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D00960

United Nations Industrial Development Organization

Distr.
LIMITED

ID/WG.60/6
2 June 1970
ORIGINAL: ENGLISH

UNIDO - DECHEMA - Seminar on Operation Maintenance, Design and Manufacturing of Chemical Plants and Equipment in Developing Countries

Königstein (Taunus) near Frankfurt/Main
Federal Republic of Germany
25 - 26 June 1970

MANUFACTURING OF CHEMICAL PLANT EQUIPMENT 1/

by

Dipl.- Ing. F. Wesser
Linde Aktiengesellschaft
Werksgruppe München
Federal Republic of Germany

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Some big European plant equipment manufacturers have released their program for the 70ies. They clearly stated their intention to arrange the production of machinery and plant equipment in developing countries by all means within their possibilities. These intentions are based not only on economic considerations but also on the perception that some of the developing countries are now in a position to offer real chances for economic investments and sufficient quality standard in manufacturing specific plant equipment.

This paper will deal with the basic aspects on the most important economic and technical conditions for the fabrication of chemical plant equipment.

Of basic importance is a proper selection of the types of equipment to be produced out of the extensive variety of equipment necessary for common chemical plants (a list of standard equipment will be attached to the final paper).

A proposed selection will be based on (1) the investment cost distribution of standard chemical processes, (2) the production program considerations, (3) the availability of local skilled labour and (4) the training facilities involved in the manufacturing workshops for an additional development of local labour resources.

By numerous examples the aspects and possibilities of manufacturing processes for chemical plant equipment will be discussed. In addition, details will be given why certain equipment should not be fabricated in developing countries.

When discussing this point, the frequency of certain types of equipment involved as well as the fabrication facilities required to achieve an international accepted quality standard will be considered.

As a result from these considerations some problems might arise with respect to the size of the production facilities, the extent of administration and organization involved and the requirements of highly skilled specialists who, on the other hand, need large workshop for an extended production variety to keep their high level of qualification and experience.

To avoid these problems an example will be given for a reasonable manufacturing program. The final paper will show the layout and equipment necessary for an industrial workshop and will deal with the production planning, fabrication organization, production control and final inspection necessary to guarantee an accepted quality standard.

Contents

1. Introduction: Developing and Industrial Countries

When using the term "Developing Country" in this paper, this means that

(1) we want to state a difference to "Industrial Countries" only with respect to the achieved degree of technical development.
This means that, for this paper, any difference between "Developing" and "Industrial Countries" is strictly related only to this difference in technical and industrial development, common and applied basic technologies and, if necessary, to some connected differences with respect to social or economic facts;

(2) with regard to the manufacturing of industrial products, a minimum standard of technical development is considered to be available as a basis to start from.
This standard should not be represented by one or the other spectacular plant with an intensive automatic fabrication control system.

For the fabrication of industrial equipment in general a well developed system of craftsmen shops active all over the country or at least in some big areas is of much higher importance for our subject.

The manufacturing of any equipment still needs a high craftsman standard though more and more modern machine tools are taking the burden of hard physical engagement in the fabrication process from the workers and craftsmen.
But up to now even in "Industrial Countries" a well developed sense for handling tools (either machine or hand) and the skill of a craftsman are still necessary for manufacturing industrial equipment in a modern workshop with a good outfit of machine tools and other machinery, especially for that type of equipment we are talking about.

2. General outlook on the Manufacturing of Industrial Equipment in Developing Countries

Some big European plant equipment manufacturers have released their program for the next 10 years. They clearly stated their intention to arrange the production of machinery and other industrial plant equipment in Developing Countries by all means within their possibilities.

These possibilities have been enlarged by governmental incentives. This means cheaper long term credits for promising investments in Developing Countries.

These incentives of course will favourize those projects which improve the overall economic and social situation in a country or area. This means on the other hand that very big projects, which might have not always only economic but also some political features, could have a minor chance in the future with respect to governmental assistance compared with those projects showing better chances for a proper approach to the actual possibilities under the specific conditions of a Developing Country.

In general more or less private initiation even in Developing Countries is often in a good position to make use of the chances offered in a market and, on the other hand, to avoid any big economic risk which might lead to insolvency.

Furthermore private investments will mostly take the burden from the government or its representatives to sell the products of a state owned or state controlled production facility.

An other aspect may be to encourage other branches in a Developing Country by private initiations to take share either in supplying semifinished products, material and services for the manufacturing process or to render services in the distribution of said products.

Private initiatives to my opinion might have under specific conditions even in Developing Countries a strong effect on the overall economic structure and situation. Private initiative might help to avoid a not proper working structure in any country. This means that in general private initiative and activity can be a strong partner in the economic development of a country.

Of course there are some realistic aspects on the side of the Industrial Countries which have made companies and governments to start production facilities in Developing Countries:

(1) to help balancing the export surplus which is or will be general in the future for most of the Industrial Countries.

(2) to minimize the problems related to the expansion of the production facilities of Industrial Countries in an extremely populated area. These problems are existing especially with respect to space and labour resources and last not least with regard to the fact that those companies and the government have good reasons to believe in a good chance for a prosperous industrial and economic growth in Developing Countries.

I believe this to be a most important point because all European Industrial Countries and, to a certain extent even the United States of America are about to move in a peculiar situation:

space for expanding their works has got to be extremely expensive;

labour for common requirements must be "imported" from other countries;

it is obvious that the industrial production is going to become more and more specialised and the technology standard is growing quicker and quicker.

