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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

PIPING SYSTEMS 1/

by

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SUMMARY

PIPING SYSTEMS 1/

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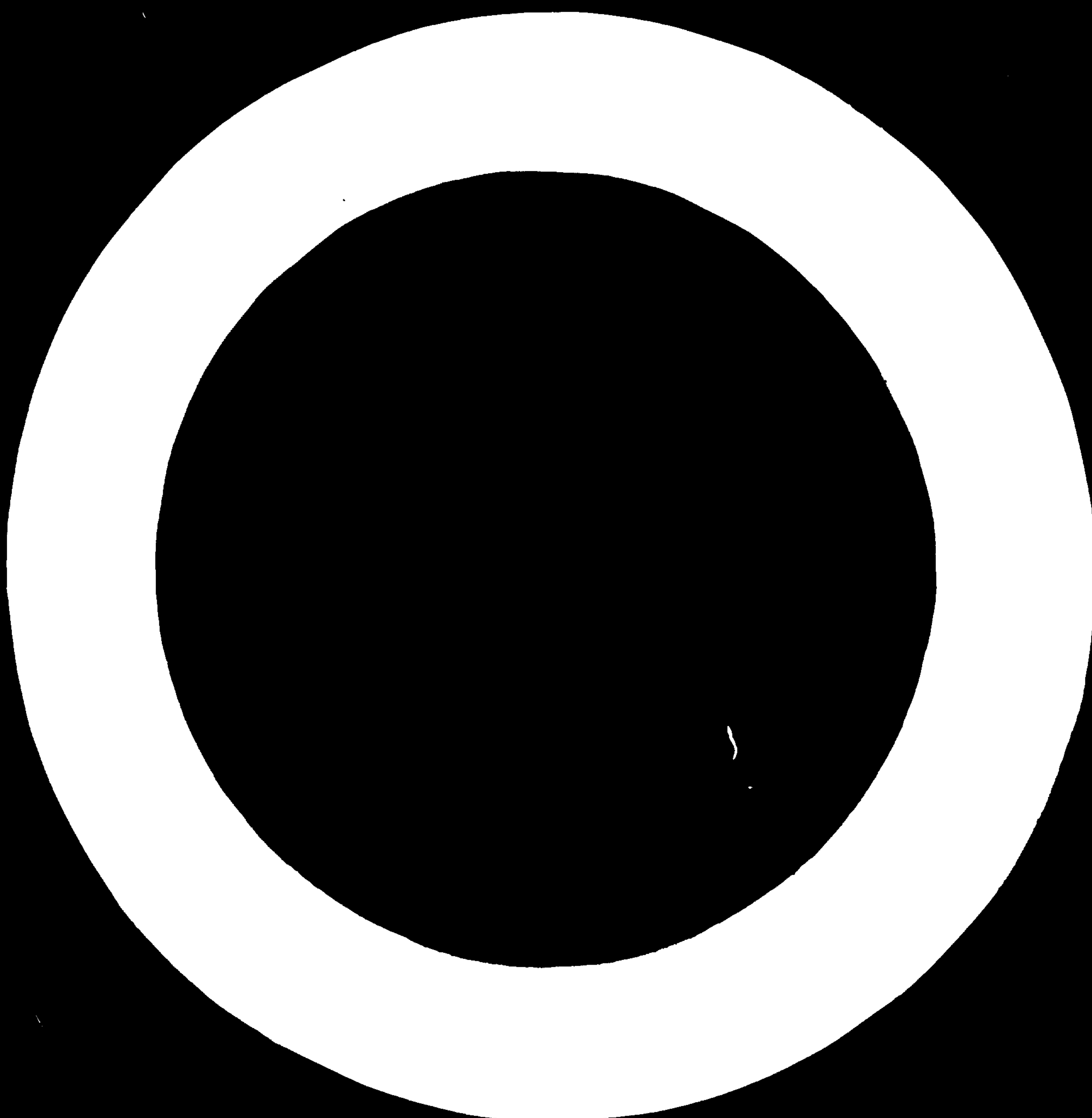

The objective will be to provide a review of the problems encountered by companies in the field of engineering, construction and maintenance of petroleum, petrochemical and chemical plants in developing countries on the general subject of piping.

