generally not consumed at the point of production. It must be transferred to the centres of consumption for distribution from there. Transmission is carried out at very high voltage through the transmission network. Near the centres of consumption the voltage is reduced to high voltage and is then sent through the distribution network where the voltage is finally reduced to medium voltage for final distribution.

Voltages in the various networks are not uniform throughout different countries. For VHV 400 kV is the most widely used in Europe, 220 kV is international, but 500 kV is widely used in the USSR and the USA. For high voltage 150 kV is now disappearing and 63 kV is the most widely used voltage; however in France 90 kV is the most widely used. At medium voltage 20 kV is used in France and Germany, whereas in Great Britain 33 kV is used.

Each of these networks requires equipment. These include the cables, appropriate to each voltage, but more particularly the stations housing the switchgear and transformers (current and voltage) together with isolating cut-outs, etc. The complexity of these stations varies with the voltage and current of the electrical energy at its terminals.

1.1 - High voltage and very high voltage equipment

High voltages require very complex equipment of high operational reliability and safety. A 220 kV unit costs about 1.5 million FF; each transformer station consists of a multiple of three units (three-phase current). The breakdown of a 220 kV unit is as follows:

VHV switchgear	400,000 to 500,000 FF
Distributors Current transformers Voltage transformers	400,000 FF
LV protection	100,000 FF
Cabling - civil engineering	500,000 FF

. Complexity

The various items of equipment are very complex to manufacture. Generally speaking this equipment requires for its manufacture mechanical engineering and boilerwork (special alloys) workshops. High power test platforms are necessary to test the equipment under load.

. Technological developments

Developments involve both the materials used and the techniques employed. In the case of VHV switchgear the blowing of the electric arc on switching is now carried out using three techniques: compressed air, oil bath and SF_6 (1). Certain of these techniques, such as SF_6 are more recent.

(1) Sulphur hexafluoride.

The actual configuration of the equipment is changing (protected stations). In the case of high voltage switchgear the trend is towards very rapid cutting facilities (1 cycle). This development is linked with the density of the interconnecting network and the voltages used in these networks; in the developing countries the low voltage and density of the transport networks do not require cutting facilities of this order. Frequently the technologies which are technically and economically most appropriate for the developing countries are those which are forgotten or are now obsolete in the industrialized countries(1).

Two obstacles exist if the developing countries are to produce this type of equipment. One is of a technical order; the complexity of the equipment involves operating through the few companies at a world level which possess the know-how. The other is of an economic order; this type of equipment, as incorporated in the distribution networks in the developing countries, is smaller in size than in the industrialized countries; the level of industrialization (industry consumes nearly 60% of the electrical energy produced in France) determines the density of the distribution networks, and the market for this type of equipment in the developing countries is not very interesting for establishing such an industry, except for those countries which are both of major geographical size and also have reached a certain level of industrialization.

(1) The French company Delle Alsthom, after having abandoned the technology of high voltage switchgear using an oil bath and springs, is again producing this type of equipment, mainly for export to developing countries since it is technically and economically more suited to the needs of these countries.

1.2 - Distribution equipment

The public distribution of electrical energy necessitates a large number of medium voltage to low voltage transformer stations; for example in France in the Strasbourg region, and within a radius of 100 km around this town[1], with a maximum installed power of 350 MW, the network consists of 700 km of high voltage lines and 23 63 kV transformer stations; the medium voltage lines extend over 2,900 km and include 3,300 transformer stations dropping to 20 kV and 13.5 kV[2].

The size of this market is sufficiently large for the developing countries to be encouraged to develop this type of production; the demand for distribution equipment (distribution transformers) represents, according to a UNIDO report, roughly twice the average annual increase in the production of electricity[3].

In all the distribution equipment the central part remains the distribution transformer, so it is essential to study in greater detail the production characteristics for this type of equipment.

The production of distribution transformers does not require the use of relatively complex production techniques. A standard

(1) A region which comprises 119 communes with 700,000 inhabitants

(2) Le Monde, 11/1/1979.

(3) Establishment of factories in developing countries for the production of electrical distribution transformers. UNIDO/IOD - 4 January 1978.

distribution transformer consists of a steel plate vessel with corrugated walls and an active part of cold rolled silicon steel plate to which are mounted the aluminium or copper windings; the active part is fixed to the cover of the vessel and rests in an oil bath.

The production apparatus needed to produce this consists of a sheet metal workshop for cutting, shearing and welding (heat or electric arc) and drilling the plates; a mechanical engineering workshop for the operations of turning, milling, drilling and tapping, together with a winding workshop using winding machines.

2 - The transfer of technology in equipment for producing energy

We will attempt to analyse how the transfer of the production of equipment goods to a developing country can be operated. It would appear that the transfer of production should be modulated as a function of the development of the receiving country: certain sub-assemblies of the equipment can easily be mastered; this is equipment using certain technical routes; other sub-assemblies on the contrary are difficult to master, both in respect of the technical routes and also because of the technical environment necessary for their manufacture. It appears that, in the manufacture of these items of equipment goods, the design studies and the methods of manufacture are directly linked to R & D. Mastery of certain sub-assemblies of the equipment necessitates the existence of close relationships between R & D, design and manufacture and it is these relationships which constitute the "hard core". R & D and design are the elements which are most difficult to transfer and to master in the receiving countries; they are also the elements which the large companies in the sector show least desire to transfer, so that they can retain "mastery" of the most valuable parts of the work since this forms the know-how of each company, on which its market domination is based.

We have retained four categories of countries according to their level of development so as to analyse, for each level, the part of the capital investment which could give rise to local production:

- level 1 : countries having little industrial experience, largely unskilled labour and very few design resources.

- level 2 : countries having some industrial experience, but scarcely reaching the field of equipment for the production of electrical energy, the existence of relatively skilled labour and some design resources.

- level 3 : countries having some industrial experience, particularly in equipment for the production of electricity, the existence of skilled labour and design facilities, and embryonic R & D resources.

- level 4 : countries having considerable industrial experience in equipment for the production of electricity, highly skilled labour, major R & D and design resources.

2.1 - Transfer of production for thermal power stations

A certain number of operations can easily be transferred to the developing countries; these are mainly operations such as civil engineering, the assembly of equipment and the manufacture of certain equipment sub-assemblies.

For a certain number of items of equipment access to the technology is difficult for the developing countries and certain prior stages are necessary.

- Civil engineering and installation work

These account for 25% of the cost of a thermal power station, and the civil engineering can easily be carried out by local companies.

In the case of the installation work, which also accounts for 25% of the cost of a power station, the painting and lagging work can also be carried out by local companies. In the case of the pipework the general pipework can be produced, but by contrast the pipework carrying high temperatures and high pressures necessitates a high level of competence on the part of the pipeworkers and welders. The electrical cabling, if it is to be carried out locally, requires the supply of production layouts (details of the assembly, paths of the cables, etc.) and for the installation of the instrumentation recourse to foreign companies is essential.

- The equipment

* The boiler

Without being extremely complex the manufacture of the steam boiler for the power station remains subject to possessing the technology, particularly in the machining and welding of tubes of special alloys, heat treatment, welding and complex quality control.

Access to the technology of boilers for power stations can be achieved by means of experience acquired in the field of industrial boilers, it being understood that the shift has to be carried out by mastery of the problems of regulation and reliability required in boilers for power stations.

A certain number of developing countries including India and Mexico, are, at the present time, producing boilers for power stations.

* The turbine and the condenser are extremely complex. There is no technological frontier between the production of low power turbines (60 to 100 MW) and high power turbines (600 MW). India produces turbines in the region of 200 MW.

* The alternator. It is possible to produce an alternator more easily than a turbine. Access to the technology can be effected by way of experience acquired in the production of large electric motors; there is no technological frontier between a small power station alternator and a large alternator; only the resources necessary for forging the stator parts are different.

* The boilerwork equipment (condenser reservoirs, fuel storage tanks, etc.) can partly be produced locally; for those directly linked to the process the manufacture necessitates the supply of production drawings.

* The structural metalwork for the buildings and the structure necessary for the equipment. Structural metalwork for the buildings is easily mastered by the developing countries; for the structures needed for the equipment production drawings need to be supplied.

- Countries at level 1 can only participate to a very limited extent in the production of equipment for power stations; their participation will be located principally in the engineering and installation work; this covers:

- 80% of the civil engineering
- 65% of the installation work:
  of which: 10% is structure erection
  20% is pipework
  10% is painting and lagging
  10% is electrical cabling
  15% is installation of the equipment
- 6% of the equipment goods, involving mainly the production of simple structural steelwork and boilerwork.

- Countries at level 2 can provide:

  - all the civil engineering
  - 90% of the installing work (including the instrumentation)
  - about 10% of the equipment: this covers all the simple boilerwork and structural steelwork, part of the valves and the electrical equipment.

- Countries at level 3, in addition to all the civil engineering and installation work, can produce more than half the equipment for thermal power stations locally. This covers all the equipment related to the sheet metal and profile working route (structural metalwork, boilerwork and boilers), certain parts of the casting-forging-machining route such as sub-assemblies for the turbine and condensers and valves, and finally certain sub-assemblies of the equipment linked with other routes such as pipework, control and electrical equipment sub-assemblies.

- At level 4 the complex sub-assemblies of the turbine and alternators, part of the pipework, of control and electrical equipment are mastered. The manufacture of these sub-assemblies depends both on a specific production appa[illegible], considerable R & D and highly skilled labour.

Conclusions:

- Entry into the production of equipment for thermal power stations can be carried out initially through the "sheet metalworking, structural metalwork, boilerwork" route.

- There is an important threshold between level 2 and level 3 which corresponds both to mastering the "casting, forging, machining" route and mastery of the complex levels of the "sheet metalworking, boilerwork" route. Below this threshold national participation in the production of equipment remains marginal (of the order of 10%), whereas beyond this national participation can account for more than half the value of the equipment.

- Finally certain items of equipment are very difficult to master since they require, for their manufacture, both a considerable production apparatus and high skills in the labour, coupled with considerable R & D and design efforts.

2.2 - Transfer of production in diesel power stations

The most complex parts of a diesel power station are the engine and alternator unit and the regulation part. The production of such equipment necessitates access to a relatively high level of technology. In particular the production of sets of less than 100 kW can be carried out by countries having access to the production of engines for trucks or tractors; in the case of higher powers it is engines of the type of those used for rail or marine application which are used.

The possibilities for local production concern:

- Level 1 : Civil engineering (100%)
  (60%) : cabling
  installation of equipment

- Level 2 : Installation (90%)
  Fuel storage equipment (9% of all equipment)

- Level 3 : Installation (100%)
  Equipment: Engine (about 80% of the assemblies)
  Alternator (all)
  Electrical and instrumentation equipment (about a third)

- Level 4 : The most technical parts of the motor and instrumentation, which account for about 20% of all the equipment of a diesel power station.

It can be seen therefore, that in total:

- Apart from the civil engineering and installation work, which is easily mastered by the developing countries, it is through the "sheet metalworking" route that these countries can enter the production of equipment for diesel power stations.

- Mastery of the "casting-forging-machining" route, with which more than two-thirds of the equipment are associated, makes it possible to give effective support to the production of equipment for diesel power stations.

- The "hard core" of equipment for diesel power stations relates to certain engine and instrumentation sub-assemblies, the production of which depends on R & D and design work together with considerable human and material resources.

2.3 - Transfer of production in hydraulic equipment

In what follows we will describe the experience of transfer of production of a large company producing hydraulic turbines at its subsidiary located in Latin America. The methods of transfer can vary from one country to another or from one company to another, so that this experience cannot be generalized (in particular the time required for transfer may vary from one country to another). However this experience makes it possible to identify four successive phases for a country which is to produce hydraulic turbines, these phases being characterized both by the nature of the technological routes transferred, the level of increasing complexity, and the magnitude of the production and design studies necessary for certain phases.

First level

This relates to those parts which can be produced anywhere: exhaust systems, ring (except before the distributor), chute, linings, walk-way, pressure reservoir, etc.

These parts do not require any major industrial resources, since they are not technical components. They are mainly straightforward boilerwork, using plates of less than 60 mm thickness. The resources needed relate to the methods of bending and welding (manual welding, without major quality control).

No design office is necessary, production being carried out on the basis of execution drawings provided by the firm having transferred this type of activity. An artisan could even produce this type of part. No competence in regard to hydraulics or mechanical engineering is necessary.

Mastery of manufacture of this type of part by the DC requires 3 to 5 years and represents 25% of the overall cost of a hydraulic turbine, excluding the installation cost.

