MARS SPACE CONSTRUCTION, LLC

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INSTRUMENTATION

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Section 13

INSTRUMENTATION

13.1 GENERAL

The Control Systems Group of the Refinery and Chemical Division handles all instrumentation work, and its activities are project-oriented. These activities include engineering design, drafting, control systems analysis and simulation, and other work related to instrumentation for specific projects. Instrumentation on specific projects is sponsored by an Engineering Supervisor of the Control Systems Group; project work is actually headed by a Project Control Systems Supervisor who represents the department on a given project.

The Simulation and Advanced Controls Section of the Instrument Group analyses and sometimes simulates on an analog or hybrid computer the more difficult or complex control systems. The Control Systems Group also has personnel who specialize in control valves, relief valves, analyzers, general control system applications, and instrument installation design.

The work of Control Systems personnel interfaces with work done in other groups including Process, Process, Piping and Plant Design, Electrical, Vessels, Architectural and Structural. In the following discussion, we will demonstrate how these interfaces develop.

13.1.1 Correlating Activities with Other Groups

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Control Systems personnel work with members of the Process Group to determine control schemes by inspecting process variables and establishing the best means for controlling a process.

The control schemes determined in the process design stage are then translated onto P&ID's by the Project and Control Systems Groups. Vessel design data sheets are generated which contain sufficient information to permit the Vessel Group to proceed with vessel design.

At this point, an interface occurs between Control Systems, Process, Project, Vessels, and Plant Design and Piping. Personnel of these groups must discuss and deternrine level control, level transmission and measurement, level indication, pressure and temperature points, and analysis instrumentation, Engineering Instruction A-33 covers all the ground rules and hardware limitations for this phase of design. It establishes technical (hardware) limitations, and also defines the procedures by which design and interfaces are handled.

In addition, Control Systems personnel and Plant Design and Piping personnel must work together in providing plans for the installation of flow instruments, control valves, and other line-mounted equipment including information regarding pressure-sensing points and temperature-sensing points. The specific responsibilities of the Plant Design and Piping Group will be covered in the technical portion of this Section.

13.1.2 Application of Technical Information

In order to have a bird's-eye **view** of the flow of events, let us consider the development of a level control loop. First, the process requirements are determined, the desired levels are established, and the vessel sizes and the various connections are defined.

At th same time, the sensor range is determined, as well as whether the loop will b• blind (not indicating or controlling) or recording and/or indicating. The type of control is determined by the Control Systems Engineer.

The following information is required to perform the foregoing operations:

- P1·essures and temperatures
- Fluid characteristics (viscosity, density, corrosion, enrtainment, toxicity, and explosive or other dangerous characteristics)
- Desired levels for control and alarms

All of this information must be furnished to the Control Systems Engineer by Process and Project before the level-sensing device selection can proceed.

Between the level-sensing device and the controller we may provide a rtansnritter, or merely a mechanical linkage. The controller usually acts ona control valve. The control valve is the most conunon means used to perform the actual control work. So.metimes, other means of conrtol are used, for example, pump speed.

Standard mounting and piping details are developed by the Control Systems Group. These standards are intended to aid the Piping Group and Vessel Group in the actual installation design.

The Control Systems Engineer then completes data sheets which are transmitted to Piping for orientation of such instruments as level transmitters and controllers located in the field. The data sheets also tell Piping what type of instruments are involved, and transmit other necessary information.

Later, after orders have been placed, vendor prints are checked against preliminary orientation to assure agreement between design specifications and equipment actually being fur ni sh e d.

Awareness of each other ' s problems will simplify the effort necessary to achieve the coordination required tl+roughout these procedu re s.

13. 2 TECHNICAL DISCUSSION

13. 2. 1 Ins tr ume nta tion - Definition

An instrumentation system acts as the central nervous system of the plant. Process temperatures, pressures, flows, and levels are monitored and regulated by means of instru1nents, control valves, etc. , in ordei- to produce the plant products within prescribed limits.

There are two basic types of instrumentation systems: the "open-loop" system, and the "closed-loop" system. "Open-loop" instrumentation exerts no control but only indicates existing conditions. Examples of the "open-loop" system are **a** simple level gauge, or a pressure system which transmits data to a control-room indicator. One example of a "closed-loop" control system consists of a level transmitter, a controller in a central control room, and a control valve regulating flow in the line.

Since both systems must first measure variable conditions, let us look at measurement first.

132.2 Measurement

Pressure Measurement

In order to measure the pres sure of a fluid, we must bring the fluid into contact with a pressure-measuring element of same type. The standard symbology used in development of the P&ID' s is shown in the appropriate figures.

Bourdon Tube: The simplest of all pressure-measuring elements is the bourdon tube (Figure 13-1) and its fami-, such as spiral and helical elements. A bourdon tube consists of a flattened piece of tubing bent in semi-circular shape. The material and thickness of the metal in the bourdon tube is designed to suit the pressure situation for a specific process. For the given design condition, an increase in pressure within the bourdon tube tends to make the tube straighten and assume a round cross-section much as a fire hose straightens and assumes a

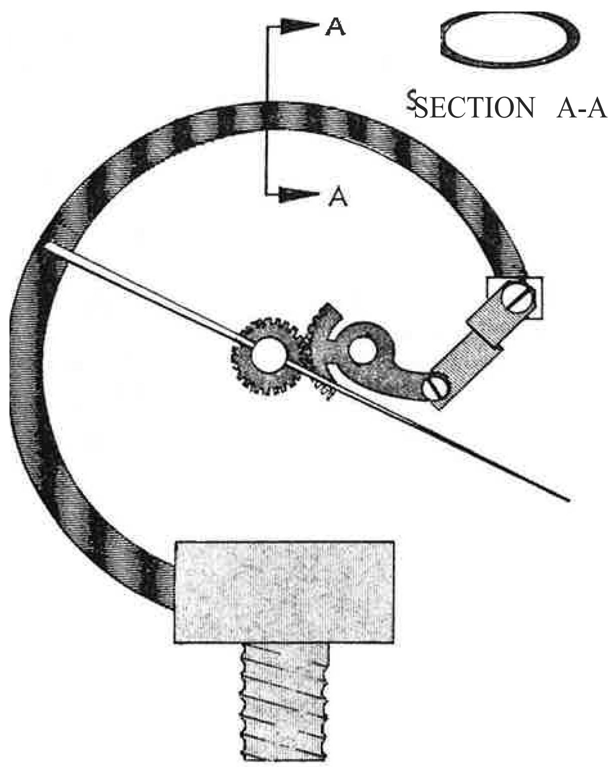


Figure 13-1. Bourdon Tube

round cross-section when pressure is applied. However, unlike the soft, pliable fire hose, the bourdon tube is similar to a spring and assumes a given position for each pressure. This position is then transferred to a pointer by means of linkages and gear elements. For greater accuracy, movement, and power, bourdon tubes are sometimes made longer, and coiled into helical or spiral shapes. See Figures 13-2 and 13-3.

