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Joint ESCWA/UNIDO Industry Division

PROJECT PROFILE
ON
MANUFACTURE OF POWER BOILERS
IN THE ARAB REGION

Prepared by

the Joint ESCWA/UNIDO Industry Division
for
the Arab Industrial Development Organization

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Introduction

The heavy electrical equipment industry is a core industry and plays a vital role in industrialization. Advanced countries have developed a strong base for the manufacture of power equipment. Many developing countries, such as India, Brazil and the Republic of Korea, have also met with a high degree of success in their efforts to set up this industry, and have been able to acquire and adapt its sophisticated and complex technology.

The heavy electrical equipment industry is a high technology industry. Its establishment requires heavy capital investment, the building up of technical expertise and skills of a high order and the creation of a large infrastructural base.

With regard to heavy electrical equipment, the manufacture of boilers is highly job specific. Most boilers are designed to meet a specific set of power plant requirements. It is a product which is almost never fully assembled on the shop floor. Its erection and commissioning on the site is as complex as its manufacture on the shop floor.

For this project profile, an attempt has been made to utilize the experiences of the world heavy electrical equipment manufacturers. However, the bulk of available information is based on the Indian experience. It is hoped that, with the information contained herein, the authorities concerned will be able to decide on various issues involved in setting up this industry and take further steps towards its establishment in the region.

1. DEMAND

The installed generating capacity in the Arab region between the years 1984 and 2010 is projected as follows:

Table 1. Projected demand for installed generating capacity (MW) in the Arab region, 1984-2010

Country[a/]	1984	1990	1995	2000	2005	2010
Algeria	2,835	5,645	8,855	12,122	15,390	18,657
Bahrain	833	1,416	2,294	3,709	5,987	9,656
Egypt	7,856	13,244	20,276	29,126	37,976	46,826
Iraq	6,170	14,011	22,646	32,832	43,019	53,205
Jordan	700	1,272	1,840	2,447	3,052	3,659
Kuwait	5,086	6,842	8,933	11,024	13,114	15,205
Lebanon	1,067	1,528	2,207	3,203	4,200	5,197
Libyan Arab Jamahiriya	2,785	5,563	7,701	9,840	11,978	14,116
Morocco	1,956	2,755	3,860	5,383	6,907	8,430
Oman	818	1,298	1,910	2,810	3,709	4,609
Qatar	1,424	2,016	2,396	2,776	3,156	3,536
Saudi Arabia	13,319	21,006	25,626	31,247	36,868	42,488
Sudan	470	525	754	1,107	1,460	1,813
Syrian Arab Republic	2,062	5,882	10,438	17,055	23,672	30,289
Tunisia	1,085	1,586	2,297	2,983	3,749	4,515
United Arab Emirates	2,568	4,695	7,004	10,396	13,788	17,180
Total	51,068	89,284	129,037	178,060	228,025	279,381
Average increase (5 years)	38,216	9,753	49,023	49,965	51,356	
Average annual increase	6,370	7,950	9,800	9,993	10,271	

Source: Electric Power in the Arab Region; Present, and Prospects (1970-2010) (Arab Industrial Development Organization, September 1986) (in Arabic).

a/ Data not available on following countries: Djibouti, Mauritania, Democratic Yemen, Somalia and Yemen.

The average annual increase in generating capacities between the years 1996 and 2010 is projected to be about 10,000 megawatts (MW) as shown in table 1.

Currently, steam generation is considered the primary source to meet this demand. It represents about 70 per cent of the total generation. This pattern of generation is most likely to continue, owing to the limited potential of hydropower and other sources of generation. Accordingly, the size of demand of steam generation in the Arab region will be about 7,000 MW per year from 1996 and onward.

Most of the steam generating units are of 30, 100, 150 and 300 MW units. Recently, larger units of 600 MW were introduced in the region, but units of 150 and 300 MW will remain the dominant pattern for many years to come.