Under the specific headings, indicated below, the following items will be covered:

I Quality
II Safety
III Reliability
IV Safe Operating Conditions
V Personnel Qualifications

1) Design and Engineering
2) Specifications and Standards
3) Personnel
4) Manufacturers
5) Codes and government requirements
6) Equipment
7) Inspection and Testing
8) Quality control
9) Construction
10) Operation
11) Maintenance
12) Spareparts
13) Insurance
14) Training

PIPING SYSTEMS

I QUALITY

Piping systems in chemical plants have to be operated under the most diversified conditions and therefore the type of piping most suitable for each condition should be carefully selected.

1. Design and Engineering

In the design and engineering of a chemical plant, the normal and extreme operating conditions have to be considered in selecting the proper piping.

(Slide of process flow and P & I)

A list is made of all pipes and for each the operating conditions are indicated such as: flow rate; flow conditions - liquid/vapor; temperature; pressure; specifications of the fluid: density, viscosity, corrosivity.

(Slide of line schedule)

This information is used to determine the size, the wall thickness required, the piping material.

After a first determination of the line size in relation to the flow velocity, a more detailed pressure drop calculation can be made. For this calculation, a preliminary pipe study will be needed in order to determine the equivalent length of the pipe line. This equivalent length is the sum of the total length of pipe inclusive an additional length for all other piping components such as elbows, tees, reducers,

I **QUALITY** (cont'd)

1. Design and Engineering (cont'd)

valves, etc. The other leading factors in these calculations are the velocity, the viscosity, the roughness of the inside of the pipe wall and the specific gravity of the fluid. These pressure drop calculations, in combination with the required static head and the required available pressure drop for regulation or other instruments and the operating pressure conditions, form a part of the pipe and pump calculations.

Equivalent calculations are made for the suction lines to the pump in order to get the available NPSH (net positive suction head), which data then should be stated on the pumping data sheets.

Special attention shall be paid to the two phase flow lines. These lines require a special study as the two phase flow, a mixture of vapor and liquid, can occur in different patterns.

After the line sizing and the finalizing of the plot plan of a process unit, an estimate can be made for bulk ordering of the expected required quantities of piping materials. Thi is a matter of experience or based on statistics and has to be checked during the progress of engineering in order to prevent a delay in construction due to shortage of piping materials.

Nevertheless, the engineering of a piping layout can be done by taking into account a certain amount of basic rules. A major portion of experience, know-how and cooperation with maintenance, instrument and other technological experts form the key to a safe and good operational plant layout.

I **QUALITY** (cont'd)

1. Design and Engineering (cont'd)

Some basic rules for piping layout and design are:
Piping should not form any restrictions for accessibility for maintenance equipment such as cranes, trucks or fork lift trucks.
Sufficient clearance should be maintained under pipe bridges, especially under road crossings.
Piping shall have sufficient drains in low points and vents in high points to prevent liquid or vapor obstructions in flow.
The location of instruments should be such that accurate readings can be expected.
Valves and instruments should be accessible for easy operation, maintenance and inspection.
Provisions shall be made to avoid condensate from entering steam turbines which could result in severe damage of these turbines.
Condensate entering columns with stripping steam could result in damage of the stripping trays.
Pump- and compressor-piping should be laid out so that no excessive vibration occurs.
Piping layout should often be symmetrical so that equal flow can be realized in parallel exchangers, parallel lines in heaters etc.

Special attention shall be paid to compressors, pumps and turbines piping layout with regard to the thermal expansion and the total weight of the piping system, in order to minimize forces and moments on the equipment nozzles, and in any case to keep these values within the allowable range, as stated by the manufacturer, to safeguard a troublefree operation.

I **QUALITY** (cont'd)

1. Design and Engineering (cont'd)

Relief valves installed in piping systems to safeguard equipment or piping shall be so located that no unexpected back pressure can occur. The relief header shall slope towards a knock-out drum. A suitable and safe drainage system shall be present.

Heating of pipe lines shall be considered to prevent congealing at ambient temperatures of highly viscous liquids, to prevent freezing of a product in particular for those lines with no or intermittent flow in areas where frost may occur, and to prevent hydrate formation. Heating of pipe lines can be done by steam, hot water, hot oil or by electrical heating.