As a consequence: why not overcome all these problems which, for one or the other company, are of existencial importance and to start the fabrication of standard products with a normal demand on the ability and qualification of labour in the Developing Countries ?

This is, of course, not only to sell all those products in such a country but also to do a big portion of export.

It is not the subject of this paper to discuss these aforementioned aspects in detail with regard to the overall economic consequences for the Developing Countries. But I believe it to be important for the discussion of manufacturing problems in detail to clarify something of the background of the proposed manufacturing program for chemical plant equipment.

3. Principles for the Set-up of a Manufacturing Program

The fabrication of chemical plant equipment in Industrial Countries has got to be more and more specialised with respect to:

- type of equipment;
- size and weight of equipment;
- material to be handled;
- the maximum wall thickness of pressure vessels to be manufactured.

These are only the four most important points out of a lot of others, which take into account the local labour situation, a favourable or unfavourable transport situation (rail connections, location near to a harbour, the sea or navigable rivers), a historic development of a manufacturing program and a corresponding position in the market and so forth. Some of the above mentioned points have their origin only in pure economic considerations. Others are based on special local conditions as for instance the close cooperation with a chemical company.

Such specialisation is not of restrictive character in an Industrial Country. It is even a necessity to meet the extremely differentiated requirements of the industry in these countries.

In the Developing Countries the specialisation of the manufacturing facilities should be of different character. It is quite obvious that manufacturing "everything" does not give any chance to manufacture the right thing in the right way at the right time. Therefore a proper selection must be made of the equipment to be manufactured and that to be imported.

Five points of view are necessary to be considered:

(1) Which equipment in general should not be manufactured now in Developing Countries for economical and technical reasons ?

(2) Which processes and their related equipment should be taken into account ?

(3) Which equipment for these processes should be fabricated (or not) for economical reasons ?

(4) Which equipment for these processes should not be fabricated for technical reasons ?

(5) Which equipment for these processes should not be fabricated because sufficient skilled labour cannot made available ?

This more or less negative approach to the problem will give finally the answer to the question:

> "What type of equipment should be fabricated and what should be the size and outfit of the workshop ?"

With reference to point (1), the list of "Standard Chemical Plant Equipment" (see attachment 1) shows a classification of the equipment into two main categories:

> categories A: manufacturing possible
> categories B: maintenance possible

All not classified equipment is considered to be normally imported. It is furthermore understood that this classification is only an approach and not binding. It must be varied and adapted to the specific conditions in each Developing Country. Maintenance is mentioned because every fabrication facility includes the possibility of repair work except for those cases, where special repair tools for maintenance are required.

The main reason for assuming a lot of equipment items to be imported is of general economic or technical character.

Some of these items need a very sophisticated manufacturing process, a big staff of highly specialised and experienced workmen and engineers, a big staff for research, development and testing and big fabrication facilities, which all together pay only if the production numbers of items are reasonably high (i.e. compressors, turbines, various types of pumps, gears, fans and most of all machinery, some electrical and instrumentation equipment).

Other items are used only in a very small number, for instance tanks and gasholders, fired process equipment, flares etc.

An other group of items is considered to be bulk material as for instance all pipes, valves and joints, insulation material and some electrical and instrumentation material. Most of this equipment even needs special materials, semi-finished products and numerous subsuppliers, which are not available in most of the Developing Countries.

With reference to point (2) we should neglect sophisticated processes for products with a small range of application and a small actual demand in the market of a Developing Country.

Furthermore all processes should not be taken into consideration which need highly specialised equipment in small quantities as for instance equipment for the pharmaceutical industry, for artificial fibres, special condensation products and the like.
All processes considered should supply those products which are of importance to overcome basic requirements in the economic and social program of a Developing Country.
These processes should be modern and reliable in design, reasonable with regard to their operating and maintenance requirements.

For further considerations the following processes will be of importance:

- refinery processes including handling of natural gas
- petrochemical basic processes including fertilizer fabrication
- standard processes based on petrochemical feed stocks (i.e. processing of ethylene, propylene, C4-hydrocarbons, aromatics etc.)
- other standard processes without special requirements on pressure and/or corrosion.

With reference to point (3) it is evident that the machine tools and other equipment in the manufacturing facilities should allow for:

- universal use in the fabrication process, this means standard machine tools for standard equipment;
- a high utilisation factor due to a proper arranged fabrication program and a good workshop organisation. This means to avoid any special but seldom used machinery or machine tools which need extremely skilled operators.

For these reasons some economic points are of interest which might give an idea of money involved in the various classes of equipment necessary for chemical plants.

In appendix 2, tabula 1, an "Investment Cost Distribution in Chemical Plants" is given for erected material.

As we have excluded already piping material, machinery, electrical and instrumentation from our manufacturing program, vessels, towers, reactors and heat exchangers are of importance. This class of items needs nearly the same type of machine tools and workshop equipment.

With a share of 20 to 39 % in the total costs of erected material this class of equipment is of high economic interest.

Tabula 2 in appendix 2 shows the cost distribution for the same type of plants for unerected material. The given split-up of the pressure vessels into single items gives a more precise idea of money involved in the various types of pressure vessels.

This tabula 2 should be compared with tabula 3 in appendix 2 which gives an idea of the number of items involved.