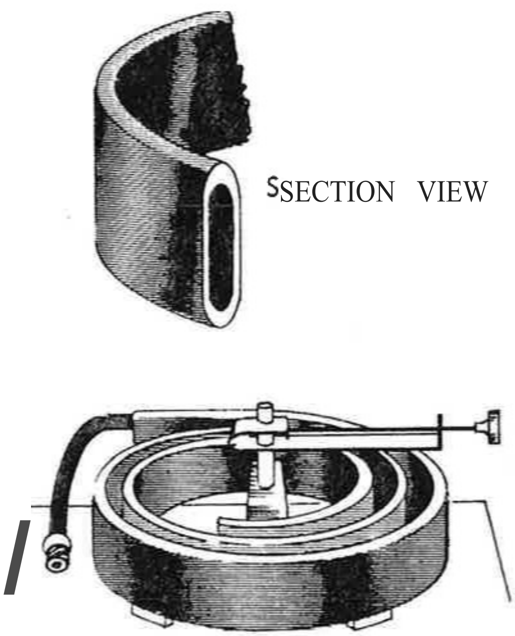


Figure 13-2. Spiral Element

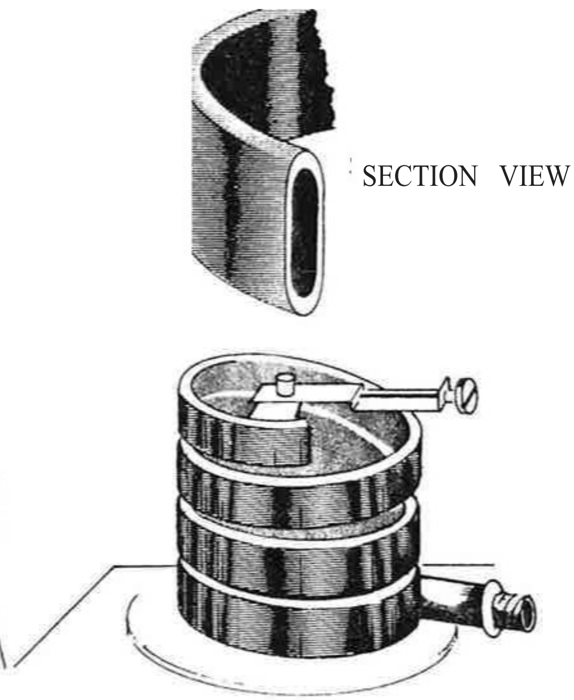


Figure 13-3. Helical Element

<u>Diaphragm:</u> Another type of pressure-sensing element is the diaphragm. Diaphragms are usually used for low pressures. A diaphragm is clamped between two flanges or other holding device, with one side exposed to the pressure and the other connected by linkages and levers

to an indicating pointer or other instrument mechanism (Figure 13-• The thickness and material of a diaphragm are designed f'>r the specific pressures and service conditions involved in a given process.

Bellows: Another type of measuring element is the bellows. This device if' also used for low pressures, An advantage in using the bellows instead of the diaphragm is that greater movement can be developed by the bellows to mov.i! a pointer or other instrument mechanism. The bellows consists of a series o/ convolutions which expand with increasing internal pressure and contract with increasing external pressure. See Figure 13-5.

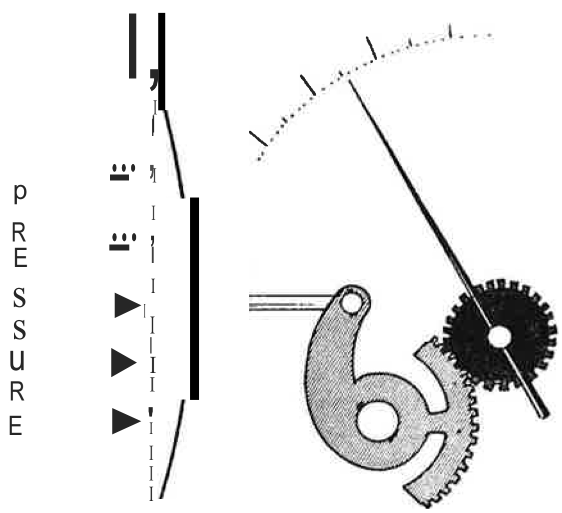


Figure 13-4, Diaphragm

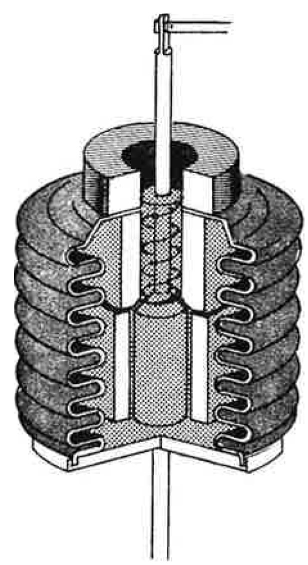


Figure 13-5. Bellows

The number of convolutions and the type and thickness of metal are all chosen in accordance with the service conditions specified. However, the larger cavity of the bellows may be fouled by process fluid under certain conditions.

Strain Gauge: Strain gauges are also used for pressure measurement. These elements are electrical, and are generally connected to a diaphragm which acts as a seal for the process fluid.

Diaphragm Seal: Diaphragm seals are often used to overcome a basic incompatibility between process fluids and mea·suring elements. Most of the elements described up to this point would be fouled by fluids such as tar and pitch, which "set up" or solidify at normal ambient outdoor temperatures. The diaphragm seal permits a more favorable type of fluid to be substituted in the measuring element. One side of the diaphragm is exposed to the flowing process fluid, and the other side is connected to the pressure element by means of a small-bore capillary. The entire system, consisting of the capillary and the pressure-measuring element, can then be filled with a fluid that is capable of withstanding header. This piping is generally not $hown 0n the P & ID.

(2) Tracing: When instruments require tracing {symbol T o"r dashed line onP & ID) the plant design group shall design a header with branches on the steam side and traps with collection header on the condensate side. The steam supply line shall be brought within 5 feet of 1:he insrtumeRt to be traced. The steam trap manifold or assembly shall also be located within 5 feet of the instrument. One or two traps are required for each insrtument. (See instrument tracing details.) All instruments mounted on a strongback should be considered as one instrument for tracing. Traps may discharge to a sewer or the atmosphere if no condensate return header is located in the general area. A block valve shall be ·nstalled for the steam supply to each instrument.

ln.struments (valves and meters) mounted in-line shall be traced with the same tracer used for the piping.

the temperature of the process fluid (which, for example, must be kept hot in order to stay fluid), and yet will not plug the measuring element at normal ambient temperatures. The diaphragm seal allows use *of* bourdon tubes, spirals, and helicals, in otherwise impossible **service** conditions.

Other limitations such as over-range, corrosion, and high temperatures, as indicated above, may require special treatment in order to provide means to measure the pressures of some fluids.

Level Measurement

Again, a variety of elements is available to the Control Systems Engineer for sensing the level of fluids ir. vessels and tanks. Several are listed as follows:

- Gauge glasses
- Displacers and floats
- d/p cells
- Radiation (nuclear)
- Sound
- Light
- Capacitance

The nature of the application determines the type of element to be used. Ideally the least expensive, most practical, and most trouble-free element that willfulfill the service requirements will be used. However, all these features are not always available in one type of element.