It will be clear that engineering inclusive drafting of piping layouts and piping details for shop fabrication is a complicated and time consuming job. In order to minimize the number of piping drawings, showing views and sections, and to get the benefit of a quick check of the pipe runs, a piping model is used frequently.

(Slide of piping model and block model)

Reinforced plastic wire or full scale plastic tubing is used for showing all pipe lines. For representing the equipment and pipe bridges wood, plastic or brass is used. The piping is shown in different colors for a quick and easy distinction of the destination of the lines, e.g. green for process lines, red for steam lines, blue for water lines, yellow for fuel gas lines, black for relief lines, etc.

I **QUALITY** (cont'd)

1. **Design and Engineering** (cont'd)

All valves, control valves, temperature and pressure points, flow measurements, drains, etc. are shown. Insulated lines can be indicated by a specific color and where necessary also by snap-on pieces to show the thickness. All lines are carrying an arrow tag indicating the flow direction and the line number. A label indicating the tag number is provided to all instruments.

During the issue of the detailed piping drawings (isometrics) the piping model can be consulted. The model will also be a tool for determining support locations. Most piping models are made to a scale of 1 to 33 1/3 and match the scale of the piping drawings. In general, piping models are sent to the erection site for consulting by the erection team.

This paper showed you a brief summary of some piping design and engineering items, however, it does not have the intention to be representative for all piping problems. It should be recognized that a piping problem can extend to the field of different specialists, and during the design and engineering stage it will never be a one man job, but the best results will always be obtained by a good team work of all affected experts.

Stress calculations may be required due to the thermal expansion of the line. For more complex systems this is normally done by computer. For these lines, input sheets are prepared and the computer makes provision for a detailed accurate review of stresses, moments and forces on pipe and anchor points. A check has to be done on sagging of the line in relation with the span of supports and due to the weight of pipe inclusive the

I **QUALITY** (cont'd)

1. Design and Engineering (cont'd)

fluid, valves or any other thrust. Reactions on connected equipment due to thermal expansion must be carefully checked and sometimes reviewed with manufacturers.

2. Specifications and Standards

Piping is the collective word for the following components:

pipelines, fittings, flanges

valves, gaskets, bolting

supports and hangers, insulation and

special items such as expansion joints, starting up strainers, swivel joints, etc.

Pipe lines are standardized in sizes as expressed in inches in diameter. Odd sizes of five inches and upwards are out of standard. For seamless pipe, standards are available for sizes up to and inclusive 24 inches. For welded pipe, standards are available up to and inclusive 36 inches.

Fittings is the collective word for elbows, tees, reducers, caps, specials for branch connections and reinforcings.

Flanges are available in different types such as welding neck and slip-on; for the smaller sizes, up to 2 inches socket weld or screwed-on flanges may be used. Instead of caps, blind flanges can be applied at the end of the pipe lines. For safety reasons or to avoid contamination of the products, spectacle blind flanges or spade type flanges can be inserted.

I **QUALITY** (cont'd)

2. Specifications and Standards (cont'd)

Valves are the most important items of the piping. Some essential functions are:

1. To start and stop the flow. A low flow restriction and pressure loss in case the valve is open and a tight shut-off in case the valve is closed should be aimed at. Gate, plug and ball valves are normally used for shut-off service.

2. Regulation or throttling of the flow. Throttling causes a resistance to the flow, resulting in a pressure drop. Globe or needle valves are generally used for throttling. In case accurate regulation will be required, a control valve will be specified by the instrumentation engineer.

3. Prevention of back flow. Check valves are installed to prevent a reversal of flow caused by a pump or compressor failure or process mis-operation. In case a back flow occurs, the check valve will open and flow is again in the correct direction. Swing, piston or feather types are the most common.

4. Relieving pressure. To safeguard equipment and piping, safety relief valves are installed. The set pressure of the usually spring loaded relief valve is related to the maximum allowable working pressure of the equipment or piping, which it protects.

Valves are available with flanged or butt weld ends. For the smaller sizes up to 2 inch socket weld or screwed ends may be used as well.