The share of towers in the total is heigh in value due to the heigh portion of special and alloy steel involved though this number is always low.

It is obvious in each modern process that heat exchangers of any type have a big share in costs as well as in number and vessels a smaller share in costs but a big share in number. But in total heat exchangers and vessels form such a big portion of equipment by value and number that they are of highest interest for a production program. Towers need much fabrication space which can be provided in some cases outdoors, but only few additional workshop equipment.

For a fabrication shop tabula 3 is perhaps of highest interest. It gives an idea of the capacity required and the material involved.
The material to be used will be subject of further discussions.

Steelstructures, steelwork and some machinery designed in the steelwork technique are another class of items, which can be locally fabricated.
In some processes the tonnage of steelwork and steelstructures is considerably high and therefore of importance.
In most of the Developing Countries weather conditions will allow for steelstructure fabrication outdoors.
The additional workshop equipment is not of importance especially when steel blasting is not required before priming.

Another group of items to be considered for the manufacturing program are certain types of tanks, silos and containers, which may be classified as a mixture of vessel fabrication and steelwork.

With reference to point (4) some general remarks have been made in point (1), especially as far as machinery and piping material is concerned.

In addition these are some items, which should not be fabricated for pure technical reasons:

pressure vessels with high wall thickness especially from alloy or special carbon steel. They need special welding techniques, special machine tools and in some cases heat treatment of the entire vessel.

pressure vessels with internal cladding from alloy material. They need special welding and cladding equipment, high qualified craftsmen with permanent training in this field, special fabrication control, testing facilities and testing personnel.

pressure vessels with fix internals of complicated design and manufacture (special towers, adsorbers and reactors).

air-coolers (bundles, not frames)

heat exchangers of the armature wound ("spaghetti type") and "fin-plate" type. They need complicated manufacturing processes and equipment and are subject of the special fabrication technique of only a few suppliers in the world.

valves and caps for distillation and rectification trays; sieve trays of special design with respect to supports in the towers.

With reference to point (5) most of the remarks for point (1) and (4) can apply. In general: every complicated equipment or manufacturing process needs specialists. They need a special training before capable of doing their job and they require a permanent activity in their job. As the number of items is small for which these specialists are necessary, there is always the chance that these specialists loose their ability due to a lack of training. On the otner hand their ability is the prior condition for a good quality standard and a safe operation of the plant. Therefore all equipment which needs special but seldom required craftsmen should not be incorporated in the fabrication program. This means f.i. to avoid aluminum and high alloy material to be welded, this means not to install machine tools with a high operating "comfort" (f.i. numerical operated drilling machines). This type of machinery is not required for the standard equipment of chemical plants, it would have a bad utilisation factor and the operators do not have any chance to remain qualified for this job.

To summarize, the workshop should be designed for the fabrication of the following items:

1. pressure vessels:
   - towers
   - vessels with and without internals
   - heat exchangers (TEMA-Type)
   - (adsorbers, dryers, reactors)

2. atmospheric vessels and similar equipment:

   tanks (specific types)

   silos (specific types)

   containers (specific types)

3. steelstructures and steelwork including:

   specific machinery designed in the steelwork technique;

   pipe supports

4. the fabrication should be restricted, at least for the start up period in the shop, to:

   the handling of carbon steel;

   wall thicknesses for jackets and shells of 15 mm in maximum;

   a diameter of heat exchanger bundles of appr. 800 mm.

4. Manufacturing of Chemical Plant Equipment

As summarized before the following will deal with some details of the manufacturing processes for pressure and atmospheric vessels.

The manufacturing of steelstructures and steelwork will be neglected. These processes need, for normal sizes, weight and design and under a normal competitive situation in the market, no special or abnormal manufacturing equipment.

The overall conditions for the erection of a fabrication shop for pressure vessels and heat exchangers may be assumed as the following:

(1) location of the workshop with respect to:
- labour resources;
- clients of the fabricated equipment;
- transport connections (rail, road, ship) for semi-finished products as well as for fabricated equipment;
- energy supply;

(2) size and capacity of the workshop, i.e.
- overall dimensions (main and secondary face);
- capacity in manhours per month and shift;

(3) equipment for the workshop, i.e.

machine tools;

tools;

storage facilities;

transportation equipment;

inspection and testing facilities;

planning and supervision requisites;

energy and utility supply (electric power, welding gases, compressed air etc.)

maintenance requisites for tools and machine tools (including special tools for the maintenance of machine tools);

general requisites for offices, change room, cloak room etc.

With reference to point (1) the location near to a big chemical company might be, under certain circumstances, of the highest importance for various reasons:

First the alternating effect produced by the possibility of a close cooperation between the manufacturer and the user of plant equipment. The exchange of informations about the behaviour of the equipment under process conditions and a cooperation in the fabrication stage between the fabrication shop and the maintenance department of a chemical company will be a very useful instrument to increase the quality of the equipment and the overall ability of the fabrication shop.

It will strengthen the position of the workshop in a free competition with other plant equipment manufacturers in a Developing Country.

Second the workshop will be used also for maintenance purposes. As some bigger maintenance work on vessels and exchangers requires a rather big and well equipped maintenance shop quite similar to the manufacturing shop, it is under certain conditions more economic to use the fabrication shop also for specific maintenance work.

Third the transportation problems for big or heavy manufactured plant equipment will be minimized.