Gauge Glasses: These elements usually consist of a steel body, transparent glasses, and steel plates for retaining the glasses in place. They permit a visual indication of level at the vessel.

Displacer: Displacers are usually the least expensive type of element to be used for control and/or transmission of level. However, above a level range of approximately five feet, a d/p cell becomes more economical.

D/P Cell: A d/p cell is a differential pressure measuring device which uses a diaphragm or system of diaphragms to sense differential pressure or, in this case, the liquid height - similar to a U-tube manometer. In applying a d/p cell to level measurement, we install the instrument at the lowest connection, or below the vessel, with one side hooked up to the lowest level to be measured and the other side either open to atmosphere (if the vessel **is also** at atmospheric pressure) or connected near the top of the vessel or at the top of the section where the level is being measured, in order to eliminate the effect of vessel pressure and prevent its interference with the measurement of level.

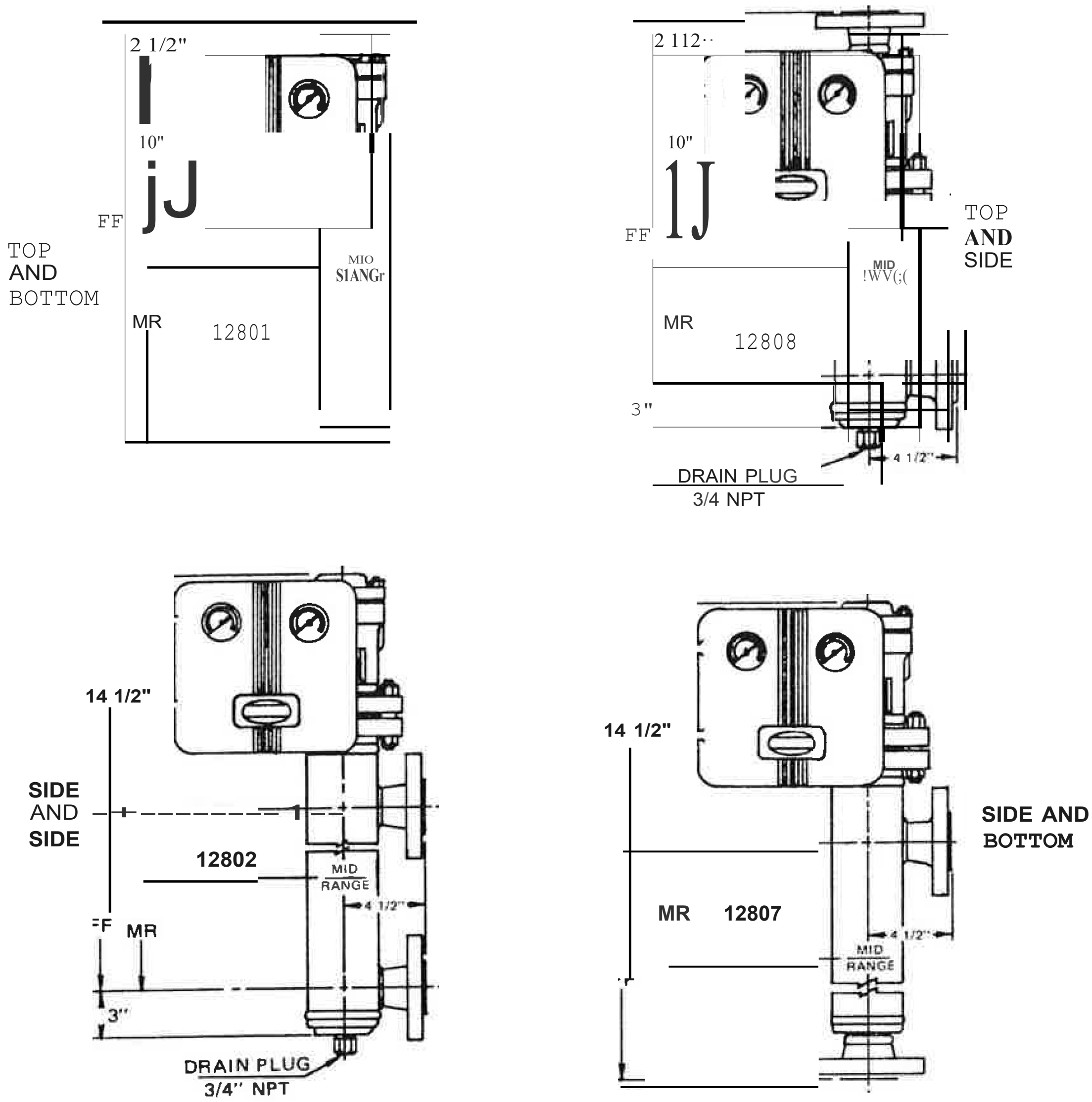
Radiation: In some instances, the type of material in the vessel is too hot, sets up solidly in the vessel at times (a coker, for example), or requires excessive pressure. Such a material precludes completely the use of elements that are dependent upon contact with the material or which require the material to flow outside the vessel. In this case, we can measure the level of material inside the vessel by means of radiation instruments which use a nuclear source on one side and detectors on the other side of the vessel. As the level rises, it absorbs more and more of the nuclear radiation. The detectors are calibrated so that the degree of radiation absorption is transformed through electronic amplifiers and linearizers into a level reading. Generally, there is little or no piping connected with a radiation-type instrument.

Other types of elements utilizing sound, light, and capacitance may be used as required. These elements require special treatment and consideration on the part of both the Control Systems Engineer and the Piping Designer.

Level Instrument Connections: In addition to the Limitations already discussed, there are physical hardware limitations. Some of these limitations are covered in Engineering Instruction A-33, which in essence explains the relationships between displacer-type level instruments and level gauges. This instruction also provides definite correlations regarding vessel lengths, types of connections, and orientations.

Displacer-type instruments are usually mounted externally in a displacer housing. This housing is connected *to* the vessel by means of valves, fittings, and pipe. Displacer instruments come with four common types of connection arrangements: top-and-bottom, top-side and bottom, bottom-side and top, and the side-and-side. (See Figure 13-6.)

The most common types are the bottom-side and top, and the top-side and bottom. The top-and-bottom type



Dimensions (inches)

Range	12801		12802		12807		12808	
	FF	MR	FF	MR	FF	MR	FF	MR
14	26	11	14	7	18	7	22	7
32	44	20	32	16	36	16	40	16
48	60	28	48	24	52	24	56	24
60	72	34	60	30	64	30	68	30
72	84	40	72	36	76	36	80	36
84	96	46	84	42	88	42	92	42
96	108	52	96	48	100	48	104	48
120	132	64	120	60	124	60	128	60

Fip:ure 13-6. Common Connection Arrangements for Displacer Instruments.

is nlore expensive because it requires a longer vei;scl. The side-and-side type is difficult to install because i_t requires absolute]y parallel flanges which are exactly spaced. Vessel fabricators find it difficult to maintaiu the close toleranc.es r quired. As a result, leaks develop in the field when the instt·ument is buttoned up, or the instrument cannot be installed at all.