I QUALITY (cont'd)

2. Specifications and Standards (cont'd)

Some special valves are: butterfly valves, diaphragm valves, line blind valves. Selection of a specific type of valve depends on the particular service; the pressure, the temperature, the fluid, the shut-off or regulation requirements, the frequency of operation. Will it be hand or motor operated? Will it be remote operated? How often will it need servicing? These are some aspects which should be considered. A great number of valve manufacturers make these special valves.

Gaskets.
The gasket materials can be divided in two main groups: non-metallic and metallic. Non-metallic gaskets are: compressed asbestos fibre, rubber sheets with or without cloth insertion, PTFE, viton and neoprene sheets. Some metallic gaskets are: solid metals, e.g. soft aluminum, soft copper, soft steel; corrugated metals, or special wound metal, asbestos filled; corrugated metal jacket, asbestos filled; flat metal jacket, asbestos filled.

Bolting.
Bolting sizes and material are set by flange geometry and process conditions, i.e. stream chemistry, pressures, temperatures, etc.

Supporting.
Pipes should be adequately supported to prevent excessive sagging, vibration and strain on connected equipment. A pipe bridge structure forms a main part of a plant layout. Pipes are supported directly on the structure base or provided with shoes in order to keep space for the required insulation. The location of the support and the type of support should always be determined in relation with the total weight of pipe

I **QUALITY** (cont'd)

2. Specifications and Standards (cont'd)

line, valves and fluid, and the movement of the line due to the thermal expansion. Instead of shoes, pipes can be supported by means of hangers, consisting of clamps, hanger rods or bars and U bolts. Spring hangers or spring supports are used in case the movement of the pipe due to the thermal expansion makes it necessary. Spring supports will permit the line to move up or down without unduly disturbing the distribution of load. Where the amount of vertical movement to be absorbed is large, constant load spring support insulation should be applied. These supports containing springs mounted in a toggle action enable to give an approach of constant support over a considerable range of travel.

Insulation.

Insulation will be applied to hot and cold lines. The purpose of applying a proper hot insulation is conserving heat and for personnel protection. For cold insulation it can be said: keep heat away and prevent surface condensation. Another reason for insulation is personnel protection. Some insulation materials normally used are: mineral wool, slag wool, glass wool, asbestos, 85 percent magnesia. For cold insulation, foam glass or polyurethane foam can be used. Preformed sections are fabricated for straight runs of pipe and sheets or blankets are applied for non-standard configurations. The insulation material can be provided with a weather protection shield of tar paper, flintkote and a steel jacket cover. Cold insulation is usually provided with a jacket for weather protection and as a vapor barrier.

I **QUALITY** (cont'd)

2. Specifications and Standards (cont'd)

The application of special items of piping components depends on the typical requirements to solve a certain piping problem. Corrugated expansion joints of the bellows type can be applied for solving a thermal expansion problem. In those cases where a pipe loop can't be realized due to lack of space, or in case non-acceptable forces and moments occur on the anchor points, e.g. equipment nozzles, or in cases where the pipe stress remains too high, bellows may be the answer. The application of bellows requires a special attention for guidance and anchoring of the line. Besides that, the bellow has to withstand the maximum line pressure. For each application, a careful study will be required to decide which type of bellow or combination of bellows will be recommended.

More can be said about other items such as strainers, special valves, e.g. flush bottom valves, parallel slide valves, impulse traps and receiving traps for transport pipe lines, special branch reinforcing pieces, etc., but the application of these specialties will depend on the particular requirements for a specific problem.

Some most commonly used piping materials are: carbon steels, in general used up to 425 °C; the ferritic alloy steels such as chrome-molybdenum steels, where required due to the expected corrosion rate and where higher temperatures are involved, normally used up to about 625 °C; the austenitic steels such as chrome-nickel steels, also where required as a corrosion resistant steel and where higher temperatures are involved up to about 600 °C. This material is also applied in low temperature service.

I **QUALITY** (cont'd)

2. **Specifications and Standards** (cont'd)

Certain special corrosion problems require piping materials such as copper and aluminum alloys. Aluminum brass may be used for sea water. Aluminum may be used in cases where ammonia attack requires a special corrosion resistance. Aluminum pipe, used also in cases where a high corrosion resistance is required and temperatures are ambient, e.g. fatty acid.

A special corrosion resistant pipe is the clad lined pipe.