In case of a close location to a chemical company, labour resources might not be decisive for a proper selection of a site for the workshop.
In any case one should give very careful consideration to all questions concerning local labour especially when a high floating rate of labour is to be expected.

It is a common observation in some Developing Countries that, after some training in a modern workshop and after having got familiar with some modern or special welding and fabrication techniques, skilled workmen leave the shop for a more independent job or to set up for themselves. This means that a fabrication shop cannot, for a considerable long time, get rid of the start up difficulties.
It is up to the management of the workshop to take action against a high floating rate and a permanent training process on the same training level by means of incentives or whatever the social and political status in a Developing Country might allow for.

Though sizes and weights of the equipment to be manufactured in the start up period will not have a considerable influence on the choice of the location for the workshop with respect to transportation, it is necessary to keep in mind some futural aspects concerning not only the area around the workshop but also transport connections.
The area around the workshop should allow for:

enough storage area for big sized semi-finished products, profiles, bottoms etc., which should not be stored in the main storage of the workshop;

- a considerable free area near the exit of the workshop for finished equipment to be moved by truck or rail. One should keep in mind that towers or tower sections of appr. 40 m length must be carried;

- a good approach to rail facilities, harbour or piers, if possible.

The transportation of equipment from the workshop to rail connections, main roads or harbours should not be limited by thoroughfares through towns, villages or the like.
This is very important for big sized or heavy equipment especially with respect to the allowable weights for some bridges or roads in towns.

Energy supply might only be of importance with respect to electrical energy. As the power demands are not very high the location of the workshop normally will not depend on the availability of electric power.
The same may be valied for water.

Welding gases can be stored in cylinders which will be in most cases combined to transportation units of 10 or 20 or even more.

They are located in the utility room or outside the workshop under a simple roof in a small fenced area and connected to the welding gas supply system in the workshop.

Compressed air will also be distributed by a supply system all over the workshop. The compressor and working vessel should be located in the power and utility room.

With reference to point (2) "size and capacity of the workshop" the following might be of importance.

The size of the workshop is depending not only on the capacity but also on the type and size of equipment to be manufactured. As we have fixed the requirements with regard to type and size, the most important factor for the dimensions of the shop has been settled.

The capacity depends more or less on the machine tools available and last not least to a minimum of skilled labour to operate these machine tools. Of course there are some other influences on the capacity from the "overhead personnel" and auxiliary labour available, but for both the direct influence on the capacity allows for more flexibility as for instance with regard to skilled labour.

As we have decided for the manufacturing of vessels, towers and heat exchangers, the workshop should show two separate manufacturing lines for:

a) jackets, shells and skirts, i.e. manufacturing of the pressure vessel itself.

b) bundles and internals, i.e. manufacturing of pipe bundles, tube sheets, baffles, trays, bottom internals (towers), nozzles, manholes, etc.

The attached plot plan for a workshop (see "Attachment 3") may be used as a sample. It clearly shows the flow of material through the workshop within these two lines. Size and dimensions are indicated. The capacity of this workshop is expressively not based on a fixed tonnage per month or something the like but only on manhours to avoid the influence of manhour efficiency, ability of manpower to operate the machine tools, organisation, planning and supervision, quality and organisation of maintenance and last not least the efficiency of the initial and permanent training of labour.

Under these considerations the proposed workshop sample allows for

15.000 manhours per month and shift (8 hours per shift) on production

appr. 90 labourers (skilled and unskilled) per shift on production

appr. 25 men for storage, auxiliary services, planning, inspection and supervision.

As already mentioned before the storage should be used only for small semi-finished products as for instance flanges, bolts, nuts, small profiles, thin sheets, tubes, gaskets and any other material to be protected from weather, dust and similar influences. Big parts as for instance dished heads, heavy plates and profiles should be stored and cleaned outside the workshop before used in the manufacturing process.

Cleaning of equipment or parts thereof before final assembling should, if required, also take place outside the workshop. Under certain weather conditions even sandblasting before painting may take place outside the shop.

Due to the limitation in material and wall thicknesses any facility for heat treatment either for entire vessels or for parts thereof has been excluded. Even in Industrial Countries only a few of the big plant equipment manufacturers have heat treatment facilities for big equipment parts or entire vessels in operation for their own production. Most of them make use of the heat treatment furnaces of the very big equipment manufacturers who have furnaces in operation of sufficient size and modern temperature control.

Rest room, change room and cloak room should be considered not only as a necessity from their purpose itself but also as an instrument of organisation, this means to keep the production area free from rest places and the like which is necessary to have a good control on the working area and to avoid accidents.

With reference to point (3) "equipment for the workshop" it is of high importance to be aware that chemical plant equipment manufacturing is basically a single-part production.

For some parts in some special cases a manufacturing in series and the related machine tools seem to be applicable but precise pay-out calculations mostly show that the additional machinery or equipment required does not pay. And, as the demand for some plant equipment of which pieces may be manufactured in series is not known in due time in advance, there is no chance to make the additional workshop equipment available quick enough.

Therefore, as already mentioned in chapter 3, all workshop equipment should be of good standard and for universal use, easily to be operated and without demands for highly specialized and qualified operators. This means to avoid machine tools like numerically controlled drilling machines and gas cutting machines, copying lathes or similar.

A list of the standard workshop equipment is attached to this paper. This list is restricted to machine tools and some major items required for the manufacturing process.