Second level

This relates to the most difficult parts: before the distributor, the distributor, the valve servo-motor and the mechanical engineering boilerwork parts.

These are heat welded parts requiring major machining resources. In the first stage the manufacturing personnel consist essentially of welders and boilerworkers, the training of which can be carried out in six months in the DC; in the second stage it involves mainly engineers, the training for which is considerably longer, taking 3 to 5 years, and also necessitates an industrial environment since the time for assimilation of technologies depends on the existence or not of an industrial infrastructure in the country.

Such parts require good boilerworking facilities with heavy resources (plates of 100 to 120 mm thickness, parts of 100 to 150 tonnes weight and 8 to 10 metres diameter) and major mechanical engineering resources, whilst the welded parts require very strict quality control (high degree of development of the labour, both in welding and engineering generally).

At this stage the country must be able to carry out the manufacturing methods which are very strict in this phase, so that a methods office is necessary. At this stage a small part of the execution studies can be integrated locally, but most of the studies will still come from the company which is operating the transfer of production.

The time needed for assimilating this phase will vary according to the country, and also according to the industrial level reached in other sectors. In the present case the time taken was 5 years. The firm was involved in training engineers by training local personnel in its establishments and also by sending personnel to the country concerned.

Integration of this phase in the DC covers 25 to 30% of the value of the turbine.

Third level

This relates to the production of the wheel and the shaft. Here a new factor comes into play, since the country which wishes to produce such parts must have a basic metallurgical industry and have mastered this technology. In fact the resources for casting and forging must be considerable; for example to produce a wheel for a 700 MW plant it is necessary to have a casting capacity of 240 tonnes; the wheel itself, after the various sub-assemblies have been fitted to it, weighs 300 tonnes.

In this stage we enter the field of very difficult matters in regard to skills, so that the labour must have competence in respect of mechanical engineering and also in the field of hydraulics (compliance with hydraulic shapes). The design of the manufacturing range, the range of tools, the supervision of the work being carried out, the control of parts, etc., are all of great importance in organizing the production work. A highly structured methods office is necessary.

Furthermore all the execution drawings must be produced by the local company in this stage; the assistance of the company transferring the technology is necessary for a local enterprise, as it has not yet mastered the design studies, these studies have an implication on the execution studies.

At this stage confidence between the firm operating the transfer and the company receiving the transfer is an essential factor. In transferring the manufacture of the wheel it is the know-how and experience of the company in the field of hydraulics which is partly transferred to the local company. The wheel is a strategic part since the firm is transferring its hydraulic secret (hydraulic pattern - shape of the wheel) which has sometimes required several years of R & D and accumulated experience. The firm ensures, in advance, that the local company does not risk becoming a potential competitor. In the case where this confidence exists this implies, for integrating this phase into the company, very close relationships in communications between the company and the local company at all levels (Direction, Design office, Methods office, workshops). If such confidence does not exist this is shown, for the local enterprise, in enormous additional costs.

According to the nature of the relationships between the firm and the local company the period required for assimilating this stage can, with difficulty, be reduced to less than five years.

In this phase it is 30% of the value of the turbine (wheel 25% - shaft 5%) which is integrated locally.

Fourth level

Here we are dealing with the hard core in the production of hydraulic turbines, consisting essentially of:

- Research and development
- Design studies
- The manufacture of very difficult and strategic components.

In the case of these parts it is the active part of the pivoting unit which is involved. This is the essential part of the turbine; it is also on this part that the turbine depends since these are parts of high responsibility, faults in it resulting in deterioration of the whole of the turbine. Pieces of high technicity, involving work down to 0.1 or 0.01 mm and hence requiring highly skilled labour, very accurate machines, know-how in regard to certain techniques (babitting - coating with antifriction metal - measuring components, etc.).

This stage also integrates completely all the regulation work on the turbine (the electronic and electrohydraulic assembly) making it possible to control the operation of the maching from a point of view of speed, stability, response to current demand, etc. There are electronic sub-assemblies and also hydraulic sub-assemblies: servo-motors with a diameter of 1,000 mm fitted with enormous valves; very accurate mechanical engineering which demands very complex design studies and trials.

R & D is very considerable and relates both to the pivoting parts and all the other components of the turbine. The interdependence of each of these sub-assemblies in the design of a turbine explains why the firm cannot transfer part of the design in favour of a local company. The design of a turbine is a whole, which also requires very close links with R & D. R & D and the installation of the turbines

TABLE 5 - Phases of entry into the production of hydraulic turbines

Parts produced	Production route	Resources necessary	Skills necessary	Percentage of the value of the turbine	Period for assimilating the techniques
I - Exhaust components Ring (except distributor) Chute Lining Footway Pressure tank	Boilerwork less than 60 mm → Bending → Manual welding without quality control	No design office necessary Execution drawings provided by the firm	Boilerworker Welder	25%	3 to 5 years
II - Pre-distributor Distributor Valve servo-motor Mechanical engineering and boilerwork components	Heat welding → Machining → Welding Working plates 60 mm and above	Major machining resources Engineering control of parts Methods office Execution drawings largely supplied by the firm	Engineer Heat welder	25 to 30%	Depends on the industrial environment of the country; minimum 5 years
III - Wheel Wheel shaft	Forging Casting Very large machining	Major metallurgical resources Engineering and hydraulic control of the parts Structured methods office Design office for execution plans	Metallurgists	30%	Depends on level of confidence with the firm operating the transfer; 5 years minimum
IV - Active pivoting parts Turbine regulation (Strategic and very complex parts)	Precision engineering Electronics Electrohydraulics	Micro-engineering and electrohydraulic resources Resting resources Design studies R & D	Precision engineers Electrohydraulics engineers	15 to 20%	

(design, execution and manufacturing studies) are closely linked; research and development relates to the varied and complex techniques, and this explains the difficulty of transferring R & D. Only those firms having major R & D resources can remain in international competition. The speed of development means that they benefit from a certain turnover volume; for example in the case of large Francis wheels one or two ordered every year are necessary. There is no reproducibility from one turbine to another: on each order it is necessary to redesign certain sub-assemblies and to modify the manufacturing techniques to minimize the time required for manufacture.

At the present time only Canada, outside the major world manufacturers, has reached this fourth stage.

2.4 - The possible stages of transfer

On the basis of the three cases set out above it can be seen that mastery of the various kinds of work involved in installing power stations can be carried out progressively by the developing countries:

- a first stage concerns the major part of the civil engineering, certain installation work and the production of equipment relating to the "general structural metalwork and boilerwork" route. The resources necessary for carrying out this work are small and the competences of the skilled labour required can be easily acquired during a short period of training (one to six months, according to the type of work). All this work can be carried out on the basis of execution drawings provided by the firms operating the transfer.

- a second stage involves the whole of the civil engineering, a large part of the installation work and the production of equipment relating to the "heavy boilerwork" route. The resources needed relate to the competence of the labour force (initial training three to five years, industrial experience), whilst the methods of organizing work need to be mastered (methods office in the field of equipment production, coordination and supervision of the various installation operations). During this stage part of the execution drawings could be integrated locally.

- a third stage involves the almost total integration of installation work and mastery of the "forging-casting-machining" route. This mastery necessitates detailed skills in various fields: metallurgy, engineering, hydraulics, etc. Organization of the work becomes of great importance in production (large and fully structured methods office). Mastery of the studies should also be fully covered; assistance of the firm operating the transfer is important at this level. In addition to its own manufacture of the equipment it is a large part of the know-how of the firm which is being transferred at this level, so that this requires close and permanent contact between the staff and mutual confidence.

- a fourth stage concerns mainly the "hard core". This hard core covers the manufacture of certain very complex and strategic sub-assemblies, calling on very special techniques together with all the research and development activity and design studies associated with the production of all the equipment. The design of the equipment and, in the last resort, the manufacturing methods and the manufacture itself must be closely linked with research and development efforts. This involves very varied and complex technologies and necessitates financial, human and technical resources which only a few companies of world status are capable of putting into effect. For the firms the mastery of this "hard core" constitutes the only means for safeguarding their position in international competition; hence their reticence in transferring this part.

CHAPTER II

THE SUPPLY OF EQUIPMENT GOODS FOR THE PRODUCTION AND DISTRIBUTION OF ELECTRICAL ENERGY, AND THE PRINCIPAL ACTORS

1 - Analysis of production and trading

1.1 - Analysis of world production

It must first of all be pointed out that there is a lack of statistics which would make it possible to identify world production of equipment for electrical energy. The only sources giving information on this are those from OECD[1], published in the following documents:

- Mechanical and electrical engineering industries in the member countries of OECD,
- Annual surveys on electrical equipment.

The first document provides information on all the European countries, Japan and North America. The statistics are given in terms of value (US$ millions), using the SITC nomenclature.

The second document provides information on production of certain items of equipment for power stations and the distribution of electricity, but only covers the European countries.

In the present state of statistical sources we have no way of determining the production of electrical energy equipment in the planned economy countries. These countries have a major industrial potential in this field, and this makes it possible for them to enter international competition for supplying equipment to power stations and transmission networks. No resources are available which makes it possible for us to ascertain the importance of these countries to world production.

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(1) OECD - Deliveries of 100 individual products. Mechanical and electrical engineering industries in the member countries of OECD. Basic statistics, Paris 1977.

TABLE 6 - Production of equipment for the production and transmission of electrical energy in the market economy countries - 1975 in US$ millions

groups / countries	711.1, 2, 3	711.6	711.7	711.8	722	723
West Germany[1]	835	126	N.A.	43	4,509	2,243
France	206	33	N.A.	51	2,155	1,737
Italy						
Belgium	68			N.A.	320	117
Holland[2]	54	N.A.			174	N.A.
Austria	67		N.A.	26	74	182
Sweden	196	29	4	35	514	312
Switzerland						
UK[3]	315	N.A.	N.A.	N.A.	1,586	N.A.
USA	3,158	N.A.	N.A.	N.A.	12,968	5,552
Japan[1]	1,145	71	1,115	287	7,733	3,327

(1) 1974
(2) 1972
(3) 1973

711.1, 2, 3 : Steam boilers, heating units and steam machinery (including turbines)
711.6 : Gas turbines, other than for aviation
711.7 : Nuclear reactors
711.8 : Hydraulic turbines
722 : Electrical generating machinery and equipment for switching electrical circuits
723 : Equipment for the distribution of electricity

Whilst recognizing the limits of such an analysis the study of world production will relate only to Europe, North America and Japan.

1.1.1 - OECD data on the mechanical and electrical engineering industries

This data, although fragmentary, shows the importance of the USA, followed by Japan and West Germany, in the production of equipment for power stations and distribution.

- In the field of steam boilers American production is larger than European and Japanese production added together. Japan has a production which is about one-third of the American production, whilst West Germany represents about one-quarter. European production, excluding West Germany, is at about the same level as German production.

- In the field of electrical generating machinery one again sees the importance of the USA, but the gap between its production and that of Japan and Europe (in particular West Germany and France) is smaller: the level of Japanese production is at about 60% of the American level for this type of equipment, that of West Germany is more than a third, that of France 17%.

- In transmission equipment the gap between American production and that of the other countries is even smaller: Japan is at 60% of the American level, West Germany at 40% and France at 31%.

In total therefore the production of equipment for the production and distribution of electrical energy is dominated by the USA. The magnitude of this production arises essentially from the size of the American market for energy equipment, which is the largest in the world, and also by the barriers imposed by American legislation on access to this market by foreign companies, whilst the demand for electrical energy in America is the largest in the world.

The size of the production makes it possible to understand the domination which American firms have in this sector, both in the field of technological knowledge, patents and R & D.

1.1.2 - Surveys on electrical equipment

With the development of equipment for nuclear energy the trend which has been seen in Europe since the beginning of the seventies is a steady fall in deliveries of conventional boilers. In 1970 all the European production of this type of equipment had a steam capacity of 70,000 tonnes of steam per hour; in 1976 European deliveries were of the order of 46,000 tonnes of steam per hour.

Although there is an overall reduction in the steam production this is unequally distributed amongst the principal producing countries. In fact West Germany, far from seeing its production reduced, is actually increasing the volume of its deliveries. In 1976 West Germany accounted for half the European production of steam boilers, and German exports represented more than half the European exports; in 1970 German production was only a quarter of European production and German exports were only just in fifth position in European exports. By contrast one can see a very clear falling off in Great Britain and, to a lesser extent, in Spain, in European production of this type of equipment, the same falling back also being seen in exports.