Therefore, the use of a side connection combined with a bottom or a top connection is the most popular arrangement, since it penni.ts flexibility in orientation and piping design regarding the vessel. Although these arrangements could require a slightly longer vessel, this factor is compensated by the reduction of ins ta Uation costs.

Aninspection of Engineering Instruction A-33 also reveals that a dead space between the connection eleva tion and the n1ax/min elevation for indication or tr ansmission varies with the type of instrument selected. The hardware limitations imposed by these conditions must be carefully considered in actual installation practices . It must be possible to read a level gauge above and below the maximum and minimum displacer range. Otherwise, it will be impossible to field-calibrate the displacer-type level instrument. Refer to Drawings J-L-6701 and J-L-6702.

The Plant Design and Piping Group determines the orientation and "plan" location of level control instruments and alarm float switches. This is done in coordination with the Control Systems Group as outlined in Engineering Instruction A-33. Float- and displacer-type level instruments must be positioned to permit access for service and maintenance. They must also be positioned so that an operator adjusting one of these instruments will be able to see the corresponding gauge glass.

The Plant Design and Piping Group also determines the orientation and location of gauge glass units in coordination with the Control Systems Group, as indicated in Engineering Instruction A-33. It is important to locate the gauge glass where it is accessible for service and maintenance and is visible to an operator from the valve controlling the liquid level in the vessel. Multi-unit gauge glasses may be placed on a "strongback" (usually fabricated from 2-inch pipe) or mounted directly on the vessel. Job specifications usually determine which of these two arrangements will be used.

Sufficient room must be left a round level inst rumr.n ts for fi t ti n gs , hand wheels , vent and drain valves, nee- essary piping, etc. All toooften platforms are too narrow in design or present obstacles which inte l'fe rc with instrument functions, access, and 1maintenance, and a completer edesign isr equri ed to m.ake the arrange- ment workable. Finally, revisions should be made during the design stage to avoid field redesign, which is considerably more expensi ve,

Flow Measurement

Flow is usually measured as the material flows thr ough the pipeli ne. A variety of devices are used, depending on the nature *of* the 1naterial and its flow characteristics. Again, economics and suitabili ty determine the type of flow element to be used. Figures 13-7 and 13-8 show some different types *of* flow elements.

Orifice P late: The simplest and least expensive of all flow elements is the orifice plate, This is a flat plate, usually fabricated of s tainless s teel, which is install ci between two flanges. Without going into the technical background of orifice plate design, the orifice plate functions by changing the ene rgyr ela tionshi ps as the fluid flows through a hole very carefull y machined in

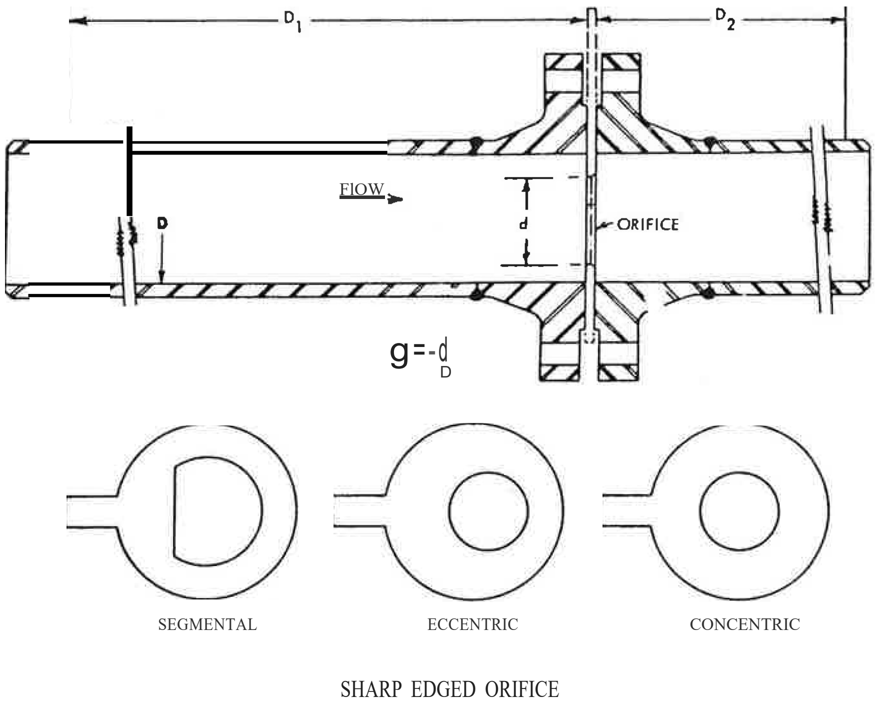


Figure 13-7. Flow Element

the plate, due to the constriction of the plate in the pipe, As a result, a lower pressure exists downstream from the plate. This difference in pressure is a function of the flow, and by measuring this pressure differential, we can measure, in effect, the flow. This differential is usually expressed in "inches of water" (27. 7 inches of water is equal to I psi).

A high degree of turbulence in the pipe at this point causes impingement of the fluid on the pressure-sensing taps for differential pressure which in turn

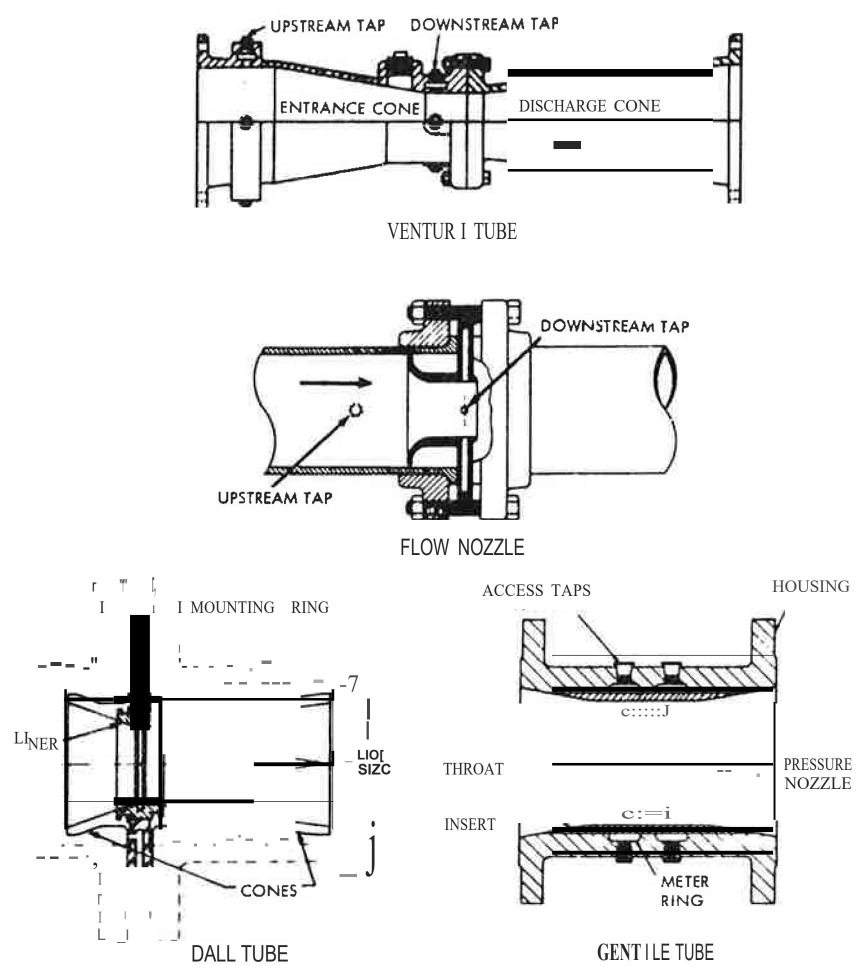


Figure 13-8. Flow Elements

causes false readings. Therefore, relatively long runs of pipe are required upstream of an orifice installation to assure trouble-free and reliable flow measurement. The piping requirements for meter runs on the various piping configurations are shown in Instrument Engineering Standard Drawings J-F-0101 through - 0108. This group of drawings also indicate s downstream runs of st raight pipe required for a pro- per meteri ng.