In addition all the other equipment as mentioned in the beginning of this chapter has to be selected out of a big and useful variety but always under the aspects of universal usability.

This is especially with reference to floor transportation equipment, inspection and testing equipment to ensure an accepted quality standard, and the maintenance requisites for tools, machine tools, cranes and the energy and utility supply equipment.

For the planning and supervision of the manufacturing process it is of importance to know in detail how this process actually proceeds. This requires detailed knowledge about

- the actual supply date to shop of semi-finished products and components required for each item to be manufactured,
- the time and manpower required for each manual operation in the manufacturing process,
- the time (and manpower) required for each operation on each machine tool or welding equipment,
- special tools and devices required including those which have to be prepared in advance (time and period of use),

to set up a detailed planning for the manufacturing program including all inspections and testing.

This procedure is necessary for a controlled manufacturing process as well to meet the accepted delivery date as to take care for a high utilisation factor for the workshop equipment. Furthermore this procedure is necessary for the overall workshop planning and to recognize bottle-necks in the manufacturing process.

Last not least this procedure and its demonstration item by item on progress panels is one of the most important factors in the workshop organisation. Some others are a good procurement, an effective expediting, a flexible labour planning in connection with a reasonable manpower training and within the company's overall labour policy.

The supervision of the manufacturing process of course should involve, besides the progress control, all single activities in the shop to avoid waste of material and misoperation on machine tools and workshop equipment. Furthermore supervision has to initiate inspections and preventive maintenance activities on the machine tools, tools and other workshop equipment.

A good supervision is the basis for an effectively working inspection service.

As supervision is restricted to organisation and progress of the manufacturing process and inspection to quality and reliability of the manufactured item, both are necessary to ensure the reputation of the workshop i.e. efficiency, reliability and quality.

On the background of these three criteria highest priority should be given to the maintenance of tools and machine tools.
A proper working maintenance department needs some special trained workmen for the maintenance of tools and some others for maintenance and repair work on machine tools.

Specialists on the maintenance of tools are requested especially for standard and carbide tipped drills, cutters and turning tools, for taps, broaches, for electric tools and complicated hand tools. They should have experience in operating lathes, drilling and milling machines and should get special training in maintaining said tools.

Maintenance of machine tools in general requires special training by specialists of the supplier. But this training normally will only be sufficient for standard maintenance work and small repair work.

For the change of important components and adjustment procedures the assistance of the supplier might be necessary or advisable.

5. Summary

There is no doubt that the Developing Countries will be involved in the future in the manufacturing process for chemical plant equipment. The increasing demand worldwide on this type of equipment on one hand, the required specialisation and the labour situation in Industrial Countries on the other hand will encourage big manufacturers of plant equipment to produce certain types of equipment in Developing Countries. These intentions will be intensified by governmental incentives for promising projects.

Some of the aspects concerning an efficient manufacturing process have been mentioned and discussed.
Nevertheless one factor should have the highest priority among all considerations as important they ever may be, that is the training and education of skilled labour for all manufacturing processes, for maintenance, for inspection, testing, for production planning and supervision.

Though the workshop plot plan sample does not show a special training area, I consider a regular

training program executed at least for some time in a special training area within the workshop under the advice of qualified instructors to be indispensable. A continuous training might be an expensive and long term investment but will bear the highest interests for the whole industrial and economical situation in a Developing Country.

Attachments

No 1 List of Standard Chemical Plant Equipment

No 2 Investment Cost Distribution in Chemical Plants

Tabula 1: General Cost Distribution for Erected Material

Tabula 2: Cost Distribution for Specific Unerected Material

Tabula 3: Number of Items Involved in Some Petrochemical Processes

No 3 Manufacturing of Towers, Vessels and Heat Exchangers:
"Workshop Plotplan Sample"

No 4 Manufacturing of Towers, Vessels and Heat Exchangers:
"Workshop Equipment List for Major Items"

Attachment 1

List of

STANDARD CHEMICAL PLANT EQUIPMENT

Index

Categories

All civils and related work are excluded

Category A : Manufacturing possible

A 1 : without special workshop Equipment or with only small additional equipment or machine tools.

A 2 : detailed written manufacturing advise or consulting required.

Category B : Maintenance possible

B 1 : without special spare parts or with spare parts out of stock.

B 2 : only with suppliers service.

Not categorized equipment in category A is assumed to be imported.

	A1	A2	B1	B2
1. Pressure Vessels				
(interior or exterior pressure)				
Towers, Columns :				
paked	x		x	
trays	x	x	x	
Vessels, Drums				
without internals	x		x	
with internals	x	x	x	
Heat Exchangers				
TEMA-Type	x		x	
Special			(x)	x
2. Storage Tanks				
Gasholders				
cylindrical	x	x	x	x
spherical			(x)	x
special		(x)	(x)	x
Tanks				
cylindrical	x		x	
spherical			(x)	x
special		(x)	(x)	x
Silos	x	x	x	
3. Fired Process Equipment				
Submerged Flame Liquid Heaters			(x)	x
Direct Fired Reactors			(x)	x
Incinerators			(x)	x
Tubular Reactors				x
Tubular Furnaces				x
Non Metallic Indirect Fired Heaters				x
Steam Generators				
boilers				x
waste heat recovery systems				x