TABLE 7 - EUROPEAN PRODUCTION OF TURBINES AND ALTERNATORS (in MW) and POWER TRANSFORMERS (in MVA) from 1970 to 1976

	1970	1971	1972	1973	1974	1975	1976	1977*
Turbines	29,979		34,772	45,027	49,556	43,692	35,407	46,175
of which:								
. steam	22,883	(29,199)	24,953	32,322	(34,024)	30,620	25,034	34,152
. nuclear	3,608	4,916	3,761	6,273	7,885	10,587	9,461	15,443
. hydraulic	5,358	(5,781)	7,157	9,000	10,960	8,577	6,740	8,221
. gas	1,738	2,337	2,662	3,705	4,572	4,495	3,713	3,802
Alternators	29,116		34,783	48,484	40,009	42,635	43,017	48,500
of which:								
. for steam turbines	23,835	(33,434)	28,520	36,745	31,332	35,829	36,421	40,308
. hydraulic	5,281	(8,825)	6,263	11,739	8,677	6,806	6,596	8,192
Transformers			156,882	163,602	(164,739)	136,715	149,411	144,616

* Ordered on 1.1.1977 for delivery in 1977.

Over the whole of Europe the increase in exports of steam boilers has made it possible to limit the fall in production. One trend can be seen: that of the importance of exports to the Third World. In 1976 exports, mainly to the developing countries, represented two-thirds of all exports of boilers from the principal European manufacturing countries.

- In the hydraulic turbine sector the contribution of this type of equipment to all European deliveries of turbines - steam, hydraulic and gas - expressed in MW remained unchanged during the period 1972 to 1976, being of the order of 20% or, on average over the period, 8,000 MW of annual production. The trend during this period is towards increased exports; in 1976 exported production was of the order of 70% as against 50% in 1972. The degree of development of European technology in this type of equipment has made it possible to assume a dominant position in the Latin American and African market.

- As far as gas turbines are concerned European production has increased under the joint effect of an increase in the European demand, resulting from the development of a nuclear programme in certain countries for peak energy supplies:

. but particularly from a considerable growth of this type of installation in the oil producing countries.

In 1976 exports represented 80% of European production, the latter reaching a total power of the order of 4,000 MW, West Germany and the United Kingdom providing two-thirds of the European production.

1.2 - Analysis of international trading

It is very difficult to evaluate international trading in equipment for the production and distribution of electrical energy from the international statistics. This difficulty is related essentially to the nomenclature (SITC) which only takes account with difficulty of equipment linked with the production and distribution of electrical energy; this equipment is in most cases included with other equipment, the use of which is located outside the sector of the production and distribution of electricity.

The SITC nomenclature distinguishes:

711 — Generating machinery other than electrical machinery,

including:

- 711.1, 2 and 3 — Steam machinery
- 711.6 — Gas turbines
- 711.7 — Nuclear reactors
- 711.8 — Other engines (including hydraulic turbines)

722 — Electrical generating machinery

723 — Equipment for distribution

The grouping of the equipment is carried out according to their technological characteristics, not according to their final use. In this way group 711.1 to 3 includes both industrial boilers and boilers for the production of electrical energy. Group 711.6 includes all gas turbines for industrial uses, where the applications for the production of electrical energy relate to half the industrial applications for gas turbines.

TABLE 8 - World exports of equipment for the production and distribution of electrical energy

SITC group - revised	FOB value in millions Eurodollars		Increase between 1966 and 1975	Contribution to total mechanical and electrical engineering industries	
	1966	1975		1966	1975
Generating machinery (711)	616	3,232	5.24	1.9	2.2
of which:					
Steam turbines (711.1, 2 and 3)	403	1,644	4.08	1.2	1.1
Gas turbines (711.6)	68	856	12.59	0.2	0.6
Nuclear reactors (711.7)	51	380	7.45	0.2	0.3
Other engines (711.8)	94	352	3.74	0.3	0.2
Electrical generating machines (722)	2,325	10,200	4.39	7.1	6.9
Distribution equipment (723)	640	2,672	4.17	2.0	1.8
Total of listed equipment	3,581	16,104	4.50	11.0	10.9
Total of mechanical and electrical equipment goods (71-72)	32,546	148,208	4.55	100	100

Source: United Nations. Statistical bulletin on world trading in products from the mechanical and electrical engineering industries - 1966-1975.

1.2.1 - Overall data on international trading

The following table shows the growth of international trading in the various groups. World trade in 1977 in this equipment reached $16 billion and represented 11% of international trading in mechanical and electrical equipment (groups 71 and 72). In this type of equipment the increase of international trading during the period 1966-1975 was effectively identical with that of all mechanical and electrical equipment goods.

TABLE 9 - International trading in equipment goods for the production and distribution of electrical energy
Exports by countries - 1966-75
- in $ millions, FOB, at current prices.

Countries \ Groups 71 and 72	TOTAL			
	1966		1975	
	$m	%	$m	%
USA	712	19.9	3,926	24.7
West Germany	694	19.4	3,033	19.0
France	245	6.2	1,628	10.2
Japan	216	6.0	1,346	8.5
UK	439	7.2	1,502	9.4
Italy	149	4.1	696	4.3
Eastern Europe	394	11.0	1,526	9.5
TOTAL	3,576	100	15,903	100

The increase was rapid in the case of certain items of equipment, such as gas turbines and nuclear reactors. This phenomenon is understandable because of the very low level of world trading in this type of equipment in 1966, and because of the rapid development of power stations using gas turbines during this period in countries having supplies of hydrocarbons.

By contrast steam turbines and distribution equipment show a less rapid rate of increase.

The structure of international trading by type of equipment shows the importance of electrical generating machines (63% of international trading in the equipment concerned), whereas the other items of equipment made a relatively small contribution.

1.2.2 - Structure of exports by countries

International trading in equipment for the production and distribution of electrical energy is highly concentrated, and the change over the period 1966-1975 is towards even greater concentration. The USA, West Germany, France, Japan, United Kingdom and Italy dominated in 1966 with 68% of international trading in this equipment: in 1975 the same six countries accounted for 76% of international trading.

The EEC alone accounts for 50% of international trading, and West Germany, France and the United Kingdom are the largest exporters in this zone. Over the period 1966-75 a relative stability on the part of West Germany in international trading can be seen. France has increased its penetration on international markets, but on the other hand the United Kingdom, the third leading world exporter in 1966, had fallen to fourth position by 1975.

The contribution of the planned economy countries remains small in world trading in equipment for the production and distribution of electrical energy, and in fact this contribution fell over the period from 11% in 1966 to 9.5% in 1975.

Finally we should point out that, although the data are not included in this table, certain developing countries are engaged in this international trading. Certainly their participation in international trade remains very marginal, but their appearance on international markets during the period 1966-75 is a noteworthy fact; the countries concerned are Brazil, which in 1975 exported \$23.6 million of equipment for the production and distribution of electricity, Singapore (\$63 million), South Korea (\$58 million) and, to a lesser extent, India and Mexico. Certain developing countries seem to have a capacity for exporting these categories of products.

1.2.3 - Destination of the exports

The destination of the exports shows that the industrialized regions receive most of the world exports of electrical equipment: Europe and North America absorb 55% of all the equipment, the EEC being the principal importing region. The industrialized regions therefore contribute largely towards international trading in electrical equipment: the industrialized countries are at the same time both the principal exporters and also major importers.

However the development regions do represent not unimportant markets: Africa absorbs 9% of world exports of electrical equipment, Latin America 9%, the Middle East 10% and Asia 12%: it is true that Japan, included in this region, tends to boost the relative contribution of this region. Approximately a third of the world exports of electrical equipment are sent to the developing regions. The rapid increase in imports of electrical equipment in certain developing regions (in 1966 the Middle East imported about \$100 million of electrical equipment, or 3% of world imports, whereas in 1975 it was \$1,688 million or 10% of world imports) shows that world exports will be increasingly directed to these zones in the future. In the developing regions various factors - supplies of spares, technical assistance, the colonial inheritance and the existence of close relationships between clients and suppliers, etc. - contribute towards creating markets in which certain industrialized countries are particularly well established. This is the case with British exports to the Commonwealth countries, of Japanese exports to South-East Asia, and of West German and French exports to European countries outside the EEC.

TABLE 10 - Destinations of exports in 1975

Countries \ Groups	Part of 711	722	723	Total	%
Africa	227	968	318	1,513	9
North America	206	824	192	1,212	8
Latin America	293	1,007	181	1,481	9
Middle East	372	898	418	1,688	10
Asia (including Japan)	473	1,213	314	2,000	12
EEC	510	2,707	426	3,643	23
Other European countries	505	1,589	223	2,317	15
Other countries	31	232	165	428	3
Total	2,880	10,200	2,672	15,732	

2 - The principal actors concerned with equipment for the production and distribution of electrical energy

The electrical equipment industry at a world level is characterized by:

- A small number of countries capable of manufacturing all the equipment necessary for a power station or a distribution network. At the present time only the industrialized countries manufacture all this equipment. The developing countries produce certain heavy electrical equipment, but without manufacturing all the equipment for a power station or a network; only India seems to have reached this technological level and to have the required industrial capacity.

- A high level of integration of this activity: the national markets of the industrialized countries are dominated by a small number of very large and very diversified firms; it is these which carry out most of the industrial production in this activity, and which possess the greater part of the advanced technology. Concentration in the electrical equipment industry has been largely favoured by national policies encouraging the horizontal mergers of companies. Successive agreements have been signed between the companies, intended to make their production apparatus profitable, to provide all the equipment for power stations (turnkey power stations), and at the same time to retain control of their domestic markets.

The major manufacturers organize their activities so as to produce "turnkey power stations". This trend covers hydraulic, thermal and nuclear stations. The restructuring of groups, both at national level and also at international scale, is evidence of the desire to master these routes leading to the delivery of power stations; hence the groups do not necessarily integrate the manufacture of all categories of sub-assemblies, certain of these sub-assemblies being transferred to their foreign subsidiaries, others to national companies specializing in the manufacture of one category of equipment.

- The domination of a few companies: the American companies and some European companies exercise world domination which is technical, financial and commercial. It is these companies which possess the greatest part of the advanced technology in this sector; they exercise control by subsidiaries both in the industrialized countries and in the developing countries, and they carry out most of the international trading in electrical equipment. Their dominant position is reinforced by commercial agreements.

2.1 - The American companies

A number of American companies are involved in the field of equipment for power stations and electrical transmission networks. However whilst some of them have activities limited to certain types of equipment two of them provide all the equipment for the production and distribution of electrical energy (General Electric and Westinghouse).

The hydroelectric equipment sector is dominated by two major firms: General Electric and Westinghouse. However neither General Electric nor Westinghouse manufacture hydraulic turbines at the present time. In the field of electrical power stations these two groups produce only the electrical equipment for the power stations: they have moved out of the engineering part, namely the hydraulic turbines.

These two groups, whilst building only the electrical parts, deliver hydroelectric power stations as a result of agreements concluded by them with the manufacturers of hydraulic turbines: in this field four companies are present on the American market, including one Japanese company. In decreasing order of importance these companies are:

- Allis Chalmers
- Baldwin Lima Hamilton
- Newport Mews & Shipbuilding
- Mitsubishi.

Amongst these manufacturers Baldwin Lima Hamilton and Newport Mews & Shipbuilding work for General Electric and Westinghouse. Allis Chalmers provides the two latter companies with hydraulic turbines. On the basis of agreements signed between General Electric and Westinghouse on the one hand and Allis Chalmers on the other 60% of the production of hydraulic turbines of the latter are supplied to General Electric, 30% to Westinghouse. The remaining 10% of the hydraulic turbines manufactured by Allis Chalmers are coupled to its own alternators.

The structure of the production of hydroelectric power stations can be shown in the following way:

Hydraulic turbine	Alternator	
Baldwin Allis Chalmers -->	General Electric -->	turbine and alternator
Newport Allis Chalmers -->	Westinghouse -->	turbine and alternator
Allis Chalmers Mitsubishi -->	Allis Chalmers -->	turbine and alternator

The conventional thermal power stations sector is also dominated by the two companies, General Electric and Westinghouse. However these two companies, whilst producing thermal power stations, only produce the electrical equipment: thermal turbines, alternators, control equipment and power transformers.

In the field of boilers three American firms dominate the market, and their technology imposes itself at a world level: these are Combustion Engineering, Babcock and Foster Wheeler; in addition to these three firms a number of smaller firms are active in this field.

In equipment for the control and regulation of thermal power stations we find Bailey Meter (a subsidiary of Babcock & Wilcox), the Computer and Instrumentation Division of Westinghouse, together with General Electric and Combustion Engineering. Foxboro offers a complete range of process control equipment, certain of which are used for the control and regulation of boilers.