2. PLANT CAPACITY AND PRODUCT MIX

In view of the above and with due consideration given to the nature of facilities required for manufacturing power boilers/steam generators as related to minimum economic plant capacity, the capacity of the plant under consideration, as elaborated in this project profile, is 3,000 MW per year. This plant capacity, however, represents only 30 per cent of the total demand of generating capacity and 42 per cent of the estimated market of steam generating capacity in the Arab region. These percentages are considered an acceptable rate of penetration of the market, as the project is to be developed on a regional basis.

Based on the trend of the size of steam generating units in the region, as outlined above the following product mix as annual production has been assumed:

8 units and 300 MW	2,400 MW
4 units and 150 MW	600 MW
	3,000 MW

In elaborating this project profile, consideration has been given to the manufacture of larger unit sizes of 600 MW in the future in order to meet the demand in the region.

It should be pointed out that the full capacity of the plant should be attained over a number of years through successive expansions. It is important to match the phasing of the investment with the phasing of production. For example, to start with, action can be taken to establish a set-up with a capacity to produce about 1,000 MW and start production. Then the set-up would move on to a capacity of about 2,000 MW. At the third stage, the plant would expand to its final capacity of 3,000 MW. Thus production and investment can proceed together.

3. PRODUCT DESCRIPTION

Conversion of thermal energy in fuels to steam energy is one of the most widely used methods in power and industrial applications. A boiler is the conversion equipment wherein the thermal energy of the burning fuel is used to heat water and produce steam. The boiler typically consists of a series of heat exchangers that gradually raise the temperature of the feed-water, converting it to steam and then heating it to the required superheat.

In power applications, the boiler is one link of the chain in which fuel energy is converted to electrical energy. The steam from the boiler drives a turbine, thereby producing mechanical energy which in turn is converted to electrical energy in the generator.

The boiler is specified generally by the rate of steam that it is designed to generate in kg/s, T/hr (tons per hour) or lbs/hr along with the parameters of steam, i.e. outlet steam temperature and pressure, reheat temperature and pressure (only in reheat boilers), quantity of flow in main and reheat systems. In power plants, it is usual for the boiler to be designated in MW. For instance, a 300 MW boiler signifies that the boiler coupled to a turbogenerator set can give 300 MW of electric power. A boiler, as mentioned above, consists of a series of heat exchangers. The various heat transfer sections of a boiler can be grouped as follows:

- Economiser;
- Furnace and water walls;
- Superheater;
- Reheater.

The function of an economiser in a steam generating unit is to absorb heat from the flue gases and add this as sensible heat to the feed water entering the evaporative circuit of the boiler.

The economisers are usually located ahead of air-heaters and following the primary superheaters in the gas stream and are horizontally placed.

The furnace is the primary part of the boiler where the chemical energy available in the fuel is converted to thermal energy by combustion. A furnace is designed for efficient and complete combustion. It is water cooled.

Water wall construction has gone through various stages of development, from the conventional refractory backed walls to the present-day welded panels. The water walls consist of carbon steel seamless tubes welded together to form a gas tight enclosure.

Superheaters are meant to raise the steam temperature above the saturation temperature by absorbing heat from the flue gas.

The superheater and reheater are made of a range of materials like carbon steel, alloy steel and stainless steel depending upon the temperature of steam.

The boiler drum forms a part of the circulation system of the boiler. The feed-water is received in the drum through the economisers and gets distributed through the down comer pipes and water wall headers into the water walls. Again, the water and system mixture circulates back into the drum where the steam gets separated from the water.

The boiler drums can be made of carbon steel or alloy steel plates. However, carbon steel plates are preferred.

The piping components consist of pipelines, supports and hangers, fitting and valves. The four major systems of piping are:

- Boiler integral piping;
- Power (critical) piping;
- Turbine house piping;
- Other miscellaneous piping.