	A1	A2	B1	B2
4. Various Process Equipment				
Cooling Water Make up				
cooling towers			x	x
well water make up		(x)	x	x
inhibitors injection units		(x)	x	x
Boiler Feed Water Make up				
degassing units		(x)	x	x
desalting units		(x)	x	x
deionisation, ion exchange		(x)	x	x
chemicals injection units		(x)	x	x
Waste Water Handling				
oil-water-separators		(x)	x	
flocculation facilities		(x)	x	(x)
biological treating		(x)	x	(x)
chemicals injection units		(x)	x	x
Waste Disposal Handling Systems			(x)	x
Flares, Flare Systems		(x)	x	
5. Machinery				
Pumps				
centrifugal pumps			x	x
reciprocating pumps			x	x
rotary pumps			x	x
special pumps			x	x
Ejectors			x	
Fans				
centrifugal fans			(x)	x
axial flow fans			(x)	x
Compressors				
centrifugal compressors				x
axial compressors				x
rotary compressors				x
reciprocating compressors			(x)	x
Gears				
planetary gears				x
spur gears				x
bevel gears			(x)	x
worm and worm wheel gears				x

	A1	A2	B1	B2
Turbines				
steam turbines				x
gas turbines				x
expansion turbines				x
Mills, Crushers, Grinding Equipment			(x)	x
Classifiers		(x)	(x)	x
Granulators, Pelletizers			(x)	x
Extruders			(x)	x
Separators (rotating or vibrating)		(x)	(x)	x
Mixers (rotating)			(x)	x
6. Transportation Equipment				
Cars, Trucks, Trailers			(x)	x
Railroad Freight Cars			(x)	x
Standardized Floor Conveying Equipment	x	x	x	x
Fork Trucks, Tractors, Walkie Trucks			x	x
Containers, Pallets, Drums, Bins	x	x	x	
Conveyors				
screw		(x)	x	
belt		x	x	
chain		x	x	
bucket		x	x	
vibrating		(x)	x	
slide		(x)	x	
roller		x	x	
continous flow		(x)	x	
Cranes, Lifting Equipment			x	x
Loading and Unloading Equipment (for ships, railroad cars, trucks)			x	x
7. Piping				
Pipes and Tubes				
a) manufacture :				
seamless			x	
welded	x	x	x	
forged			(x)	x
cast			(x)	x
machined			x	x

	A1	A2	B1	B2
b) sizes :				
normal diam.			x	
large diam. (> 16")			x	
normal) wall thickness			x	
small)			x	
high ratio of wallthickness to diameter			x	(x)
c) material :				
carbon steel			x	
killed carbon steel			x	
alloy material (low and high)			(x)	x
Bends, Elbows, other Fittings				
a) manufacture b) sizes c) material } see "pipes"				
Joints				
a) normal types				
welded	x		x	
taper pipe thread	x		x	
flanged	x		x	
b) for special services :				
packed gland joints			x	
poured joints			x	
O-ring joints			x	
groove joints			x	
clamp joints			x	
flare fitting joints			x	
etc.				
Valves				
gate valves			x	(x)
globe valves			x	(x)
diaphragm valves			x	(x)
plug valves			x	(x)
ball valves			x	(x)
butterfly valves			x	(x)
check valves			x	(x)
safety valves			x	x
Hangers, pipe supports	x	x	x	
Special				
rupture disks			x	
automatic condensate drain valves			x	(x)
fire nozzles, sprinkler nozzles			x	(x)

	A1	A2	B1	B2
8. Structural Steel				
Pipe Bridges, Pipe Racks	x	x	x	
Steel Structures for Vessels	x	x	x	
Steel Structures for Machinery (steel foundation)			(x)	x
Steel Structures for Buildings (compressor houses, fabrication buildings, storage buildings)		(x)	x	
Ladders, Steps, Platforms,	x		x	
Footbridges	x		x	
Davids, Small Steelwork	x		x	
9. Insulation (incl. weather protection) (Application)				
Hot Services				
slag wool	x		x	
mineral wool	x		x	
asbestos	x		x	
special		x	x	
Cold Services				
slag wool	x		x	
mineral wool	x		x	
cork	x		x	
polymeres			x	
Weather Protection				
metal sheeting	x		x	
mastix	x		x	
polymer films	x		x	
Noise Protection		x	x	
Fire protection (by insulation)				
concrete	x		x	
brick work	x		x	
gun asbestos concrete		x	(x)	x
10. Paintings, Coatings				
Atmosphere Corrosion Protection	x		x	
Chemical Corrosion Protection (equipment surfaces in contact with a corrosive flow)				
metallic coatings		(x)		x
email, glass, ceramic coatings				x
rubber, synthetic rubber			(x)	x

	A1	A2	B1	B2
special polymerisation and condensation products			(x)	x
Special Services				
protection of surfaces in extreme hot services or under combined (atmosphere and chemical corrosion) influence		(x)	(x)	x
11. Electrical				
Power Generators				
normal				
emergency systems				
Transformers				
Switch Gears				
Motors				
Small and Minor Equipment				
Alarm Systems				
Cables				
12. Instrumentation				
Measuring Devices				
Positioners				
Transmitters				
Controllers				
Indicators				
Recorders				
Electronic Equipment (incl. computers)				
Cables (electrical, pneumatic)				
Minor Equipment				