The gas turbine sector is also dominated by General Electric and Westinghouse. General Electric is the world's leading manufacturer of gas turbines. At the end of 1975 the company had more than 2,500 turbines in service throughout the world. General Electric has developed its own technology in this field and at the present time a certain number of firms are "manufacturing associates" of the American firm: these are John BROWN Co., Ltd., (UK), AEG (WG), KWAENER BRUG (Norway), HITACHI (Japan) and THOMASSEN (Holland). ALSTHOM ATLANTIQUE (France) is a licencee of GENERAL ELECTRIC.

Westinghouse is the second largest world manufacturer and its technology is operated through its subsidiary ACEC (Belgium) and MITSUBISHI (Japan).

In the production of electrical energy aerospace turbine manufacturers offer gas generators to which are adapted the expansion turbines manufactured by certain electrical manufacturing companies. This dissociation of the manufacture of gas turbines for the production of electrical energy (gas generators on the one hand, and expansion turbines on the other) is not profitable when seeking the best efficiency. Furthermore these turbines of the aerospace type rarely make it possible to reach powers of more than 30 MW. Amongst the firms offering gas generators are:

United Technologies
Curtiss-Wright
Cooper Industries
Dresser Industries
Ingersoll Rand

In the equipment for diesel power stations it is the companies manufacturing diesel engines for the automobile industry, public works plant and marine equipment who are most active in this field. The principal suppliers of equipment for diesel power stations are:

0 to 30 hp	:	ONAN Teledyne
30 to 500 hp	:	Detroit Diesel (General Motors) Cummins Mack Allis Chalmers Perkins(1)

(1) Perkins is the leading world producer of engines, with a production of 560,000 engines in 1978. Of these 10% have applications in the production of electrical energy. Perkins is present through its subsidiaries or licencees in more than 40 countries. The company is established in certain developing countries and in 1978 negotiations were carried out in Colombia, Egypt, Indonesia, the Philippines and Taiwan for local establishment in partnership with local governments or interests. Financial Times, 8 January 1979.

500 to 5000 hp	: Electro-Motive (Division of General Motors) ALCO (General Electric)
Above 5000 hp	: Delaval Fairbanks Morse (Colt Industries)

In high voltage and very high voltage transmission equipment it must be stated that American technology is less advanced than in the equipment power stations. The USA remains the recipient of foreign technology from Europe and Japan. The principal manufacturers are:

. Westinghouse, which has agreements with Mitsubishi in respect of 500 kW switchgear

. General Electric (agreements with Hitachi)

. Allis Chalmer (agreements with Siemens)

The size of the American market(1), with which the European or Japanese markets cannot be compared, has contributed towards giving American firms in the heavy electrical industry a technological, industrial and financial status which is considerable. This explains why, outside a few rare non-American firms (Siemens, BBC), the American firms hold licences and know-how in the advanced technology; their capacity in this industry is the largest in the world.

(1) Between 1965 and 1975 the average production capacities for power stations installed in the USA were of the order of 25,800 MW per year (including nuclear power stations).

The two groups, General Electric and Westinghouse, cover practically all electrical engineering construction, and for them the construction of power stations is only one activity amongst many (Westinghouse obtains a third of its turnover through equipment for the production of electricity, the remainder is obtained from consumer goods such as domestic electrical appliances, TV and radios, from industrial and defence equipment, from TV programmes and stations, etc.). In the field of manufacturing electrical power stations these two groups produce the whole range of equipment in the USA. Because of their size, amongst other factors, these two firms have acquired considerable power; they exercise their domination in various ways:

- By technology: these two companies sell their licences and exploit their technology; General Electric has sold more than 600 licences.

However whilst certain European and Japanese firms have acquired the technology in the field of hydraulics and conventional thermal power stations from American firms most of them have then developed their own technology.

The domination of these two American firms with European and Japanese companies is exercised at the present time in the technology of nuclear power. The sale of licences for hydraulic and conventional thermal equipment from General Electric and Westinghouse are now directed mainly towards the developing countries.

- By shareholdings in the capital of foreign companies: General Electric has holdings in AEG (West Germany), Toshiba (Japan), CETAG, a joint subsidiary of ALSTHOM ATLANTIQUE and GENERAL ELECTRIC (France), in CANADA, in Spain and in many developing countries such as Brazil, Colombia, etc. For Westinghouse shareholdings in the capital of western companies remain exceptional (ACEC - Belgium); however in the developing countries the strategy is the same as that of General Electric.

2.2 - The Japanese firms

Japanese firms in the heavy electrical equipment sector have acquired experience in the electrical equipment industry on the basis of technological agreements signed with foreign companies. At the present time Japanese companies dominate international trading in equipment for power stations.

In the field of hydroelectric power stations Japan is the leading world exporter, accounting for more than half of world exports of turbines and alternators for hydroelectric power stations.

Unlike the situation in the United States the production of hydroelectric equipment in Japan is less concentrated; however three groups of major manufacturers are distinguished both by their size and also by the fact that they cover all hydroelectric equipment; these are:

- Tokyo Shibaura Electric (Toshiba)
- Hitachi
- Mitsubishi Electric Corporation (Melco)

The other firms which deliver equipment for hydroelectric power stations are of more modest size, and their principal characteristic is their specialization in one category of sub-assemblies:

- Mitsubishi Heavy is one of the principal manufacturers of heavy equipment. Turbines are its speciality.
- Ebara Manufacturing specializes in hydraulic turbines.
- Fuji specializes in hydraulic alternators.
- Meidensha Electric specializes in alternators and transformers.
- Nisshin Electric specializes in transformers and switchgear.
- Osaka Transformer specializes in transformers.
- Yasukawa Electric Manufacturing specializes in transformers and switchgear.

Close relationships link the Japanese manufacturers with foreign manufacturers. The technical agreements which link the Japanese firms to these foreign companies date more or less from their creation:

- Toshiba, the leading Japanese manufacturer, resulted from the fusion of Tokyo Electric and Shibaura Engineering. Tokyo Electric was founded in 1899 using know-how supplied by General Electric which, at the time of the merger, held 40% of the capital of Tokyo Electric; this holding was converted into a 12% holding in the capital of Toshiba.

- Melco developed on the basis of Westinghouse technology. The technical agreements were signed two years after the creation of Melco in 1923.

- Fuji is linked to Siemens by technological agreements.

<u>In the field of thermal power stations</u> one finds the Hitachi, Toshiba and Melco groups. These three groups supply all the equipment for thermal power stations (boilers, turbo-alternators, regulation

and control equipment, transformers, etc.) and supply turnkey power stations.

<u>In the field of gas turbines</u> one finds:

. Hitachi, licensee of General Electric,
. Mitsubishi, licensee of Westinghouse,
. Toshiba, licensee of BBC.

<u>In diesel sets</u> for the production of electrical energy:

. Mitsubishi produces sets from a few hp up to more than 5000 hp.

. Mitsui manufacture sets above 5000 hp.

<u>In the transmission equipment</u> one finds:

. Mitsubishi
. Hitachi
. Toshiba (licensee of BBC)
. Fuji (licensee of Siemens)

The three groups Mitsubishi, Hitachi and Toshiba dominate the Japanese economic activity. These three groups share a characteristic which is highly specific of Japanese groups: their structure is at the same time industrial, commercial and banking.

In the case of the MITSUBISHI group, one of the largest Japanese groups since it represents 10% of the Japanese activity and consists of about 40 companies which themselves control hundreds of enterprises, three companies constitute the main pillars of the group:

. Mitsubishi Bank
. Mitsubishi Corporation
. Mitsubishi Heavy Industries

The company which represents the group more particularly in the electrical equipment sector is MELCO (Mitsubishi Electric Corporation) which is closely linked with Mitsubishi Heavy Industries. The production of a power station involves the activities of the following companies:

- Melco: manufactures electrical equipment and alternators (turbo-alternators and hydraulic alternators). This company forms the electromechanical pool.

- Mitsubishi Heavy Industries: manufactures boilers and turbines (hydraulic and thermal).

- Mitsubishi Steel Manufacturing: manufactures cast and forged sub-assemblies.

- Mitsubishi Aluminium: manufactures copper and non-ferrous parts.

- Danichi Nippon Cables: manufactures cables and wires.

- Mitsubishi Corporation: manages buying contracts and sales at international level.

An important division of work within the group makes it possible for MELCO to produce power stations and networks on the basis of a joint collaboration between the firms of the group. The division of work is operated not only at the level of production but also at the level of marketing. A marketing network with several branches makes it possible for the Mitsubishi group to apply a very effective strategy in international calls for tenders. Mitsubishi, like the other Japanese groups, is particularly well armed to meet European and American manufacturers and to obtain orders, in particular from the developing countries, offering terms for payments in the form of raw materials, semi-finished products or agricultural products. This barter system serves not only to assist the export of equipment from the group but also to develop the commercial activities of the Mitsubishi Corporation.

2.3 - Swiss companies

Switzerland is one of the principal manufacturers of heavy electrical equipment, in particular as a result of the power of the BBC group. The highly internationalized structure of this company makes it one of the world's leading groups in the sector.

In hydroelectric equipment two firms are present, Sulzer and BBC:

- Escher Wyss AG is owned equally by Sulzer and BBC, and manufactures a wide range of equipment for hydraulic power stations.

- Bell Maschinenfabrik AG manufactures mainly hydraulic turbines of small and medium power. It forms part of the Escher Wyss company.

- Les Ateliers des Charmilles, S.A. manufacture hydraulic turbines.

- Les Ateliers de Constructions Mécaniques de Vevey manufacture hydraulic turbines.

- Les Ateliers de Sècheron manufacture turbines and alternators for hydroelectric power stations, and form part of the BBC group.

In the equipment for thermal power stations BBC is the only Swiss manufacturer producing all the equipment for thermal power stations (turbo-alternators, power transformers, etc.).

In gas turbines the BBC company has developed its own technology and has two licensees, Toshiba (Japan) and the Turbodyne Co. (USA).

In diesel power stations Sulzer produces sets of more than 500 hp.

In equipment for transmission networks only BBC is present. The firm is one of the three world leaders, with Siemens and Delle Alsthom, in the manufacture of high voltage and very high voltage interconnection stations.

The BBC group is the third largest in the world after General Electric and Westinghouse to retain technological autonomy and in diffusing its own technology at an international scale in the heavy electrical equipment industry. In addition to its subsidiaries BBC has granted licences to major international groups including:

- ASEA and Mitsubishi for turbo-alternator sets.
- Kawasaki and Takoaka for transformers.
- Toshiba and ITE for switchgear.

The granting of manufacturing licences to companies and subsidiaries in the developing countries enables the group to take an important place on the markets of these countries.

In those countries which require minimum participation of local industry when calling for international tenders for the construction of equipment goods the existence of subsidiaries or firms having a BBC manufacturing licence favours the obtaining of orders by the group.

Another characteristic of the BBC group is its international presence, based firstly on its exports and secondly on its establishment. The size of the Swiss market very soon forced the firm to enlarge its markets and to establish itself at an international level. Amongst the principal subsidiaries are CEM in France and BBC-Mannheim in West Germany, deliveries from which exceed those of the parent company, Norsk Electric and BB in Norway, TIBB in Italy, Oesterriche B.B. Ltd. in Canada, B.B. Corporation in the USA, BB Mexicana, Industria Electrica BB in Brazil, etc. The first subsidiaries created by the group were in the industrialized countries, making it possible to absorb the production of the group, but after the Second World War the strategy of the BBC was directed towards establishment in the developing countries.

2.4 - The German companies

In equipment for hydroelectric power stations

- Voith is the only manufacturer of hydraulic turbines.
- Siemens, AEG and the German subsidiary of BBC (Brown Boveri Baden) manufacture hydraulic alternators.

In equipment for thermal power stations

The regrouping in 1969 of the activities of Siemens and AEG in the field of power station manufacture within a joint subsidiary KWU (Kraftwerk Union A.C.) makes it possible for the latter to dominate the German market.

AEG and Siemens have united their efforts within two companies having distinct objectives:

- KWU manufactures boilers,
  turbo-alternators,
  hydraulic alternators.

- Trafo Union manufactures transformers.

The two companies utilize Siemens and AEG technologies for this type of equipment.

- Siemens and AEG have retained their autonomy in the field of switchgear. This regrouping of the two companies makes it possible for KWU to provide turnkey power stations.

The other manufacturers of equipment for thermal power stations are:

- The German subsidiaries of the BBC group manufacture turbo-alternators (BBC-Mannheim).
- MAN manufactures both boilers and turbines.
- DEUTSCHE BABCOCK manufactures boilers under Babcock licence.
- Stein Müller manufactures boilers under licence from Combustion Engineering.