The types of piping connections at the orifice plate or other locations of differential-producing devices are shown in Instrument Enginee ing Standard Dra,ings J -F-0201 through - 0205.

Other Flow-Measuring Inst ruments: Flow conditions may make the selection of an orifice plate undesirable. Other types of differ ential -producing devices which also depend upon the principle of flow restriction may be used, such as venturi tubes, and venturi-t ube in- serts.

Rotameters: In some cases, another type of flov,, m ea - suJ.·ement device is used which maintains e ss entiall y constant diffe ential but varies in cross-sectional ar ea. This device is basically a conical tube having a cross-sectional area which incr eases with the height of the tube. A "float" is suspended inside this tube which is positioned by the flo'l.ving fluid in accordance with the rate of flow. These inst ruments - called ro- tameters - are installed in the main flow li ne. A change in the piping configuration is requi red, 1·e s n Hi.ng in. a more complex arrangement than is reqni rcrl in th , case of an orifice plate. Rotameters must he Loca tNl where they can be maintained and observed, and srim.c.'-tirne s require purge connections in order to keep the necessa t·y float-extension tnbe clear and thus pre,·('nt binding. The extension tube is used to house a metal core; a magnetic follower on the outside of the tube provides a magnetic link between the float position inside the tube and the instrumentation mechanis1n on the outside. Rotameters n1ay be equipped \Vi.th t ra ns m i tter s, indicators, 0 1· recorders.

Dead-Ended Leads: When the fl owing f111ids have characteristics such that they cannot be per mi tted to enter the d,ea d - e n d e d leads at a differential- pr essur measuring device such as a d/p cell, we must resort to fluid seals or purges to prevent the measured fluid from entering the dead-ended leads. The Control Systems Group is responsible for the design of such systems used beyond the first shut-off valve.

Orifice F lange Location: The locati.q n of o r ifi.c e flanges is determined by the Plant Design andP iping G1·up. Lhilitations of upstream/downstt'eam pip runs are determined from the Instrument Standard Drawings mentio-ned previously. Ther equir ed clearances for valves, piping, etc. are determined from Standard L-550. Reasonable access to orifice flanges as defined in job instrument "J" specification .isr equir ed. Tap ori enta tions, which should be shown on isometr ics, are determined by the job standards. However, special services, such as cr yogenics, require special consideration . These should be determined by consultation with the Control Systep1s Engineer.

Other inst ruments such asr otameter s, turbine-meters, positive displacement meters, etc. are usually located by the Plant Design and Piping Group. The most important point we must keep in mind is that these instruments must be located so that they may be easily seen and maintained,

Temperature

Temperature can be measured by either mechanical or electrical mean . Let us examine each of these categories separately.

Mechanical Temperature Measurement: Figure 13-9 shows some examples of mechanical temper-ature instruments. Mechanical means of temper-ature measurement, in its simplest form, is the common mercury-in-glass the1·mometer well known to all of us. This measurement depends on the expansion of mercury from a bulbous section into a thin capillary tube. Graduations on the stem around the tube correlate the position of the mercury and the temperatu1·e at the sensing bulb.

Howe v er , the use of glass is impractical in rugged industrial installations, and we resort to other means. Similar to a glass thermometer in con-struction, these devices consist of a metal bulb portion instead of glass, with a small-volume cap-illary extending *to* a spiral or helical element. This type of system is referred to as a "filled" system. As the temperature rises, the liquid in the system expands, thus increasing the pressure in the spiral (Figure 13-2) or helical (Figure 13-3), and changing its position. Suitable linkage and lever connections *to* indicators, pens, and other instrument compo-nents provide means to indicate, record, control,

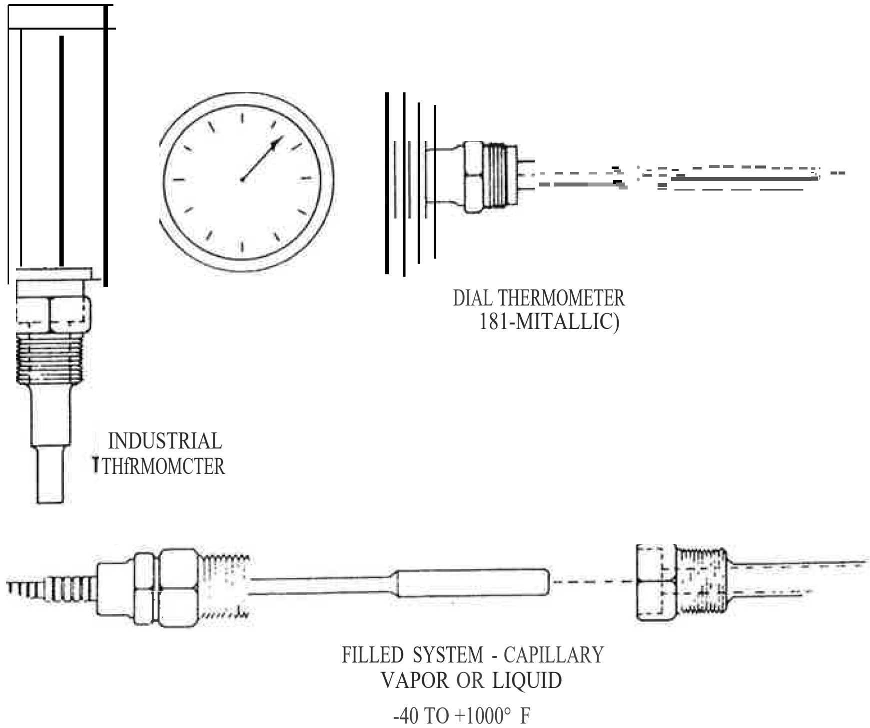
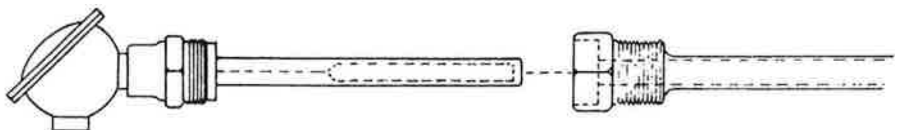


Figure 13-9. Mechanical Temperature Instruments

and transmit temperature conditions. The one thing we must remember is that the bulbs need to be fully irrunersed in the material being measurec:l. However, instead of being immersed directly, the measuring element is usually inserted into the thermowell attached to the pipe or vessel carrying the material whose temperature is to be measured. The thermowell provides protection for the measuring element and also permits its removal while the process is in ope ation.