Appendix 2

Tabula 1

INVESTMENT COST DISTRIBUTION IN CHEMICAL PLANTS

1. General Cost Distribution for Erected Material

Item:	% of Total
vessels, towers, reactors, heat exchangers	20 - 34
piping, valves, supports	14 - 22
compressors and turbines	1 - 18
pumps	1 - 6
electrical	4 - 11
instrumentation	10 - 22
civils	6 - 16
steelstructures, steelwork	3 - 10
thermal insulation	1 - 3
painting	1 - 2
various	1 - 5

Appendix 2

Tabula 2

INVESTMENT COST DISTRIBUTION IN CHEMICAL PLANTS

2. Cost Distribution for Specific Unerected Material

Item:	% of Total
towers	5,6 - 6,3
reactors	0,3 - 2,0
vessels	2,3 - 3,4
air coolers	0 - 6,4
heat exchangers	10,8 - 15,4
furnaces	18 - 22
other apparatus	0,5 - 10
piping, valves, supports	12,3 - 15,5
compressors and drives	1 - 15
pumps and drives	1 - 2,7
electrical	2,3 - 5,7
instrumentation	8,4 - 11,7
various	11 - 13

Tabula 3

NUMBER OF ITEMS INVOLVED IN SOME PETROCHEMICAL PROCESSES

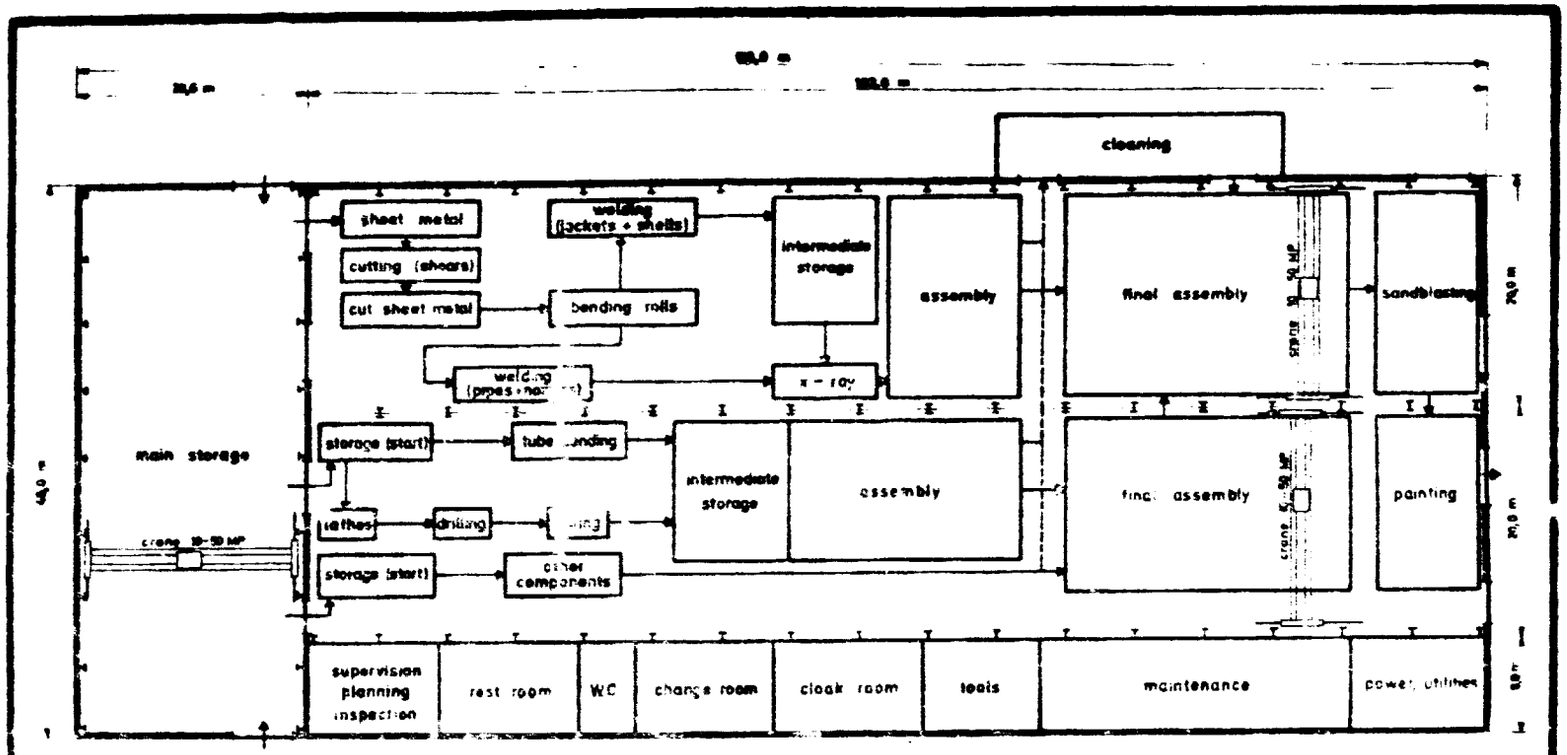
Item	Total Number	Material Involved	
		Alloy + Special	Carbon Steel
Towers Adsorbers	14 - 23	6 - 7	8 - 16
Dryers Reactors	14 - 19	10	4 - 9
Vessels x)	115 - 123	41 - 18	74 - 105
Heat Exchangers	177 - 196	41 - 43	146 - 153

x) with and without internals

Attachment 3

Manufacturing of Towers, Vessels and Heat Exchangers

"Workshop Plotplan Sample"



Design Basis:

manufacturing capacity:	15.000	h/month (one shift)
workmen	appr.	90 men
supervision, services:	appr.	20 men
storage	appr.	5 men

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Manufacturing of Towers, Vessels and Heat Exchangers

Workshop Plotplan Sample

1 – 16 323

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Attachment 3

Workshop Plotplan Sample

(Remarks)

Main Storage:

Hacksawing and band sawing machine should be installed in this area to avoid sawing of profiles and the like in the manufacturing area.

