REQUIREMENTS FOR PRESSURE VESSEL BASIC ENGINEERING DESIGN

Most generally, basic process equipment design, manufacture, and assembly involve the following stages:

1. STAGES DURING BASIC ENGINEERING DESIGN

a) Definition of basic design data;

b) Definition of equipment process data;

c) Equipment process design;

d) Thermal design (for heat exchanger);

e) Materials selection;

f) Mechanical design;

g) Design and specification of internal accessories;

h) Assisting detailed design;

i) Assisting supplying;

j) Assisting equipment manufacture and assembly;

k) Assisting commissioning and start-up of installation;

l) Conducting acceptance tests.

2. STAGES DURING DETAILED ENGINEERING

a) Monitoring of detailed engineering;

b) Issue of Material Requisition;

c) Issue of Purchase Order;

d) Evaluation of proposals (Technical and Commercial Opinion);

e) Placement of Authorization for Material Supply or signature of contract;

f) Purchase or supplying of materials;

g) Monitoring of manufacturing design;

h) Manufacture of equipment;

i) Inspection;

j) Field assembly;

k) Supervision of assembly.

3. DESCRIPTION OF EACH STAGE IN BASIC ENGINEERING DESIGN

3.1. Definition of basic design data

The basic design consists of data and information on local ambient conditions, definitions of loads and specifications of the products to be obtained, utility conditions available, recommendations for ambient control, and user preferences.

3.2. Definition of equipment process data

During this stage, data on the equipment's working conditions are determined. Such data include:

a) General type of equipment (e.g., distillation tower, storage vessel, reactor, or heat exchanger);

b) Nature, properties (e.g., chemical composition, concentration, density, impurities and contaminants presents), rate of flow, temperature, and pressure for all fluid streams that flow into or are discharged from the equipment (working values, maximum and minimum values possible);

c) Equipment working temperature and pressure (normal values, maximum and minimum values, and respective variations as a function of time, when applicable);

d) Volume stored;

e) Position of installation (vertical, horizontal, and sloped), when it affects operation;

f) Design pressure and temperature;

g) Position and elevation of nozzles (only when they affect operation);

h) Required equipment elevation (only when it affects operation);

i) Requirements as far as non-contamination of contained fluid (when applicable);

j) Instructions for commissioning the equipment for star-up (special cleaning, for example), when applicable.

In the case of heat exchangers, process data shall include the following informations, in addition to that listed above:

k) Thermal load;

l) Temperature, viscosity and molecular weight of the fluids (inflow and outflow conditions);

m) Scaling factors;

n) Maximum allowable pressure drop.

3.3. Equipment process design

Equipment process design - also called analytic design - consists of determining those general dimensions of the equipment that affect its operation and also of defining all those details concerning the equipment itself or its internal accessories that may likewise affect equipment operation, based on process data.

Informations included in process design are:

a) Schematic drawing of equipment;

b) General dimensions (diameters and lengths), when these affect the equipment;

c) Type of heads;

d) Nominal diameter for all nozzles connected to piping;

e) Type, location, shape, general dimensions, spacing and details on internal accessories;

f) Indications of nozzles for all instruments connected to the equipment;

g) Indication of whether or not there is a need for thermal insulation, refractory lining, or other lining, and the purpose of the insulation or lining.

h) Special requirements concerning transportation, assembly, disassembly, maintenance, entering the equipment, inspection, or removal of internal accessories.

3.4. Material selection

Materials selection consists of the basic indication of the materials for the shell and internal accessories, taking into account working pressure and temperature conditions, the erosion and corrosion potential of contained fluids, and the need for non-contamination of these fluids; it also entails determining all corrosion overthickness allowances. When applicable, anticorrosive or refractory lining or special painting shall also be defined.

a) Selection of materials shall be based on supplier experience and on information found in the technical literature, supplemented by the following documents:

NACE - Corrosion Data Survey

Corrosion Data Survey - Shell Company

Corrosion Guide - Erich Rabald, ed. Elsevier

All materials used in manufacture, including welding consumables, shall be accompanied by a Certificate of Material Quality, attesting to the required specification, chemical composition, mill tests, heat treatments, impact tests, and results of tests on mechanical properties.

b) The corrosion allowance shall correspond to a useful life of:

a) Outer body (shell, heads, nozzles): 20 years;

b) Internal accessories: 10 years;

c) Heat exchanger tube bundles and coils: 8 years.