Electrical Temperature Measurement: Figure 13-10 shows one type of electrical temperature measuring element. The measurement of temperature by electrical means is accomplished most commonly by



COPPER · CONSTANTAN	(T)	• 300 TO • 600F
IRON - CONSTANTAN	(J)	0 TO - 1200 F
CHROMEL • ALUMEL	(K)	• 600 TO - 2000 F
PLATINUM - PLATINUM RHODIUM	(R&S)	-1200 TO - 2600 F

Figure 13-10. Thermocouple

use of thermocouples. Thermocouples are dissimilar wires fused together at one end which have the characteristic of producing a small voltage between them as a function of temperature. They are installed in thermowells similarly to the installation of filled systems discussed above. Various types of thermocouples are ceramic insulated, metal sheath, and bare.

The type of connection on the thermowell, i.e., flanged or screwed, is shown in the piping specifications for the job. The size is usually determined from the job standards (see Standard L-549). However, we should check the Instrument Data sheets for proper connection size; there are occasions where special conditions of installation require special considerations for the thermocouple connection. We must also be aware that the piping specifications often permit screwed thermowell installation where socket welding otherwise would be necessary. These specifications are always mentioned under "NOTES" on the piping stanclard drawings.

It should be noted that there are other means of measuring temperature electrically, such as thermal radiation and resistance elements. Resistance elements are installed similarly to the thermocouple. Radiation-type devices, however, are usually installed in a manner not involving piping considerations. Some installations using thermowells require the thermowells to be filled with oil for better sensing, as oil is a better heat conductor than ari .

In this case, thermowells must be placed at a vertical angle to permit liquid filling and liquid retention. Thus, the rmowe11s in horizontal lines must be put in the vertical on top of the header, and wells in vertical lines at an angle not less than 45° up from the horizontal. See Figure 13-11.

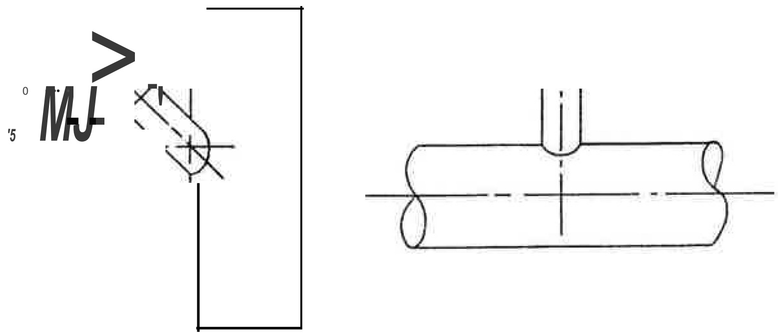


Figure 13-11. Examples of Thermowell Placement

Other Measurements

Analysis, density measurement, viscosity measurement, refractometry and other types of measurement are special cases and would be considered separately. The quantity of these types of measurement is not great and is usually worked out in detail between the Control Systems Group and Electrical Group.

13.2.3 Safety and Relief Valves

Definition: Use of pressure relieving devices is required by ASME and Piping Codes to insure the safety of vessels and piping under pressure, These devices do not function during normal operation, but must be capable of operating at any time to prevent the pres sure in the vessel or the pipe from exceeding certain predetermined limits under emergency conditions,

The Codes specify that safety and relief valves must be designed so that the failure of any part **will** permit the valve to open. This has resulted in the development of the spring-loaded type of safety and relief valves commonly in use today. Safety valves are normally used on gas or vapor service; relief valves are normally used on liquid service. However, both types are commonly referred to generically as relief valves.

Types of Relief Valves: Relief valves come in two basic designs; conventional, and pressure-balanced. These designs are illustrated in Figures 13-12 and 13-13, The conventional valve, when discharging fluid, is so arranged that the pressure in the bonnet is equal to discharge pressure. Anypressure on the downstream side of the valve is exerted on the valve mechanism, and acts in the same direction as the valve spring, Therefore, any increase in downstream pressure prior to opening the valve

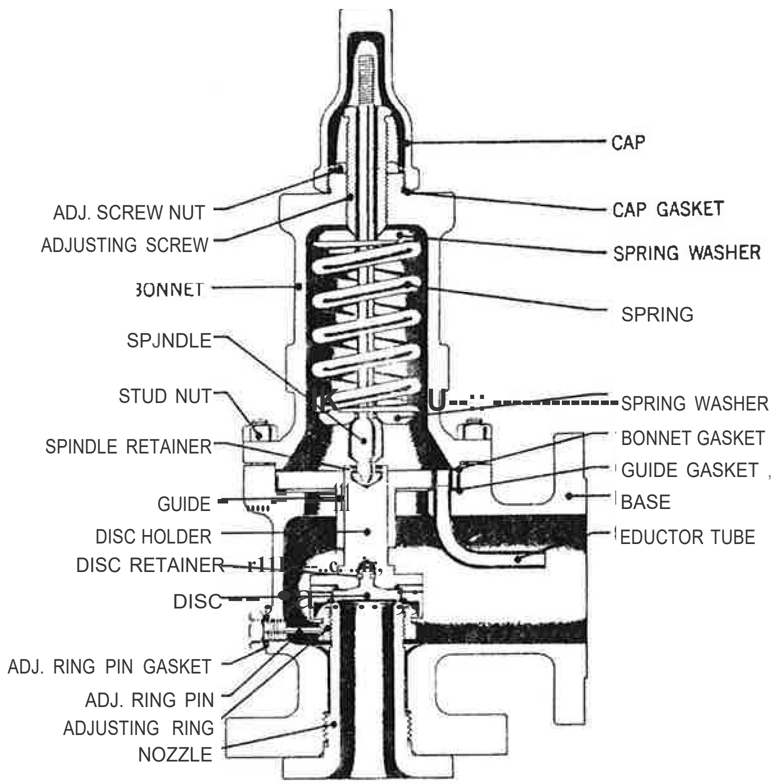


Figure 13-12. Conventional Relief Valve

will, in effect, raise the set pressure of the valve. If this increase exceeds the maximum pres sure permitted by the Code, corrective design measures must be taken. We must either redesign the downstream piping so that this condition cannot occur, or substitute a pressure-balanced valve (see Figure 13-13).