The same should apply to the gasket cutting device.

1st Line: Pressure Vessel Manufacture

Cutting of Sheet Metal:

includes plate edge preparation for welding.

Welding of Jackets and Shells:

means manufacture of longitudinal seams on jackets and shells (sections) only. Dished heads will be fit to jackets and shells in the assembly area.

Assembly:

for jacket and shell sections, bottoms, dished heads, nozzles and manholes.

Final Assembly:

fitting of tray supports, trays, ladder and platform connections, bottom internals etc. to pressure vessels.

Final testing

2nd Line: Heat Exchanger Bundles

Assembly:

of the entire heat exchanger bundle.

Final Assembly:

fitting of bundles into shells. Pressure testing of the entire heat exchanger.

3rd Line: Other Components

Manufacture of trays, tray sections, supports, davids, platform components etc.

Sandblasting, Steelblasting

Sandblasting should be carried out outside the workshop; steelblasting should take place inside the workshop.

Blower, bunker and dressing plant should be installed outside.

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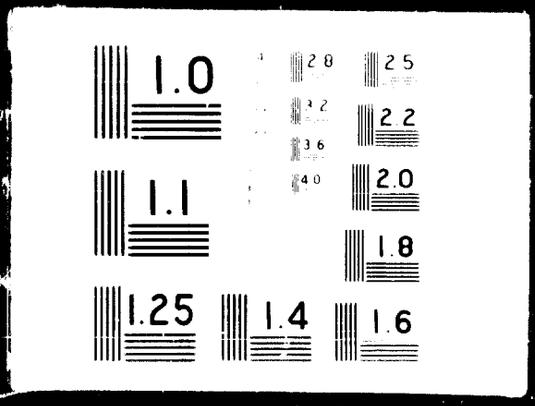

General

Various standard (two disks) grinding machines and pillar type drilling machines should be arranged along the various manufacturing lines.

Attachment 4

Manufacturing of Towers, Vessels and Heat Exchangers

"Workshop Equipment List for Major Items"

1. Manufacturing
2. Maintenance
3. Tools
4. General Equipment

Remark:

This list is restricted to machine tools and a general indication for other workshop equipment. Machine tools are not specified in detail.

Not included are: power and utility facilities, testing and inspection facilities, planning, supervision, office requisites etc.

1. **Manufacturing**

Cutting:

gas cutting machine (copying type)

guillotine shear (3 m cutting length,
top swingable for plate edge
preparation)

hacksawing machine

band sawing machine

plate edge preparation by grinding machine
and /or nibbling machine

Bending:

sheet metal bending rolls (prestressed top roll)

tube bending machine (up to 40 mm Ø)

profile bending machine

Welding:

automatic welding machines for circumferential
and longitudinal seams with welding device
support

(alternatively: automatic welding
machine with built-in infinitely variable
conveyance)

hand operated electric welding machines for electrodes and S.I.G.M.A. welding procedure

hand operated gas welding equipment

tube end welding apparatus

Turning:

vertical boring and turning mill (for diam $\geq$ 600 mm)

sliding, surfacing and screw cutting lathe (engine lathe; height of centers: appr. 300 mm; length between centers: 1000 - 2000 mm)

planetary (movable) flange milling machine

Drilling:

radial drilling machine (capacity: $\leq$ 60 mm; length of action appr. 1500 mm; power traverse)

pillar type drilling machines (capacity: $\leq$ 20 mm)

Milling:

slot (and keyway) milling machine (or face milling machine)

pipe end milling machine

Grinding:

plate edge grinding machine

standard (two disks) grinding machines

X - ray:

x - ray tube

analysing equipment

Assembling:

water pressure pump

hoses

small hoisting equipment

Sandblasting (Steelblasting)

blower

nozzles and hoses

bunker

dressing plant

Painting:

spray-painting unit

2. Maintenance

(of workshop equipment)

Tool grinding machines

universal tool and cutter grinding machine

or:

cutter grinding machine

twist drill grinding machine

tool grinding machine

tap grinding machine

saw sharpening machine (for bands)

pillar type drilling machine

shaping machine

standard (two disks) grinding machine

casehardening furnace (also for hard-soldering of carbide tipped tools)

small forging equipment

electric and gas welding equipment

3. Tools

electric nibbling machine

electric hand drills (various capacity)

electric hand circular saw

electric hand grinding machines

electric welding machines

gas welding machines

abrasive cutting-off machine

power screw driver

magnetic clamping plate

tube rolling machine

hydraulic lifting cylinders with pump

small hoisting equipment

tork wrenches

gasket cutting device

angle measuring device

drills

milling tools

broaches

turning tools

tapping tools

screw spanners, screw drivers, scrapers, files, saws and other small standard tools

4. General Equipment

vessel rotating equipment

auxiliary assembling equipment

transportation equipment

cranes

gas cylinders for welding gases

scaffolding (steel)

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