<u>In gas turbines</u> KWU manufactures turbines using its own technology. AEG manufactures turbines using the General Electric licence.

<u>In high voltage transmission equipment</u> one finds:

- Siemens, the leading world manufacturer in interconnecting stations, manufactures high voltage switchgear and distributors.
- AEG: switchgear, distributors.
- Trafo Union: transformers.
- Calor Emag: distributors.

In diesel power stations the firms producing complete equipment are:

- MAN
- MAK (Fried Kruff GmbH)
- MWM (Knorr Bremse KG)
- DEUTZ (Klöckner Humboldt Deutz)

2.5 - The British firms

The production of electrical equipment in the United Kingdom is largely concentrated within the General Electric Company group; the second group is Reyrolle-Parsons.

The General Electric Company (GEC) extends its activity over all power station equipment, both in the thermal and the hydraulic field, from boilers up to switchgear. GEC manufactures turbo-alternator sets, transformers and switchgear and gas turbines.

English Electric manufactures hydraulic turbines, hydraulic alternators and boilers.

Ruston and Paxman manufactures diesel sets.

Reyrolle-Parsons is present essentially in thermal power stations, but also manufactures turbo-alternators and switchgear.

Parsons-Peebles manufacture transformers.

Outside these two groups organized to provide turnkey power stations a certain number of companies produce specific items of equipment:

- Babcock GB (licensee of Babcock USA) manufacture boilers.
- John Thompson (licensee of Combustion Engineering) manufacture boilers.
- Ferranti manufacture transformers.
- Drake & Curbit manufacture switchgear.
- John Brown Co. Ltd., manufacture gas turbines (G.E. licence).
- Hawker Siddeley manufacture transformers and diesel sets.
- APE-Allen, Cummins and Rolls-Royce manufacture diesel sets.

2.6 - The French firms

In France several modifications in structure have taken place during recent years in the electromechanical industry. The dominant group is led by Alsthom Atlantique and its subsidiaries: this group is a licensee for certain equipment produced by the American General Electric company. The other dominant group is Jeumont Schneider, controlled by Baron Empain, and using Westinghouse licences.

- Alsthom Atlantique was created in 1976 by the merger of Chantiers de l'Atlantique (shipyard) and Alsthom (electromechanical engineering). In the field of power station and network equipment Alsthom Atlantique is able to provide all the equipment. In the organization of the group several divisions, to which subsidiaries are attached, are involved in the manufacture of equipment for power stations and networks.

- The Mechanical Equipment Division is involved in:
  - boilers (Stein Industrie, under Combustion Engineering licence)
  - condensers and heat exchangers (Delas-Weir)
  - diesel power stations (SEMT-PIELSTICK).

- The Electrical Equipment Division is involved in:
  - power transformers and measuring equipment (Alsthom Savoisienne)
  - distribution transformers (Unelec).
  - high voltage and medium voltage electrical equipment (Delle Alsthom, third world leader).
  - control equipment (CGEE Alsthom).

- The Electromechanical Equipment Division is involved in:
  - steam turbines (GE and BBC licences).
  - gas turbines (CETAG).
  - alternators.

The Energy Power Stations Division is involved in the production of complete turnkey conventional power stations and electro-mechanical assemblies for conventional power stations. This division carries out the design engineering and general construction work for these assemblies, together with the design and production of the main equipment or installations for power stations.

Alsthom Atlantique manufactures all the equipment for conventional thermal power stations, diesel or gas turbine sets and equipment for the transport and distribution networks. In hydraulic equipment the group has a shareholding in Neyrpic-Creusot Loire which makes it possible for it to carry out all construction work in conventional energy production.

In the technological field the group cooperates at an international scale with the principal manufacturers of electrical manufacturing in general. The cooperation with G.E. is already of long standing in the field of transformers, turbo-alternators and gas turbines; technological contacts with G.E. make it possible for Alsthom Atlantique to extend the field of its cooperations with other licensees of the American group. In this way Alsthom Savoisienne cooperates with th talian ITALTRAFO company, which is a licensee of GE. The aim of this cooperation is to utilize jointly the technical resources of the two firms, so forming a sufficiently large group to face up to the major European manufacturers in this field (BBC and Trafo Union).

. JEUMONT SCHNEIDER forms, with CREUSOT LOIRE, controlled by EMPAIN, the other French pole in the power station equipment sector. The diversity of the productions of the group make it possible for it to be present in all equipment for power stations and networks and to be able to build turnkey power stations. Its activity is carried out in:

- hydraulic turbines by NEYRPIC CREUSOT LOIRE, the only French manufacturer.
- boilers and condensers by CREUSOT LOIRE.
- thermal turbines by CREUSOT LOIRE (BBC technique).
- hydraulic and thermal alternators by JEUMONT.
- power transformers by JEUMONT.
- distribution transformers by FRANCE Transfo.
- high voltage equipment by MERLIN GERIN.
- industrial assemblies for thermal power stations: SPIE BATIGNOLLES.

In total the JEUMONT SCHNEIDER-CREUSOT LOIRE group manufactures all equipment associated with conventional thermal and hydraulic power stations, but this group is not present in gas turbines and diesel sets.

. CEM, the French subsidiary of BBC, has an activity which is limited to certain items of equipment:

  - hydraulic alternators.
  - transformers.
  - switchgear.

. The FIVES-CAIL-BABCOCK company manufactures thermal power station boilers under the American BABCOCK licence.

2.7 - The Italian companies

. ANSALDO is the largest Italian manufacture. Its field of activity is very large and covers:

Equipment	Company of the Group
- steam generators - thermal condensers and turbines - hydraulic turbines	BREDA-THERMOMECCANICA
- boilers	THERMOSUD
- gas turbines - high power diesel sets - alternators - power station and network control equipment	ANSALDO
- power transformers - equipment for the transmission and distribution of electrical energy	ITALTRAFO
- small power diesel sets	SIMEP

. The Italian subsidiary of BBC, TIBB, is present in the manufacture of turbo-alternators and high voltage switchgear.

2.8 - The Swedish firms

. ASEA is the principal firm in the heavy electrical equipment sector in Sweden. ASEA is one of the smallest international groups in the sector, its turnover being only a tenth of that of General Electric.

At the present time the activity of the company rotates around four poles:

- Electro-mechanical
- Industrial equipment
- Data processing
- Electrical rail transport.

In the field of electromechanical equipment ASEA is present at all stages of the production of electric power stations, apart from hydraulic turbines:

- Boilers: Stal-Laval.
- Turbo-alternators: ASEA.
- Thermal turbines: Stal-Laval Turbines
- Hydraulic alternators: ASEA
- Transformers: ASEA Electric and ASEA Per Kure
- Circuit breakers: ASEA
- Distribution equipment: CEWE - SELFA.

ASEA can therefore deliver turnkey thermal power stations.

. KMW is the only Swedish firm manufacturing hydraulic turbines.

2.9 - Firms in the planned economy countries

A United Nations document(1) makes it possible to estimate the importance of the heavy electrical equipment industry in the Eastern European countries. A number of these countries developed their activity in this industry very early on, and their companies have acquired experience both on their domestic markets and also on the major export markets.

- IN CZECHOSLOVAKIA

CKD Blansko is the only firm producing hydraulic turbines; its experience in this field goes back many years.

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(1) United Nations: Economic Commission for Europe. Market trends and prospects for engineering products used in the energy sector and for telecommunications equipment ECE/ENGIN/8, Dec. 76.

In the field of thermal power stations the Czechoslovakian firms have a remarkable level of experience:

. the production of boilers for power stations is carried out by S.E.S. TLMACE.

. SKODA PLZEN produce steam turbines.

. the SKODA Export Foreign Trading Company is capable of delivering complete turnkey power stations: this company recently obtained an international contract in TURKEY for the supply of a 330 MW thermal power station.

- EAST GERMANY has considerable experience in the production of electric power stations, together with the installation and commissioning of complete electricity distribution networks (up to 400 kV). It has installed complete turnkey distribution networks (BULGARIA, GREECE, YUGOSLAVIA, EGYPT, etc.). Most of these transactions are carried out through the foreign trading organization ELECTROTECHNIK.

- In the USSR

We do not have any information on Soviet firms in the heavy electrical industry. ENERGOMASHEXPORT is the organization responsible for exports of electrical equipment. The size of Soviet exports, in turnkey form, shows that this country has considerable experience in the field of power stations. In 1974 the USSR obtained a contract from the mixed Argentine-Uruguay technical commission for the delivery of a hydroelectric power station with a total power of 1620 MW.

Cooperation agreements were signed by the USSR with American electrical engineering companies round about 1973. More recently the USSR signed an agreement with the United Kingdom for a long-term programme of economic and industrial cooperation, providing in particular for the participation of organizations and companies in carrying out common projects, the exchange of patents, licences, know-how and technical information, and finally supplies, under special payment terms, covering mechanical and electrical production units and equipment. The two countries are particularly concerned with cooperation in fields such as the rapid and scheduled construction of electric power stations, the manufacture of turbines, high tension transformers, etc. The USSR has also signed bilateral cooperation agreements with West German and Swiss companies.

3 - The barriers to entry erected by the major firms in the sector

3.1 - Analysis of market powers in electrical engineering

In order to organize international trading in electrical equipment (in regard to price, competition, etc.), and to prevent the appearance of new producers on the international scene, the major firms manufacturing electromechanical equipment have signed agreements between themselves, so that a powerful cartel of producers has been established at an international level. An UNCTAD study[1] examines the behaviour of these firms.

The organization and forms of competition at the present time result from practices which are already very old. From the time of their establishment, during the first decade of the 20th

(1) The dominant position of the transnational companies on the international market. Monograph on the electrical industry. R.S. NEWFARMER, UNCTAD/ST/MD/13.

century the companies of the electrical industry in the industrialized countries have organized themselves in a system of interdependence (reciprocal licensing agreements, agreements in regard to patents and arrangements for the joint use of their technologies, etc.) thus discouraging active competition between the major companies and prohibiting access to the market to any new company. This system of interdependence facilitated the appearance of an oligopoly in all the industrialized countries covering equipment for power stations and networks.

More recently national policies in the industrialized countries have encouraged the horizontal merger of companies producing certain types of heavy equipment, with the object of eliminating excess capacities and assisting the largest national companies to survive. These national policies have contributed towards reinforcing the establishment of oligopolies in each industrialized country.

In addition to the actual mergers other links of a contractual character favour the concentration of companies on many national markets:

- Shareholdings allowing the major companies access to many foreign markets: General Electric has shareholdings in Toshiba (Japan), AEG (West Germany), etc.

- The major companies cooperate on many markets by way of co-enterprises (see following table). This formula makes it possible for companies to associatc their financial, technological and productive capabilities, but can also be used to divide up the market between the major companies.

- Reciprocal licences, sometimes very old, making exchanges of technology between the major firms, and possibly a limitation of competition according to the clauses of the contracts, possible.

- Cartels, intended to limit or prevent competition between firms on the basis of formal agreements signed between them. These agreements generally provide for sanctions and coercive action against non-members, and in particular those who have withdrawn from the cartel. According to the field of these agreements one can distinguish the national export cartel, which groups together only the producers and distributors of the same nationality, and which forms a group for maintaining export prices. When the cartel is also intended to limit competition at a domestic level it is termed a mixed export cartel. Finally producers and distributors of different nationalities may be grouped together in international cartels.

TABLE 11 - Links between the major firms. Some national and international co-enterprises

INVESTORS	CO-ENTERPRISES	COUNTRIES	SECTORS
(AEG (SIEMENS	KWU Trafo Union	West Germany	Power station equipment Transformers
(ERCOLE MARELLI (BBC ITALY	S.A. Elettrificazione	Italy	Electrical equipment
(ALLIS CHALMERS (KWU	Allis Chalmers Power Systems	USA	Equipment for electricity production
(ALLIS CHALMERS (SIEMENS	Siemens Allis Inc.	USA	Electrical equipment
(ALLIS CHALMERS (VOITH	Voith Allis	USA	Heavy electrical equipment
(SIEMENS (FURUKAWA ELECTRIC	Fiji Electric	Japan	Electrical equipment

All these contractual relationships between firms are intimately linked with the history of world trading in the electrical equipment goods industry.