The basic outside pipe material is normally carbon steel and the inside material, which is in contact with the abrasive fluid, can be a stainless steel, e.g. chrome-nickel or a 13% chrome depending on the chemical properties of the fluid.

The plastic pipe also has a wide field of application. Some varieties are polyethylene, polypropylene and polyvinylchloride, known as PVC. The last one is mostly used for drinking water or for the transport of chemical products such as acids or alkalies. A disadvantage of these pipes is the temperature limitation.

Special attention of the designer should be paid to the supporting of plastic pipe lines, as distance between supports must be considerably less than for steel pipe of similar rating.

To simplify the description of the different types of piping, they are divided in piping classes.

(Slide of pipe class)

A piping class encloses a detailed specification of all applicable piping components and the required material descriptions.

I **QUALITY** (cont'd)

2. Specifications and Standards (cont'd)

The material descriptions refer to standard codes such as:

ANS	American National Standard
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing Materials
API	American Petroleum Institute
BS	British Standards
DIN	Deutsche Industrie Normalen

or other applicable codes depending on local rules or requirements.

In cooperation with manufacturers and these standard organizations, the dimensions of a range of pipes and piping components are standardized.

Before design and engineering will be started, the required applicable codes for the area should be stated. When the required piping material has been identified, the wall thickness of the pipe can be calculated on the basis of the allowable stress as stated in the code, taking into account a manufacturer's tolerance of the wall thickness and a corrosion allowance based on the expected corrosion rate. Additional calculations may be required for branch connections in relation with the weakening of the header pipe.

II SAFETY

Provided the piping systems are well engineered and a proper selection is made, the systems should be safe for normal operating conditions. It is, however, always possible that emergencies occur such as:

1. Power failure
2. Water failure
3. Pump or compressor failure.

To protect the piping and equipment for these emergencies, safety valves are installed at all critical locations, so that excess pressures will automatically be released. Proper sizing and locating the safety valves form a part of the engineering.

Unavoidable pressure/temperature transients must also be considered when establishing design conditions.

As a further check on the safety of piping systems, they are pressure tested at 150% of the operating pressure before they are put in operation.

During the scheduled shutdowns of the units, all piping should be spot checked to determine whether they still have the proper wall thickness.

Experience will indicate which systems suffer more from corrosion and should therefore receive more careful attention.

III RELIABILITY

Piping systems are normally not designed for the same service life as large equipment, and less corrosion allowance is normally added to the wall thickness. Piping is easier to inspect and replace and therefore it is not economical to increase the initial investment.

Piping which is subjected to severe operating conditions should be carefully selected and the proper standards and codes should be applied.

For process piping, seamless pipe is generally used. Welded pipe is usually cheaper and can be used with adequate quality controls. We should keep in mind, however, that outside conditions such as fires, sagging of the soil, earthquakes, road crossings, etc. might put extra strain on piping otherwise in mild service.

IV SAFE OPERATING CONDITIONS

A plant is designed for a certain service and all piping is engineered and selected to be safe under the inherent operating conditions. It often occurs that the service of a unit is changed. It could be that the service is completely changed, but also that with minor changes the capacity has been increased. In such cases, the piping and especially the safety valves have to be checked if they are still adequate for the new conditions.

V PERSONNEL QUALIFICATIONS

Although a maximum of safety is built into the modern plants, experienced operating personnel is still required. Mal-operation might lead to damage or even loss of equipment. Especially in case of emergency, it is essential to have experienced operators who can take

V **PERSONNEL QUALIFICATIONS** (cont'd)

the proper actions, if necessary take the units down in an orderly manner. During normal operation, they have to check the unit for proper functioning.

The piping systems have to be checked for leaking gaskets, tightness of the safety valves. Direct repairs of small leaks are part of good housekeeping and prevent gasket blow-outs and reduce utility and product losses.

When a new unit has to be started, experienced operators should be assigned to the key positions. If not available, the future operators should receive previous training. This can be done by class training, followed by training on the unit during the last phases of construction. The operators should not only know the operating scheme, the operating conditions and the control points, but also the complete piping layout, the safety system, the location of all important valves. They should have been trained in start-up and shut-down procedures, the latter also in emergency conditions. If possible, training should be given on similar units, which is often done on other plants.

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