The principal boiler auxiliary parts are:

- Air heater
- Fans of both radial and axial type
- Soot blowers

4. PRODUCTION PROCESS

As stated above, the principal components of the boiler are comprised of the following:

(a) Drums and headers;
(b) Tubular products;
(c) Piping and related components;
(d) Structurals;
(e) Burners;
(f) Auxiliaries like fans, air preheater, soot blowers.

Of the above items (a), (b) and (c) are classified as pressure parts, since these will be components that will have to meet the high pressure generated when the boiler is working. These are components which will require a high degree of skill in manufacturing and will be subjected to rigorous quality checks by the regulatory quality control bodies.

The others are classified as non-pressure parts. In the case of burners and auxiliaries also, certain components need extreme care in production to ensure their proper functioning.

The structurals, whether these are meant to support the boiler components proper or other auxiliaries, are relatively simple items to manufacture. Care has to be taken in the production of the ducts that connect one part with the other in the steam generating system for the passage of air or flue gas because of the vibration aspects involved. The dampers which regulate the flow of these two media (some of them will be subjected to high temperatures also) are important components which have to be given adequate care in production.

The manufacturing shops are to be equipped with a range of machinery and material handling equipment for the manufacture of the boiler components. These facilities can be broadly grouped as follows:

- Metal joining
- Metal forming
- Metal cutting
- Heat treatment

Metal joining

The predominant activity in the manufacturing shops will be metal joining (welding). Many automatic, semi-automatic and manual machines employing various processes have to be used. The materials welded can range from low carbon steels to alloy steels, stainless steels and other alloys. There will be a need to develop a team of skilled high pressure welders who should be properly qualified to ensure consistent quality.

Metal forming

The major operation performed by way of metal forming machines will be tube and pipe bending. The forming operation for production of hemispherical dished ends, elbows, T-pieces, reducers and pipes will be carried out in a hydraulic press of a capacity of about 2,000 to 2,500 MT (metric tonnes). Most of these will be formed at high temperature and would call for a trained group of people. Specialized and incremental forming of the drum shells from very thick plates and large dished ends for drums are done in a large capacity hydraulic press. This constitutes the most important part of the manufacturing set-up. All these operations are tooling-intensive, and trained personnel will be required to perform a wide spectrum of operations, from process planning to designing of proper tooling and their manufacture.

Metal cutting

Well-equipped machine shops will have to be created with a number of conventional equipment parts, such as centre lathes, vertical and horizontal boring machines, milling and grinding machines. These will take care of the metal cutting operations to be performed in a variety of machine components that go into the assembly of the steam generator as well as the auxiliaries such as fans and soot blowers.

Heat treatment

Heat treatment operations such as normalizing, stress relieving and annealing will be called for during the manufacture of the steam generator components. The manufacture of tooling would in addition require hardening, case carburising and other similar operations. The production of some of the pressure parts like drums would call for plate heating facilities. All these operations will mean installation of appropriate furnaces of various sizes, capacities and temperatures.

5. MANUFACTURED COMPONENTS

The components which are envisaged for manufacture are listed in annex I.

The facilities required for producing these various components can be grouped in the following five workshops:

- Shop No.1 main boiler shop	- Drums - Headers - Burner assemblies - Piping
- Shop No.2 tubular shop	- Welded water walls - Superheaters - Reheaters - Economisers
- Shop No.3 machine shop	- Soot blowers - All machine components for main boiler and tubular shop
- Shop No.4 structural	- Supporting structures - Ductings - Other structural items
- Shop No.5 boiler auxiliary shop	- Fans - Air preheaters

6. ORGANIZATION OF THE PLANT

The organization of the plant during the production phase will be set into five major divisions as follows:

- Engineering
- Construction services
- Plant operation
- Marketing and sales
- Personnel and administration

In addition, three other units will also be established as follows:

- Quality control
- Training (welding)
- Safety

7. MANUFACTURING REQUIREMENTS

Manufacturing requirements encompass the following:

- Land, buildings, road and utilities
- Materials
- Production and associated equipment
- Personnel

The values given are for full production output level of 3,000 MW/years.