- International export cartels covering heavy electrical equipment. At an international level, from 1930 onwards, a cartel intended to restrict trading in electrical equipment was formed between the nine largest world manufacturers of electrical equipment (International Notification and Compensation Agreement, INCA). In 1936 the International Electrical Association (IEA) was established to effect better control of INCA. During the Second World War the IEA did not exist, but from 1945 onwards the IEA was slowly reformed in its pre-war form. At the beginning of 1970 the IEA consisted of 37 known companies (see following table). Although firms in the USA are not authorized to participate in international cartels at least one member is a subsidiary of an American firm whilst another benefits from a major shareholding in the USA. In the case of the Japanese firms, although they are not yet members of the IEA, the directors of the Japanese cartels take part in IEA meetings[1].

The IEA is divided into "sections", corresponding to product groups, producers being linked by contractual agreements in at least nine of the principal sections which cover practically all the production of heavy equipment. These agreements are coordinated by an overall contract setting out the general and commercial rules applicable to the product sections (Tenders and Contracts Agreement - TCA)[1].

The TCA makes it possible for the firms to act together in a common policy on prices and other conditions to be offered when tendering. Amongst other conditions certain agreements laid down at one time the sharing of profits, and members were required to pay to a central pool a certain percentage of the order which was then divided between the unsuccessful tenderers. In the E and P agreements

(1) UNCTAD, op. cit., UNCTAD/ST/MD/13

TABLE 12 - Members of the International Electrical Association in 1974

UNITED KINGDOM

Ferranti
GEC and English Electric
Hawker Siddeley Group
C.A. Parsons
Parsons-Peebles
Westinghouse Brake

WEST GERMANY

AEG-Telefunken
Siemens
Kraftwerk Union
Transformatoren Union
Voith
one unknown company

FRANCE

Alsthom (Compagnie Générale d'Electricité)
Alsthom Savoisienne S.A.
Compagnie Générale d'Electricité
Société Rateau
Société des Turbines à Vapeur Rateau-Schneider
Société des Forges et Ateliers du Creumont
Creusot-Loire
Jeumont Schneider
Cockerill Ougrée - Providence et Espérance - Longdoz

ITALY

Ansaldo San Giorgio
ASGEN
Ansaldo Meccanico Nucleare SpA
Franco Tosi
Legnano
Savigliano
Ercole Marelli SpA

HOLLAND

N.V. Electrotechnische Industrie, voorheen Willem Smit & Co.,
Smit-Slikkerveer

NORWAY

National Industri

BELGIUM

Ateliers de Constructions
Electriques de Charleroi
(Westinghouse)

AUSTRIA

Elin-Union

SWITZERLAND

Brown Boveri
Sécheron

SWEDEN

ASEA
Stal-Laval Turbine

Source: UNCTAD: The dominant position of the transnational companies on the international market - UNCTAD/ST/MD/13.

Table 13

KNOWN IEA AGREEMENTS, IN FORCE IN 1974

Section code-product	Territorial exclusions	Notification	Liabilities, guarantees, delivery time financing[a]	Pricing provisions	Quota and allocation provisions	Pooling	Price lists	Number of known section numbers
A - Steam turbines to drive generators	yes[b]	yes	yes	yes[f]			yes	18
B - Steam turbine-driven alternators	yes[b]	yes	yes	yes[f]			yes	18
E - Hydraulic turbine-driven AC generators	yes[c][h][i]	yes	yes	yes[g]	yes[g]	yes[g]	yes	10
F - Synchronous condensers	yes[c]	yes	yes					
G - Circuit breakers	yes[d]	yes	yes					
H - Transformers	yes[b][i]	yes	yes	yes[k]	yes	yes[j][k]	yes	
K - Rectifiers	yes[b]	yes	yes	yes[k]	yes		yes	9
P - Rolling mill equipment	yes[b]	yes	yes		yes	yes[k]		6
W - Hydraulic turbines	yes[b]	yes	yes					

Source: Op. cit. UNCTAD/ST/MD/13

(a) Given in terms of Tendering and Contracting Agreement in force since 1 July 1970, subject to subsequent revisions and amendments.

(b) Excludes Switzerland, East Germany, the States of the E.E.C., Norway, Sweden, Finland and USA.

(c) Excludes countries listed in (b) plus Austria and Canada.

(d) Excludes countries listed in (b) plus Canada.

(f) Includes escalator factor adjusted every 6 months.

(g) Contained in agreement P(E) put in effect in early 1960, amended March and July 1961. P(E) was replaced by Annex E of the TCR and notification agreements in 1962. Pooling was dropped in favour of direct allocation and common minimum prices in 1970 with the adoption of A(E)-70.

(h) Does not apply to AEG's sales on the USA market, or to ACEC's sales in Zaire, Rwanda and Burundi.

(i) Agreements appear to have included the following countries because parents had declared licensees: Brazil, Hungary, India, Spain, Portugal (mainland).

(j) Pooling arrangements were contained in Agreement P(H) concluded in 1959, amended in 1960 and 1961. P(H) became P(H)C, adopted in May 1965 when pooling was supplanted with compensation provisions.

(k) Reference prices are agreed upon and used by tendering parties prior to bidding as a basis for collaboration, but apparently are not used as a rigid price floor. In the case of transformers, penalties are assessed for tenders accepted below the reference price, pooled and distributed among section members.

(see table) the annexes specify in detail the part of the orders, by value, to be attributed to each producer and the procedure to be followed to nominate the company which will present the lowest tender. The fundamental rule is that the producer furthest from achieving his annual quota will receive the order.

Between 1965 and 1967 the great majority of transactions on transformers (with the exclusion of those territories not covered by the agreement, namely Austria, Canada, EEC, East Germany, Scandinavia, Switzerland and the USA) was monopolized by the members of the Cartel: in 1965 77% of total exports of high power transformers came from members of the Cartel, in 1966 72% and in 1967 86%. Most of the importing countries have come up against a market dominated by the Cartel in this sector. One of the effects of these agreements, intended to restrict competition, was to increase prices on the international market to a level higher than would have operated under a regime of free competition. Furthermore the producers were able to exercise discrimination on prices in regard to various markets or on one market so as to eliminate a company which was not a member to the agreement. Finally the agreement allows, in an implicit manner, the sharing of markets, an important method for reducing competition: between 1965 and 1969 British companies manufacturing transformers sold very small quantities to the Western European market despite its proximity, four-fifths of their exports being to other countries of the Commonwealth and to the United States. Out of European exports of transformers to other countries of Europe scarcely 3.3% went to the importing countries, the rest going to non-exporting countries; the great majority (87%) of Japanese exports of transformers went to the developing countries, more particularly South-East Asia[1].

(1) UNCTAD op. cit. UNCTAD/ST/MD/13.

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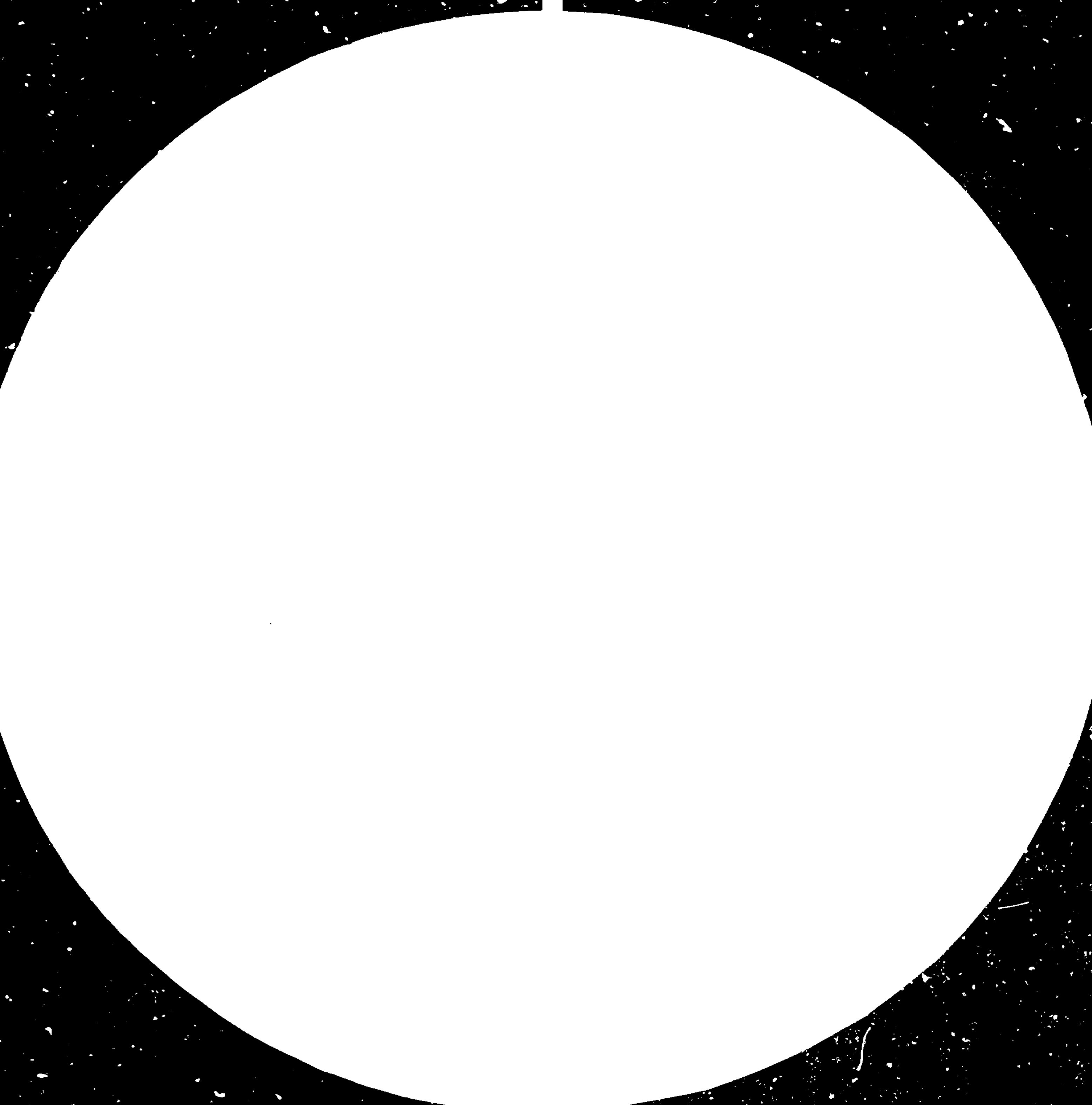

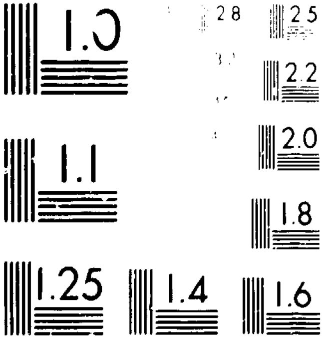
1.0
2.8
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

The UNCTAD report[1] estimates that, for the industrialized countries (outside the USA and Japan, where the law prohibits enterprises from participating in international cartels), 75% of their exports of equipment for the production of electricity, generating machinery and distribution equipment were controlled by international cartels; for other electrical appliances the cartels affected 10% of exports from these countries.

- <u>National export cartels</u>

Outside the USA there are national export cartels intended to cover many products not covered by the international cartels. National cartels in this sector are particularly important in Japan where, according to cautious estimates, they control about a third of non-intrafirm trading[1].

- <u>Transactions between parent companies and subsidiaries</u>

With the growth of direct investments in companies abroad intrafirm trading has become very dynamic, even if the volume remains relatively small. Such trading falls outside the international market and remains within the company, allowing the latter to practise an internal transfer tariff system which falls outside the control of the cartels. It can be stated that certain companies misuse the internal transfer tariff system, but no information on the electrical industry in general is available.

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(1) UNCTAD op. cit. UNCTAD/ST/MD/13.

The UNCTAD report(1) estimates that 15% of exports from companies in the electrical equipment sector in the developed countries are, in fact, commercial transactions between parent and subsidiary companies.

- Tacit agreements and ad hoc arrangements

These agreements are the most difficult to identify; however it appears that directors of Japanese companies participate in numerous international meetings, that the American firms practised amongst themselves parallel prices for heavy equipment for many years and are still more free abroad. Of the exports from the developed countries 5% are carried out within the framework of tacit agreements and ad hoc arrangements(1).

3.2 - Practices of the major firms in the electrical equipment sector: the case of Brazil

The emergence of an electrical equipment sector in Brazil goes back to the fifties when several companies with Brazilian capital began to manufacture equipment for the production and distribution of electricity. At the same time the government policy of stimulating investments and the prospects of a vast market attracted foreign capital; during the sixties there were about a dozen subsidiaries of the multinationals.