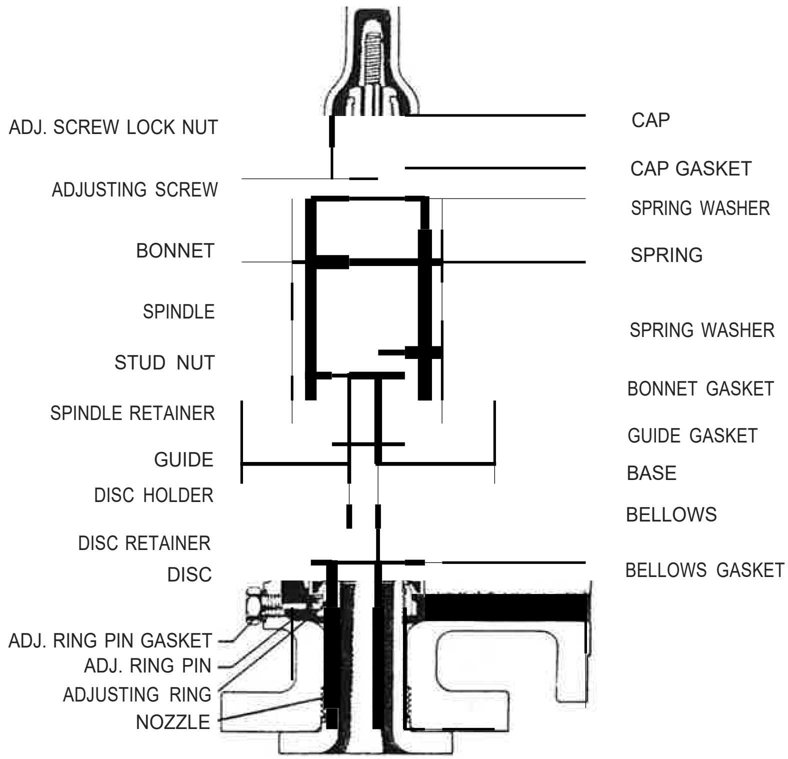


Figure 13-13. Pressure-Balanced Relief Valve

A pressure-balanced valve is more expensive than a conventional valve; therefore, we must evaluate the factors for each configuration carefully in order to provide a practical, economical arrangement through the proper selection of either a larger discharge pipe or a pressure-balanced valve.

Relief Valve Location: Relief valves must be installed in such a way that heads of liquid downstream cannot rest on them. This condition would cause, in effect, an increase in the set pressure of the valve, or possibly even plug the downstream piping.

Since some fluids will solidify at normal ambient temperatures, safety and relief valves are normally installed at the highest possible point on the vessel or piping. This means that the relief valve should be placed above the blowdown header, thus permitting free drainage of the discharge line. There may be cases where this arrangement is totally impractical. In this event, the problem should be discussed with the Unit Project Engineer and Control Systems Engineer, and an alternative solution found. One solution, for example, is to lower the relief valve and install a drain boot and level gauge, If negligible liquid is expected and there is no danger of freezing, we can simply lower the valve and drain the low point. One exception is steam valves, which normally are installed so that they discharge directly into the atmosphere by means of a short riser pipe. A small "weep hole" is usually drilled at the bottom of the vertical riser to keep the discharge line free of liquid.

Codes, Guides, and Specifications: Safety and relief valves installed in non-fired pressure vessels are subject to Section VIII of the **ASME** Code, while those installed in steam generators are subject to Section I of the Code, Both of these Code Sections are quite stringent in specifying that the valve must be free of piping strain, and also clearly limit the amount of pipe installed ahead of the valve and conditions of the installation downstream from the valve. Relief valves must be tested, checked, and maintained; therefore, convenient access must be provided to all relief valves, In most cases, this means platform or grade access must be provided. Design Guide J-1 discusses the use and application of relief valves in much more detail for those who are interested in pursuing the subject further. Wesuggest reading this Guide to make your background of information as extensive as possible. Refer also to Specification J-506 for relief valve specifications currently in use.

13.2.4 Steam Tracing

Fluid Temperature: In many of our refinery and chemical plant applications, it is necessary to maintain fluid temperature in the pipes sufficient to ensure fluidity. This practice prevents pipes from plugging, and reduces pumping costs by reducing viscosity or "drag." Thehigher the temperature of the fluid, the easier it is to pump the fluid. However, many fluids also have limitations on the maximum temperature at which they can be processed without getting into problems of "cracking," overheating, coking, and other problems associated with high temperature.

The means most commonly used to maintain the temperature of a fluid in a pipe is steam tracing. Similarly, instruments that come in contact with the major fluid must also be kept warm by the use of steam tracing. The Control Systems Group is responsible for designing instrument steam tracing systems except for inline instruments, i.e., control valves. However, the designs for instrument headers, subheaders, and trap assemblies are furnished by the Piping Group, and information must be exchanged in order to determine the steam tracing requirements. Generally, it is necessary to provide the piping drawirgs to the Control Systems Group so that they in turn can develop the instrument location plans. The means for steam tracing instruments can be selected and detailed from these plans and standards. In most instances, details already exist for steam tracing the most common types of instruments in use.

13.2. 5 <u>Control Valves</u>

Control valves installed in the piping system consist of a valve body, a valve plug, necessary packing arrangements, and a valve actuator (usually a diaphragm-type operator), The actuator receives a signal from the pneumatic or electronic controller by means of tubing or wires, The signal may be converted from an electronic impulse to a pneumatic impulse or vice versa. The actuator in turn actuates the valve plug so that it occupies more or less of the valve seat, thus regulating the flow through the valve.

The design and installation of control valve manifolds is regulated by Standard L-538. This Standard gives all of the standard piping arrangements, as well as basic dimensional and installation data. Wemust be sure that sufficient room is left around the valve for maintenance access. However, we cannot apply the basic installation diagrams to all problems. Some of our applications may require valves to absorb large amounts of pressure or "produce high pressure-drop."

<u>High Pressure-Drop:</u> High pressure-drop may be any pressure above 100 or 200 pounds, depending on the size of the valve, In hydrogen and ammonia plants, pressure-drops may range upwards into the thousands of psi.

Where high pres sure-drop conditions exist, extremely high velocities downstream of the valve produce shock waves extending long distances, Supersonic velocities are encoun tered which transmit themselves into sonic harmonics in the piping system and produce ear-splitting and sometimes damaging levels of sound.

In these cases, special cage or angle valves are used. Sometimes the outlet piping must be continued in the piping with no bends or fittings downstream of the valve for a predetermined distance. No elbows, tees, or other changes in direction or restrictions in flow can be introduced downstream for a number of diameters, usually 15 diameters or more, Another circumstance that must be considered is the fact that the intakes of angle valves are usually located on the side and the discharges on the bottom, which necessitates special adjustment of the piping arrangement. Awareness of this problem, and close cooperation with the Control Systems Group will avoid costly rework later, The Control Systems Engineer usually works these special applications out together with the Piping Design Group,

Flashing: A situation similar to high pressure-drop occurs where flashing (vaporizing) takes place across a valve, We can consider this situation in essentially the same way and specify a high pressure-drop valve; however, an ordinary globe-body valve may be used under mild flashing conditions. Downstream piping may have to be larger to accommodate the higher volume of "flash vapor" which is generated as the pressure drops across the valve and downstream piping. Longer downstream straight runs of pipe may also be required.

Another phenomenon known as cavitation occurs when a liquid vaporizes then recondenses inside the control valve producing erosive conditions. Valves, fittings, and pipe have been known to deteriorate in less than a week, making it necessary to change the type of piping material and also the piping configuration to provide longer pipe life. It would have been much more economical to have considered the problems in advance and compensated for them in the original design of the plant.