Whenever a severe external ambient (corrosive atmosphere) is specified, an external corrosion allowance shall be taken into account in defining the total corrosion allowance.

The term "corrosion allowance" shall include both external and internal corrosion and erosion.

3.5. Heat exchanger thermal design

The thermal design stage consists of determining the following data on the thermal performance expected of the equipment:

a) Type of equipment and installation position;

b) Thermal exchange surface of heat exchange and general dimensions of equipment;

c) Number and lay-out shells (when more than one), number of passes;

d) Quantity lay-out, and spacing of tubes, tubesheets, coils, etc;

e) Type of heat-exchanger tubes (e.g., smooth or finned) as well as diameter and thickness of these tubes;

f) Quantity, type, arrangement, and spacing of baffles, deflectors, and other internal accessories.

3.6. Mechanical design

a) The mechanical-structural and manufacturing design, as well as inspection, assembly, and test requirements, shall be based on ASME Sec VIII Div. 1, supplement by the Petrobras Standards.

b) Any procedures pertaining to the mechanical-structural calculations for equipment that are not provided for in ASME Sec VIII Div. 1 shall be covered by the following documents:

British Standard - BS 5500;

Pressure Vessel Design Handbook _ Henry H. Bednar;

Formulas for Stress and Strain - Raymond J. Roark;

Structural Analysis and Design of Process Equipment - Maan H. Jawad and James R. Farr;

Pressure Vessel Handbook - Paul Buthod and Eugene F. Megyesy;

Process Equipment Design: Vessel Design - L.E. Browell and E.H. Young.

c) The welding specification and nondestructive tests applicable during the manufacture and assembly stages shall be defined by the supplier if not indicated in Petrobras documents.

Spot radiography of butt welds and ultrasonic examination of other welds are indicated to guarantee minimum manufacturing quality.

This inspection may be complemented by magnetic, particle or liquid penetrant examinations, at the manufacturer's discretion.

The performance of nondestructive tests shall conform to pertinent standards.

d) Thermal insulation on personnel-protection and/or energy-saving equipment, as well as refractory linings, shall be specified, designed, and installed in conformity to pertinent standards.

e) Equipment accessories such as insulation and refractory supports, platforms, ladders, davits, lifting lugs, and earth grounding clips shall be specified, designed, and installed in conformity to pertinent standards.

f) External painting, as well as internal linings, shall be specified and applied in conformity to pertinent standards.

g) Plant and equipment fire protection shall conform to indicated standards.

h) The mechanical design of pressure vessels includes drawings and other documents containing the definition and calculation of the following vessel data:

- information on the fluids contained in the vessel: nature, concentration, specific gravity, and impurities or contaminants present;
- complete specification of all vessel materials (shells and heads) and of all parts and accessories, such as: flanges, nozzles, saddles, tubesheets, and internal piping, internal and external accessories, screws, bolts, gaskets, and linings. The specification, according to the standards (ABNT, ASME, ASTM, API, etc.), including therein material class, type and grade;
- definition of final vessel dimensions;
- selection of type of heads, if not defined by process requirements;
- definition of design, construction, and inspection standards that should be used;
- definition of weld efficiencies and type and grade of weld inspection;
- complete mechanical calculation (structural) for vessel, including thickness of all parts of the vessel, reinforcements, special flanges, saddles, tubesheets, internal and external accessories, etc.;
- dimensions and thicknesses of skirt base plate, legs, saddles, or other vessel supports;
- referenced position, type and diameter of all anchor bolts;
- definition of final positions (elevation and orientation) of nozzles, manholes, instruments, internal and external accessories, etc.;
- calculation of maximum allowable working pressure and of hydrostatic test pressure;
- calculation of approximate weight of vessel when empty, in operation and shut down and during hydrostatic testing;
- definition of vessel transport conditions (vessel transported whole or in sections);
- complete mechanical drawing of vessel, including manufacture and assembly details for nozzles and manholes, saddles and internal and external accessories;
    - definition of all dimensions (diameters, lengths, radii of curvatures, distances, projections, elevations, spacing, etc.), thicknesses, and other dimensions of the vessel itself as well as of its supports and internal and external accessories and parts;
    - location, nominal diameter, pressure rating, and facing of all external equipment flanges to which piping, instruments, etc. are connected. When dealing with non-standardized flange dimensions, thickness and face and drilling dimensions shall also be indicated;
    - location, nominal diameter, and pressure rating for all external threaded nozzles or of the socket weld to which piping, instruments, etc. are