During the seventies a large number of these Brazilian companies were absorbed by foreign investors. An UNCTAD report(2) details the ways in which domination and control of the Brazilian electrical equipment industry was effected by foreign interests.

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(1) Op. cit. UNCTAD/ST/MD/13.

(2) Consequences for the developing countries of the commercial restrictive practices of transnational companies in the electrical equipment industry: monograph on Brazil. Study produced by B. EPSTEIN and K.R.U. MIROW, UNCTAD/ST/MD/9.

Generally speaking it seems that in Brazil the multinationals set up a national cartel through the Brazilian Institute for Research on the Development of Exports of Heavy Electrical Equipment (IBEMEP), had recourse to the control of materials and components used in manufacture, and utilized import regulations and concessions to weaken local companies and to take control of them.

- Control of materials and components used in manufacture

Independent manufacturers who undertake production in a developing country are not of a sufficient size to justify the creation of specialized divisions for certain components, nor do they exercise any power in regard to their suppliers. Such companies depend therefore on the members of the cartel and their subsidiaries from which they have to obtain ancillary equipment and test apparatus, together with a number of items and components. One of the principal weapons that the International Electrical Association has is, consequently, control of the materials and components which the independent producers need. Certain indications make it possible to assume that in Brazil this weapon was used to weaken local companies in two ways, either by completely stripping the market of certain manufacturing components or by making the supply of such materials dangerously unstable. The authors of the UNCTAD report cite certain examples tending to prove that control of materials and test equipment, as carried out by the multinationals, made the situation of certain Brazilian companies precarious and so facilitated their purchase by foreign companies established in Brazil.

- Control of the Brazilian market by operating import regulations

The UNCTAD study shows how the multinationals used import regulations to their own advantage and contributed to the replacement of domestic production by imports and a reduction in the technological level:

"In the early sixties a hydroelectric power station was built in Brazil. Brown Boveri built two 50 MVA hydroelectric generators for the Peixoto power station. Bardella S.A., an independent Brazilian company, built hydraulic turbines under technical licence from Voith. However the greater part of the equipment of the hydroelectric power station was imported. The Brazilian subsidiaries of firms such as General Electric and Siemens produced locally less than 30% of the equipment to be installed in Brazil. They made the parts which were heavy and difficult to transport, whereas the factories in the country of the parent company provided the high value and high technology components".

"This was not, however, because of a lack of sufficient production capacity. According to one report the Brazilian factories were operating at about 50% of their capacity during this period(1). Nor was technology the problem".

"Bardella S.A. had built hydraulic turbines in Brazil by virtue of the licensing agreements with Voith. General Electric and Siemens made technological know-how available to their Brazilian subsidiaries. Finally in 1975 General Electric stated that it

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(1) Banco Nacional de Desenvolvimento Econômico (B.N.D.E.) Associação Brasileira Para o Desenvolvimento das Indústrias de Base (ABDIB) and Instituto de Planéjamento Econômico e Social (IPEA), Setor de Produçao de Bens de Capital Sob Encomenda Síntesa da Pesquisa. Quoted in the UNCTAD study.

had the necessary capacity and technology in its Brazilian factory to produce at least 80% of the components of hydraulic turbines and generators of 800 MW or less."

"If there was no production of hydroelectric equipment it is necessary to seek further for the reasons. In 1964 Voith opened its own factory in Brazil for the manufacture of hydraulic turbines. The production of this factory being competitive with that of Bardella Voith withdrew its technical licence from Bardella S.A. (In 1973 Bardella signed a licensing agreement with the Swedish company AB Nohab). During the same period, at the beginning of the sixties, Siemens built a plant in the Federal Republic of Germany to manufacture hydroelectric generators. There is, however, no domestic demand for this type of equipment in this country, and the demand is small in other European countries. Siemens, like other manufacturers of hydroelectric equipment, had to depend on orders from Third World countries. It may therefore be asked if Voith, by withdrawing the technical licence previously granted to Bardella for the manufacture of hydraulic turbines, was not giving way to pressure exercised by the IEA to eliminate the production of a similar local product on the Brazilian market."

"In 1964 the subsidiaries of the transnationals requested and received permission to import a hydraulic power station of a size which had previously been produced in Brazil. During the following years, from 1965 to 1975, nearly two-thirds of the 18,363 MVA of hydroelectric plant installed in Brazil were imported. This is an example of a case where the transnationals favour importing, whereas the product could have been acquired locally if Bardella had been allowed to continue to develop its potential."

In total, therefore, the multinationals established in Brazil had a negative impact on the development of the heavy electrical equipment sector. Their restrictive practices resulted in dismantling the Brazilian companies; consequently the trading balance of Brazil went into heavy deficit in regard to electrical equipment, imports of electrical equipment(1) increasing from $74.5 million in 1964 to $533.4 million in 1974, an increase of 616%(2). In 1974 the imports of electrical and electronic equipment by the 35 multinationals operating in Brazil represented half their total sales in Brazil; during the same time local installations producing the same imported equipment were operating at 52% of their capacity.

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(1) All SITC headings 711, 722, 723, 725 and 731, also including equipment for the production and distribution of electrical energy, domestic electrical appliances and rolling stock for railways.

(2) UNCTAD study as cited, UNCTAD/ST/MD/9.

CHAPTER III

POSSIBLE ENTRIES FOR THE DEVELOPING COUNTRIES

At the present time some developing countries, including India, Brazil, South Korea, Mexico, Colombia, Indonesia and Algeria, have established production capacities for equipment for the production and distribution of electrical energy. Not all have reached the same level of production, but India seems to have reached some technological independence. Its diversified production covers most of the heavy equipment for the production and distribution of energy, whereas other countries such as Colombia are producing mainly high voltage transformers and certain items of equipment for power stations such as boilers and condensers.

Their individual experiences provide the factors for judging the resources needed for local production of energy equipment.

1 - The experience of Brazil

The situation of the electrical equipment industry in Brazil is characterized by the dominant position of the subsidiaries of multinationals. At the present time about thirty companies in Brazil are producing an extensive range of heavy electrical equipment; most of these are subsidiaries of multinationals (cf. Table 14: Domestic manufacturers, Brazil). Amongst these companies two are distinguished both by the volume of their production and also by the diversity of their production: these are General Electric do Brasil SA (subsidiary of GE) and Siemens SA, with production ranges which cover turbines, alternators, transformers, circuit breakers, distributors, etc.

During 1975 expenditure on equipment for production, transmission and distribution reached $427 million; estimates for

Table 14 - BRAZIL

DOMESTIC MANUFACTURERS

Coemsa Construcoes Electromecanicas S.A. (controlled by multiple Italian firms)
Transformers, voltage regulators, water-driven turbines, generators.

Confab Industrial S.A.
Nuclear equipment.

Eletromar Industria Eletrica Brasileira S.A. (subsidiary of Westinghouse, U.S.)
Circuit breakers, panel boards, starters, safety switches, motor control centres, switchboards.

General Electric do Brasil S.A. (subsidiary of General Electric Co., U.S.)
Turbines, generators, transformers, circuit breakers, switchgear, voltage regulators, shunt reactors.

Industria Eletrica Brown Boveri, S.A. (subsidiary of Brown Boveri & Cie., Switzerland)
Synchronous generators, turbogenerators, transformers, shunt reactors, complete substations.

Ishikawajima do Brasil - Estaleiras S.A. (subsidiary of Ishikawajima Harima Heavy Industries Co. Ltd. Japan)
Diesel generators, boilers, heat exchangers, pressure vessels.

M. Dedini S.A. Metalurgica (Brazilian-controlled company, associated with Kawasaki Heavy Industries and C. Itoh & Co. Ltd., Japan)
Heavy boilers, steam turbines, turbogenerators.

Mecanica Pesada S.A. (multiple ownership; Brazilian, European and US firms)
Hydraulic turbines, gates, valves.

Siemens S.A. (subsidiary of Siemens A.G., Germany)
Generators, transformers, switchgear, circuit breakers, turbines.

Voith S.A. - Maquinas e Equipamentos (subsidiary of J.M. Voith GmbH-Maschinenfabrik, Germany)
Hydraulic turbines, pumps, valves.

Source: GMS Electrical Energy Systems, US Department of Commerce

1979 are $628 million(1) and this sum represents, by way of comparison, the volume of Italian exports of this type of equipment in 1975 or 60% of all Swedish production of energy equipment in 1975.

The size of investments in heavy electrical equipment makes Brazil largely dependent on foreign countries for its supplies of this equipment: in 1974 the value of the domestic production of heavy electrical equipment was $64 million, whereas imports were $165 million(1).

The role of Electrobras in the development of local capabilities for the design and construction of power stations has been determinant:

- in the development of local services of consultants, to draw up prefeasibility and feasibility studies.

- in the development of local engineering capabilities for defining projects and for carrying out peripheral parts of projects or the whole of projects. At the present time there are a number of engineering companies including:

. MORRISON KNUDSEN INTERNACIONAL DE ENGENHARIA S.A. (projects for the Furnas, Estreito, Porto Colombia and Itaipu power stations).

. HIDROSERVICE - ENGENHARIA DE PROJETOS Ltda. (project for the Sobrabrinho power station).

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(1) Electrical Energy Systems. Global Market Survey, U.S. Department. Commerce, Bureau of International Commerce, January 77.

. ENGEVIX S.A. - ESTUDOS E PROJETOS DE ENGENHARIA (project for the Tucuri power station and for the Itaipu lateral dam).

. THEMAG ENGENHARIA (project for the Itaipu transmission network).

. MILDER KAISER ENGENHARIA S.A.

. PROMON ENGENHARIA S.A.

. MONTREAL ENGENHARIA S.A.

- In the incorporation of locally produced equipment: although some years ago less than half the value of the equipment for hydroelectric power stations was produced locally it was decided in 1978, in the case of the Itaipu power station, that 81% of the value of the hydraulic turbines (of 700 MW unit power) and 86% of the value of the alternators would be produced in Brazil. Such a measure forced the foreign companies participating in this project to develop capabilities for execution studies in Brazil, to establish certain production capacities (particularly in forging and casting), and to contribute to the training of design office and methods engineers and technicians and workmen both in the subsidiaries of the firms established in Brazil and also in the local companies concerned by the production of this equipment. At the present time Brazil is forced to import highly sophisticated sub-assemblies for the production of turbines and alternators, mastery of these being difficult to achieve. The Brazilian industry has arrived at the "hard core" which presents most difficulties for the national integration of energy equipment. These difficulties are explained by inadequate mastery of the most advanced techniques (very high precision engineering, electronics, hydraulics, etc.) and by a weakness in the capabilities for design and research and development which contributes towards improving methods and manufacturing techniques.

2 - INDIA

In the case of India the role and place occupied by the public company Bharat Heavy Electrical Ltd (BHEL) has certainly contributed towards the development of the electrical equipment goods sector.

A study by the UNCTAD Secretariat(1) gives some evaluations of the motive role exercised by this Indian company in the development of the electrical equipment sector. "Created in 1955 this company concluded, in its initial years, agreements for technical collaboration with the United Kingdom, the Soviet Union and Czechoslovakia to train personnel and to obtain technical studies and equipment. In 1974 a reorganization of the company allowed it to develop into a truly engineering firm. At the present time BHEL, with an annual capacity of 4,000 to 5,000 MW, is one of the ten leading manufacturers of electrical equipment in the world. At the present time this company devotes 3 to 3.5% of its turnover to R & D, and has signed a cooperation agreement with the West German K.W.U. company to make large steam turbines and generators of powers up to 1,000 MW; it has already undertaken the manufacture of its first 500 MW set. The company is autonomous in regard to the production of smaller equipment. Furthermore it has played a decisive role in the realization of the Indian objective of limiting imports of electrical equipment to the maximum.

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(1) "Energy supplies for developing countries: Issues in the transfer and development of technology". Study by the UNCTAD Secretariat. TD/B/C.6/31, 17 October 1978.

Nearly 90 hydroelectric sets, 60 thermal sets and 4 nuclear sets are in various stages of design, manufacture and installation in India at the present time. Of the increase of 1720 MW in the installed capacity in India in 1974-75 80% can be attributed to BHEL and, of the additions forecast in the Fifth Five-Year Plan, 85% will consist of BHEL equipment".

India has now arrived at a stage which allows it to be present on the international market; BHEL realizes 15% of its turnover abroad(1); its level of technical competence and the low cost of labour(2), both at design and production level, gives this company the possibility of obtaining large outlets, particularly in the developing countries.