7.1 Land, buildings and roads

(a) Land including reserve for possible expansion	Area (m^2) 500,000	

(b) Buildings

(i) Manufacturing

	Dimensions(m)	Area
Shop No.1 main boiler shop	280 x 180	50,400 m^2
Shop No.2 tube shop	280 x 150	42,000 m^2
Shop No.3 machine shop, tool room and soot blowers	118 x 72	8,496 m^2
Shop No.4 auxiliaries		27,000 m^2
Shop No.5 structurals		20,000 m2
Total required manufacturing area		147,896 m^2

(ii) Ancillary services

- Oxygen plant (63 m/hr)
- Acetylene plant (25 m/hr)
- Compressed air plant (1,500 cubic feet/minute)
- Internal transport
- Storage yards
- Administrative buildings and labs
- Computer — 20,000 m^2

(c) Roads and railway lines

In view of the supply of about 100,000 MT of material required for the proposed product-mix in addition to the bulk of products, it is suggested that the plant be located near a port with access to railway lines and roads.

7.2 Utilities

Electricity supply line	10,000 KVA (Kilovolt-amperes)
Annual electric power consumption	25,000 MWh
Annual (natural) gas consumption	10-85 million m^3

7.3 Materials and parts

A rough estimate of raw material requirements is given below:

Description		Unit requirement in MT 300 MW	150 MW
Boiler quality plates		300	90
Carbon steel	(a) tubes	700	400
	(b) pipes	500	150
Alloy steel	(a) tubes	650	160
	(b) pipes	600	40
Stainless steel tubes		40	50
Alloy steel sheets and plates		50	40
Structurals	(a) sheets and plates	1,200	650
	(b) rolled section	1,400	100
Aluminium		110	30

All through the production phase, certain components will have to be imported, while others could gradually be replaced by locally produced components.

7.4 Production and associated equipment

The most important machines and equipment required are listed in annex II.

7.5 Personnel

A broad break-down of personnel required is given below:

Estimation of human resources	No. of personnel
Engineers and executives	240
Supervisory staff (including draftsmen)	480
Direct workers	1,800
Indirect workers	180
Other technical staff	180
Office staff	120
	3,000

8. MATURATION PERIOD

The plant is expected to attain maturation in eight years. The maturation period encompasses two phases:

- A three-year pre-production (construction) phase
- A five-year production phase

The length of the phases can only be approximated at this stage because it is greatly dependent on the product mix, local conditions (technological infrastructure, etc.) existing in the country hosting the factory. Those factors have to be defined in the feasibility study.

The build-up of the factory is assumed as follows:

	1	2	3	4	5	6	7	8
Prod. output (%)	-	-	-	10	20	50	75	100

9. THE TRANSFER OF TECHNOLOGY

The transfer of technology for highly sophisticated products, such as power boilers is the most significant factor governing the outcome of the project. The manner in which this problem is tackled and solved influences the medium and long-term success of the local manufacturing operation to a far greater extent than the amount of invested capital. The preparations and means for transferring the required technology can only be formulated in the course of a feasibility study, and will be based on the following factors:

- Specifications of the product(s) to be manufactured
- Product mix
- Annual production outputs
- Build-up rate of the new industry
- Prevailing local conditions, available skills, supporting industries at the country hosting the factory.

The process of transferring technology from international manufacturer(s) of power equipment to the regional industry is governed by contractual documents between the parties. The contracted licences must go beyond a simple right to copy the existing product designs; they should enable the regional industry to achieve full independence in due time.

The principal considerations underlying any technology transfer agreement can be summarized as follows:

(i) Which stream of technology is most appropriate in the current context?

(ii) What should be the routing of technology, i.e. advisability of routing the technology through another institution that has gone through this phase of technology transfer in a comparable environment?

(iii) Should there be an umbrella type of agreement extending to boilers and auxiliaries, or piecemeal agreements for individual products with one or more principals?

(iv) What should be the span of collaboration agreements?