connected. In the case of threaded nozzles, type of thread shall also be indicated;

- location and dimension of skirt, legs, saddles, or other equipment supports with position and dimensions of holes for anchor bolts;
- foundation load diagram, containing:
    - magnitude and directions of all forces and moments that the equipment exerts over all foundations in any normal or occasional working situation, under hydrostatic testing, and during assembly or maintenance. These forces and moments shall be referred to three orthogonal coordinated axes, one of which coincides with the vessel's center line;
    - amplitude and frequency of vibrations transmitted to the foundations, when applicable;

- Special analyses such as: dynamic, creep and fatigue performance;
- Whenever applicable, mechanical design also includes:
    - dimension tolerances for manufacture and assembly;
    - specification of heat treatment;
    - specification and detailing of internal or external lining (or special painting), including anticorrosive or refractory lining or lining for any other purpose;
    - selection and specification of thermal or refractory insulation, of the types of applicable supports, and of distances between these supports;
    - specification for field assembly and for field tests and inspection;
    - spaces that should be provided for or left free for vessel assembly or disassembly or removal of internal accessories (tube bundles, for example) and for operation;
    - welding specification;
    - assembly sequence;
    - inspection of raw materials used in manufacturing;
- Whenever requested, the following shall be verified:
    - tension of vessel nozzles, due to piping reaction and other external forces;
    - displacement of vessel nozzles due to thermal expansion;
    - local stress due to piping supports, platforms, or other forces;
    - information on possible interferences with structures, piping, instruments, or other installations outside the vessel.
- When foreseen in the scope of supply, calculation sheets with the following data shall be submitted together with mechanical design:

- thickness calculations, for internal or external pressure, for cylindrical bodies, heads, piping, tubesheets, and transition or concordance parts;
- calculation of thickness and sizing of skirts, saddles, legs, and other support thicknesses and sizing of anchor bolts;
- calculation of thickness and other dimensions of nozzle reinforcements, local reinforcement for concentrated loads, and external pressure reinforcements;
- calculation of thickness and other dimensions of flanges (including blind flanges) for equipment shell or for nozzles and manholes. Calculations of these nozzles may be dispensed with when adopting forged steel flanges with standardized dimensions and materials;
- calculation of internal accessory supports (trays, pans, beds);
- verification of nozzle welds;
- special analysis: dynamic, creep and fatigue performance;
- stress and buckling stability analyses;

- In the case of computer calculations, the following information shall be presented:
  - name of computer program;
  - author of program;
  - program description, indicating therein all calculation methods and criteria used, including basic bibliographic references used and history of program usage, if any;
  - description of results print-outs, including all formats used and definition of all input and output variables;
  - input print-outs;
  - output print-outs.

3.7. Internal accessories design

This stage applies to equipment with fixed and disassemblable accessories. When said accessories entail special technology, they shall be designed by the holder of this technology, who is not necessarily the same party as the equipment designer.

The internal accessories design, undertaken based on process data and on the process design shall include:

a) Process lay-out and sizing of these accessories;

b) Complete specification of all materials;

c) Structural calculation, including all supporting elements, and verification of support loads on the equipment;

d) Detailed drawings;

e) Values for dead weights of accessories and components;

f) Transportation and assembly instructions.

g) Assembly instructions;

h) Tolerances.