3 - MEXICO

The heavy electrical equipment sector in Mexico remains largely dependent on imports from abroad. Imports supply between 50 and 60% of the domestic demand for electrical equipment; recourse to imports is even greater in equipment for the production of electrical energy, local production meeting scarcely 20% of domestic needs.

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(1) During the 1976-77 financial year the company received an order from Libya for the turnkey construction of a 2 x 120 MW power station, an order from New Zealand for the supply of hydraulic generators with a total power of 544 MW, and an order from Saudi Arabia for the Wadi-Jizou electrification project.

(2) Production costs are, on average, 10 to 15% lower than those of Japanese companies.

The Mexican electrical equipment industry comprises 45 firms of which about ten specialize in equipment for the production of electrical energy; some major firms have product lines including several types of equipment. Most of the companies are subsidiaries of the multinationals (cf. Table 15).

Five companies produce steam boilers but two of these (Ce-Rrey and Babcock & Wilcox de Mexico) supply more than 60% of the market; components for the steam boilers are imported, but highly specialized local companies provide most of the components for boilers.

In the production of alternators powers of 500 MW are produced locally; in this field the largest producer is Manufacturera Fairbanks Morse (subsidiary of Fairbanks Morse USA) which has 40% of the market; the other producers are Sociedad Electro-Mecanica, Kohler and Miller which have 35% of the market. Nearly half of the components used in the production of alternators are imported.

Power and distribution transformers are provided by about fifteen companies: IEM and Electrotecnica Balteau have 40% of the market; the other dominant firms are Conductores Monterry, General Electric de Mexico and Industrias Sola Basic. More than 95% of the components for transformers are produced in Mexico.

In switchgear about twenty companies produce this type of equipment, but no company dominates the market; the subsidiaries of three American firms (Square D, General Electric and Cutler-Hammer) account for half of the national production of switchgear, whilst the Mexican subsidiary of BBC contributes approximately 20%.

TABLE 15 - MEXICO

DOMESTIC MANUFACTURERS

Manufacturera Fairbanks Morse, S.A. (subsidiary of Fairbanks Morse, U.S.)

Generating equipment: single-phase AC, single-phase light plant, and three-phase generators; internal combustion plants for lighting; specialized generator sets. Transformers: dry type, distribution and lighting transformers, and autotransformers.

Sociedad Electro-Mecanica S.A. de C.V. (licensee of Electric Machinery/ Cleaver Brook, U.S.)

Generating equipment: Specialized generator sets, three-phase generators, and power boilers. Switchgear: power and control panels for generating plants; distribution, automatic alternate control, emergency plant control panels; circuit breakers, disconnecting knife switches; and high tension safety interrupters.

Kohler de Mexico, S.A. de C.V. (subsidiary of Kohler, U.S.)

Generating equipment: internal combustion plants for lighting, single-phase AC and single-phase light plant generators.

Miller de Mexico, S.A.

Generating equipment: light plant generators with internal combustion engines.

Inductomex, S.A.

Generating equipment: specialized motor generator sets.

Conductores Monterrey (licensee of McGraw Edison, U.S.)

Transformers: control, current, and power; dephasing, rectifying, and specialized transformers; runway lighting; distribution and lighting transformers; underground lighting; variable autotransformers and cables.

Electrotecnica Balteau S.A.

Transformers: power, current, dephasing and specialized.

Industrias IEM, S.A. de C.V. (licensee of Westinghouse, U.S.)
Transformers: distribution and lighting, power, cooling, dry type distribution, dephasing, rectifying transformers for underground lighting and distribution, power transformers with forced air and oil cooling; and autotransformers. Switchgear: regulation and control systems, alternative automatic command panels, power and control panels for generator plants, high- and low-tension distribution panels, interrupters in oil, and electromagnetic interrupters.

General Electric de Mexico, S.A. (subsidiary of General Electric, U.S.)
Transformers: distribution and lighting, underground distribution and lighting, control, rectifying, dry type distribution, specialized, and power transformers with forced air and oil cooling. Switchgear: protection, control and measurement thermomagnetic interrupters; automatic command, distribution switchboards; power and control panels for generating plants; disconnecting knife, oil switches; and control relays.

Industria Sola Basic, S.A. (subsidiary of Sola Basic, U.S.)
Transformers: dry-type, control and rectifying, specialized, and autotransformers.

Cutler-Hammer Mexicana, S.A. (subsidiary of Cutler-Hammer, U.S.)
Switchgear: selective, thermomagnetic interrupters; emergency plant controls; knife switches; relievers; and control cabi-

Balmec, S.A. (licensee of General Electric, U.S.)
Switchgear: Capacity and control panels and power factor indicators.

Brown-Boveri Mexicana S.A. de C.V. (subsidiary of Brown-Boveri, Switzerland)
Switchgear: lighting and motor, emergency plant controls; automatic and non-automatic interrupters; power and control panels for generating plants; distribution, automatic control, capacitor-equipped panels; compressed air interrupters (high tension), thermal overcharge relievers; disconnecting knife switches; and bus-bars.

Square D de Mexico S.A. (subsidiary of Square D, U.S.)
Switchgear: automatic alternative command panels; emergency plant controls; power and control panels for generating plants; automatic start-up control transference and stopping panels for emergency plants; knife switches; and disconnecting, thermomagnetic, multicontact, control and measurement selector interrupters.

Honeywell de Mexico, S.A. (licensee of Honeywell, U.S.)
Switchgear: all types of control panels.

Ce-Rrey (subsidiary of Combustion Engineering, U.S.)
Generating equipment: power boilers. Switchgear: all types of control panels.

Babcock and Wilcox de Mexico, S.A. (subsidiary of Babcock and Wilcox, U.K.)
Generating equipment: power boilers.

Clayton de Mexico, S.A.
Generating equipment: power boilers.

Metalver, S.A.
Generating equipment: power boilers.

Source: GMS Electrical Energy Systems. US Department of Commerce.

Generally speaking Mexican production of all electrical equipment remains dependent on foreign technology. Between 1970 and 1977 twelve technological agreements were signed covering equipment intended for the production or distribution of electricity. Of these 75% were concluded between foreign companies and their Mexican subsidiaries and 88% of the payments can be attributed to them. Royalty payments were fixed as a proportion of the sales and reached about US$ 500,000 per year during the period 1970-1977(1).

The Mexican electrical equipment industry has not reached the level of that of Brazil; nevertheless certain analogies can be seen in the relatively important position of the subsidiaries of the multinationals in each type of equipment. A large part of local production can be attributed to them; however private Mexican firms exist in this sector, most manufacturing under foreign licences. The principal preoccupation of the government is to encourage the production of electrical equipment in Mexico, the establishment of mixed companies for 400 MW transformers, formed from multinationals, private Mexican financial companies and the Nacional Financiera, in order to favour the national industry and the creation of jobs; however it is still not known how the transfer of technology to the Mexican associates will be carried out.

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(1) UNCTAD op. cit.: TB/B/C.6/31.

4 - SOUTH KOREA

The development of the electrical equipment goods sector in Korea is a recent fact, but the rate of growth seen during recent years reveals the extreme dynamism of this activity: in 1973 the production of equipment for the transmission and distribution of electricity accounted for US$ 15.2 million; in 1975 production was US$ 30.6m whilst forecasts for 1980 are US$ 50m. At the same time exports have increased: in 1973 they represented 4% of the national production but in 1975 they accounted for 15%[(1)].

In fact the Korean production of electrical equipment is concerned mainly with power and distribution transformers (cf. Table 16). At the present time the electrical industry is producing few items of equipment for the production of electrical energy, and Korea is dependent on foreign countries for a great part of its needs in equipment for the production of electricity. About twenty companies produce equipment for transmission and distribution (transformers, cables, etc.). All of these are Korean firms which have signed licencing agreements with foreign firms, mostly American and Japanese. These companies still obtain their supplies largely from foreign firms for the production of the equipment (special steels, ceramic parts, insulating paper, etc.); in the case of the Korean Han Yung Industrial Company the contribution of imported supplies accounts for 25% of the cost of the equipment produced. The future development of equipment for the production of electrical energy will certainly be carried out on the basis of the existing units. At the present time Korean

(1) Source: GMS Electrical Energy Systems.
US Department of Commerce.

TABLE 17 - KOREA

DOMESTIC MANUFACTURERS

Dae Myung Manufacturing
Transformers

New Korea Electric Co. (Licensee of Osaka Transformers, Japan)
Transformers

Han Yung Industrial Co. (Licensee of Westinghouse, USA)
Transformers, electric motors, pumps

International Electric Enterprise Co., Ltd., (Licensee of Takaoka, Japan)
Transformers, switchgear

Brown Boveri & Cie (Switzerland)
HV transformers

In Chun Electric Mfg. Co. (Licensee of Toshiba, Japan)
Transformers

Kikje Electric Co. (Licensee of Kokan Mfg. Co., Japan)
Transformers

Lee Chung Electric Co. (Licensee of Toshiba Co., Japan)
Switchgear, generators, transformers, electric motors, condensers

Tai Han Electric Wire Co. (Licensee of Tokyo Electric Co., Japan)
Watt-hour meters

(as licensee of Nisshin Electric Co., Japan)
Capacitors

Kukje Wire and Cable (Licensee of Western Electric Co., Japan)
Cables

Union Electric (Licensee of Mitsubishi Denki, Japan)
Control panels

Dae Han Electric Wire (Licensee of Sumitomo Electric Co., Japan)
Cables

Hankuk Noble Co., (Licensee of Teikoku Communication, Japan)
Resistors and rotary switches

Hankuk Machinery Co. (Licensee of Lummus Co., USA)
Heat Exchangers

Shin Han Electric Co. (Licensee of Osaka Transformers, Japan)

Sam Yung Electric Industry Co. (Licensee of Chemical Condenser Co., Japan)
   Condensors

Pung Sung Electric Co. Ltd., (Licensee of Osaki Denki Co., Japan)
   Watt-hour meters, converters

Gold Star Communication Equipment (Licensee of Fuji Musen, Japan)
   Watt-hour meters

Gold Star Cable (Licensee of Hitachi Cable Co., Japan)
   Electric wire cables

Source: GMS Electrical Energy Systems. US Department of Commerce companies produce industrial boilers and could enter into the production of boilers for electric power stations. The Haukuk Machinery Company has built a unit for 24,000 diesel engines a year of 45 to 256 hp with the technical assistance of East Germany. The Chinil Industrial Company has units producing diesel engines; most of this production is directed towards uses for pumps or for marine engines, but these companies could also develop the production of diesel power stations based on these engines.

Summarizing, therefore, the productive capacity of the electrical equipment sector in Korea relates essentially to local companies with private capital whose technological support has been assured by licencing agreements signed with the major multinationals in the sector. Initially it was production for a national market which was developed (distribution and power transformers). However the growth of exports shows that the companies in the sector know how to enter the world market rapidly. Finally the companies are studying every opportunity to obtain support in the production of equipment for thermal, diesel or hydraulic power stations.

5 - The possible entries

The examples set out above show that access to the technology remains dependent on the major multinationals, but that certain developing countries have begun to establish their own technological capabilities in the electrical equipment goods sector.

Public organizations producing and distributing electrical energy have an important rôle to play in the creation and development of local technological capabilities. If they are content with simply producing and distributing electricity their rôle is non-existent, and the formula of turnkey contracts certainly represents the simplest formula for foreign firms to sell equipment without transferring the technology, even when the contracts include the training of personnel from the point of view of mastering the operation of units.

- The first stage of penetration into the technology of equipment consists of implementing an engineering capability in the public organizations responsible for the production and distribution of electricity, capable of initially mastering the most elementary tasks of control, leading on to more complex activities in the field of design and adaptation.

- The separation of electrical projects constitutes a way to develop local engineering capabilities, with or without the assistance of foreign consultant engineers. In this formula it is possible to envisage some productive capacity in regard to equipment by operating a buying policy orientated towards recourse to local sources.

- At the present time only a few developing countries are manufacturing an extended range of electrical equipment. The examples of India and Brazil illustrate the differentiated way in which a productive capacity can be created in this sector. Access to the technology depends essentially on the major multinationals, and only one alternative is offered to the developing countries: either to open up their markets to the establishment of subsidiaries of foreign companies, or to acquire know-how on the basis of cooperation or licencing agreements with foreign companies, to the profit of local private or public enterprises. Although these two formulae would allow the developing countries to reach comparable productive capacities it is improbable that the first alternative would make it possible to penetrate the hard core of energy equipment (design studies, research and development, manufacture of sophisticated equipment). What the transferring firm wishes least to transfer, in order to retain the mastery of what is most important to them, is its specific know-how on which its market domination is based: this is its technological capabilities in research and development and in the design of equipment.