(v) What should be the terms of agreement with regard to lump sum, know-how charges, royalties and equity participation?

(vi) What shoould be the nature of services to be rendered by the collaborators;

- Establishment of manufacturing facility
- Power plant system design, sub-system design
- Design of main elements
- Design of auxiliaries
- Procurement of know-how
- Manufacturing
- Quality assurance
- Erection
- Post-operational services

10. FINANCIAL ASPECTS

The financial analysis presented is applicable to the full production output level of 3,000 MW/yr.

10.1 Factors of costs

(a) The cost of land construction as well as wages is estimated (in US dollars) as shown below:

Land	0.2/m^2
Buildings and other civil works (averaged)	840/m^2
Ancillary services	310/m^2
Roads	50/m^2

Annual wages (in US dollars):

Staff	40,000
Direct labour	10,000

(b) The ex-factory of production equipment and materials are given below:

	In millions of $US
Production equipment (plant and machinery including material handling equipment):	
- Boiler shop	56
- Tube shop	34
- Machine shop	14
- Auxiliary shop	32
- Structurals	5
Materials	180
Total	321

(c) Royalty fees = 5% on sales value

(d) Selling prices = $US 120/KW (kilowatts)

Table 2. Capital cost

		(In thousands of US dollars)
(a)	Land and site development	
1.	Land (500,000 m at US$ 0.2/m^2)	100
2.	Grading (2 $/m2)	1,000
3.	Fencing	150
4.	Roads	500
5.	Drainages, sewage, street lighting	1,200
6.	Temporary structure to supervise construction	1,350
7.	Contingencies (10% of items 2-6)	420
	Total "A"	4,720
(b)	Building and civil works	
1.	Building (including laboratories)	130,000
2.	Contingencies	13,000
	Total "B"	143,000
(c)	Plants and equipment	
1.	Production equipment (plant and machinery)	141,000
2.	Freight, insurance, transport (7%)	9,870
3.	Erection and commissioning (10%)	14,100
4.	Utilities and service equipment	10,000
5.	Contingencies (10%)	17,500
	Total "C"	192,470
(d)	Project engineering and pre-operation cost	
	Project engineering (3%) Project establishment, know-how charge (lump sum) and interest during construction	55,000
	Total "D"	55,000
	Grand total A-D	395,190
	Round total	400,000

Table 3. Financing and working capital

Financing to be on the basis of 50/50 equity loan.

Equity	$US 200 million
Loan	$US 200 million
Working capital is estimated at	$US 80 million

Table 4. Annual cost

	Element of cost		$US million
1.	Input material		
	(a) Ex-factory		180,000
	(b) Freight, insurance, transport (7%)		12,600
2.	Wages (3,000)		
	(a) Staff: 40,000 x 500	20,000	
	(b) Direct labour: 10,000 x 2500	25,000	45,000
3.	Utilities: electricity, fuel, gas		8,000
4.	Maintenance supply for plant and equipment		9,000
5.	Maintenance supply for civil works		4,000
6.	Establishment cost including travel, office supplies, rents and taxes, etc. (2.5% of sales)		9,000
7.	Depreciation and amortization		26,000
8.	Interest on long-term and working capital		18,000
	Total		311,600

Table 5. Annual profit based on full production of 3,000 MW

		$US million
–	Annual sale at $US 120/KW	360
–	Annual cost of operation	312
	Annual profit	48
	Annual return on investment = 12 per cent	

Annex I

LIST OF MAJOR BOILER COMPONENTS

1. Boiler drum
2. Waterwall headers and drums
3. Waterwall panels
4. Circulation system components
5. Buckstays and framing
6. Superheater headers
7. Superheater coils and walls
8. Seal boxes
9. Superheater components
10. Reheater headers
11. Reheater coils and walls
12. Reheater components
13. Roof skin casing
14. Economiser
15. Soot blowers
16. Soot blowers and soot blowing system
17. Boiler integral piping and fittings
18. Manholes and furnace opening
19. Fixing components for main oil lining and insulation
20. Boiler skin casing
21. Fixing components for oil auxiliaries insulation
22. Lining and insulation materials
23. Boiler supporting structure
24. Galleries and stairways
25. Boiler outer casing
26. Interconnecting walkways
27. External structures
28. Oil and gas burners and ignitors and scanners
29. Oil and gas systems
30. Ignitor and scanner air system
31. Windbox assembly
32. Ducts, dampers and expansion joints
33. (Steam) airheater
34. "R" type heaters-round casing
35. Radial fans
36. External pipelines
37. Building supporting structures
38. Tanks and vessels (pipelines)
39. Instrumentation and control-field equipment
40. Instrumentation and control-misc. equipment
41. Lifting tackles

Annex II

LIST OF MAJOR EQUIPMENT REQUIRED

1. Main boiler shop (shop No.1)

- Automatic welding
- Gas cutting
- Centre lathes
- Vertical boring
- Horizontal boring
- Deep hole boring lathe
- Heavy duty centre lathe or facing
- Drilling
- Milling
- Planing
- Shearing
- Circular saw
- Power hack-saw
- Bank saw
- Pedestal grinders
- Pipe benders
- Plate rolling
- Section rolling
- Hydraulic press (30 to 500 T)
- 200 T press
- 8,000 T press
- Press brakes
- Furnaces
- Plate straightening
- Welders
- Linear accelerator
- O.D. turning lathe
- Welding generators
- Shut blasting machines
- Shop equipment
- Lifts of 10, 20, 30, 40, 80/100, 120, 300 ton capacity

2. Tube shop (shop No.2)

- Straight tube butt welder
- Peg fin welder
- Continuous fin welder
- Swage upset
- Hydraulic straightening (vertical)
- Chambering and cut off
- Abrasive cut off
- Power hack-saw
- Circular saw
- Shear (general purpose)

- Shot blasting
- Spiral fin welding
- Drilling
- Milling
- Cylindrical grinding
- Continuous discharge furnace
- Solution heat treat furnace
- Welders
- Orbital welder
- Bug welders
- Panel processing
- Panel bender
- Portable end scarfers
- Internal end scarfers
- Squeezing press
- Sizing press
- Induction pressure welder
- Vertical offset press
- Horizontal offset press
- Pipe benders
- System bender
- Flash butt welder
- Portable tube bender
- Shop equipment
- Welding generators
- Lifts of 10, 15, 20, 25, 50 ton capacity

3. Machine shop, tool room and soot blowers (shop No.3)

- Centre lathe
- Turret lathe
- NC lathe
- Drilling
- Milling
- Horizontal boring
- Vertical boring
- Jig boring
- Grinding
- Pedestal grinding
- Tool grinding
- Threading
- Shaping
- Slotting
- Gear machining
- Engraving
- Shears
- Abrasive cut off
- Circular saw
- Band saw
- Power hack-saw
- Gas cutting
- Welding

- Press
- Heat treatment furnaces
- Shop equipment
- Welding generators

4. <u>Auxiliaries (shop No.4)</u>

- Hydraulic press (30-500 T)
- Press brakes
- Mechanical presses
- General purpose shears
- Plate shears
- Plate straightener
- 3-roll bending
- Section rolling
- Gas cutting
- Circular saws
- Hack saws
- Auto welding
- Furnace
- Dynamic balancing
- Pedestal grinders
- Lathes
- Drilling
- Milling
- NC drilling
- Grinding
- Slotting
- Vertical boring
- Horizontal boring
- Planing
- Shotblasting
- Threading
- Tool and cutter grinders
- Other tool room equipment
- Arc welding sets
- Shop equipment
- Profiling for airheaters

5. <u>Structurals (shop No.5)</u>

- Automatic welding
- Gas cutting
- Grinders
- Horizontal boring
- Drilling
- Welding generators
- Plate shears
- Circular saws
- Pedestal grinders
- Shop equipment