We must be aware that similar problems exist on nearly all jobs and must be on guard so that costly rework can be avoided. High pressure-drop can be determined from line tables and data sheets. Flashing conditions and suspected high pressure-drop conditions should be discussed with Unit and Control Systems Engineers.

13.3 PIPING DESIGN ASSOCIATED WITH INSTRUMENTATION

13.3.1 Instruments Connected to Vessels and Tanks

(1) Connections and Elevations: Engineering instruction A-33 outlines the procedure for establishing both the types of connections to be used and their elevations. This instruction must be read thoroughly to understand the division of responsibilities in establishing connection size, type, and elevation.

(a) Temperature: These connections are usually (3/4 and) I-inch screwed or 1/2 to 4-inch flanged. No piping is required because the instrument (well or thermocouple assembly) mounts directly to these connections.

(b) Pressure: These connections are usually 1/4 - to I-inch screwed and sometimes flanged. Plant design is required to install piping, fittings, and valves through the first block valve.

(c) Level: A variety of connections are used from 3/4 screwed to 6-inch flang e d. The Control *Systems* group prepares standard installation details of level instruments *to* show the typical piping required. The designer must consult both these details and the instrument data sheets to determine what type of piping ar-rangement is required. Frequently level in-struments are connected to a strongback rather than directly to the vessel. The reasons for using a strongback are:

- To reduce the number of connections on a vessel particularly if the vessel is clad, lined, heavy wall, or of special alloy fabrication.
- To reduce the cost of valving associated with level instruments.
- To provide a rigid installation rather than use long lengths of 3/4-inch piping. For example, see Figure 13-14.

(d) Analyzer: Many analyzer connections are the same as pressure connections. The Control Systems engineer should be consulted for each analyzer connection.

(e) Relief Valves: See section on in-line instru-ments, paragraph 13.3.3.

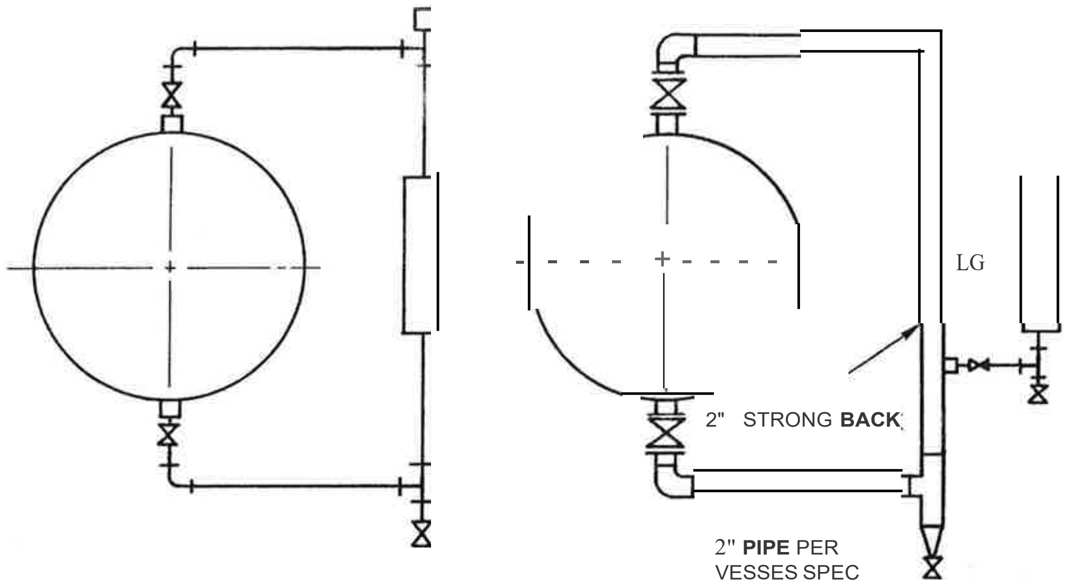


Figure 13-14.

(f) Tank Appurtenances: Tank gauging generally requires special piping which is ordered with the gauge. Do not confuse an ordinary level gauge (LG) with a tank gauge (LI).

(2) Orientation and Accessibility: Correct orientation of instruments and/or instrument connections provides for good visibility and easy accessibility.

Standard specification L-502 defines the requirements for instrument accessibility by operators.

It is important to note that accessibility from a portable ladd e r is usually defined for each project and it is not uncommon to limit the use of portable ladders to a heigh of 12 feet rather than the 18 feet mentioned in L-502.

Accessibility for maintenance reasons mus also be considered. The block valves must be located within a normal arm's reach from the platform or permanent ladder in en d er that these valves may be closed to remove instruments from service. Transmitters piped directly to a vessel or tank must be accessible from platform or ladder in order to calibrate them in place.

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(3) Responsibilities: The Plant Design Group shaU produce: orientation drawings of connections, o thog aphic drawings or model representations of connections as well as instruments themselves ii directly pjped to vessels or srt on g-backs such as level gauges. level switches and displacement level instruments. and isometri s of any connecting piping.

The designer should refer to the following documents in order to properly fulfill hisr es- ponsibilities.

Docum.ent	Purpose
Eng. instruction A-33 Std. spec. L-502	Background
Project Piping Specification	Pressure connection detaLl, material for pipe, valves, fitting, bolts and gaskets
Instrument details for level instruments	Typical piping arrangements for various level instruments
Instrument data sheets	Type of instr ument, connection size and rating, and connection arrangement
p &ID	Location and number of instrument connected to vessels or tanks
Vessel/tank drawing	Size, type, and location of primary connections

13.3.2 Instruments Connected to Piping

(1) Connections:

(a) Pressure and Temperature: Each sheet of the piping specification shows a detail Jor both pressure and temperature connections. These details will be used unless theP & ID is marked with a special connection or unless a note to the contrary is received from the Control Systems engineer.

(b) Flow: The majority of flow connections are made to taps on orifice flanges which are 1/2-inch NPT unless the flange rating is greater than 600 pounds; then these taps are 3/4-inch NPT. Other types of connections for flow measurement generally correspond to the list below, however the Control Systems engineer or the instrument data sheet should be consulted to check the connection.

- Venturi - 1/2-inch NPT or SW
- Flow nozzle - 1/2-inch NPT or SW
- Pitot tube - 4-inch flange
- Annubar - 1 or 1-1/4-inch NPT

- Corner taps - 1/2 or 3/4-inch NPT or SW
- Full flow orifice taps - 1/2-inch NPT or SW

(c) <u>Analyzer</u> <u>and</u> <u>Miscellaneous:</u> Usually these connections are the same as pressure connections, but once again the instrument engineer should be consulted.

(2) <u>Orientation</u> <u>and</u> <u>Accessibility</u>: The same points as mentioned in paragraph 13. 3. l on orientation and accessibility also apply to instruments connected to pipin,g

Special consideration is required for accessibility of temperature connections. TheP &: ID often shows a temperature point which, when located on the model, proves to be in an inaccessible location. Generally, relocating the temperature connection to a more accessible location may be difficult because the temperature reading of the fluid at the new location is different or meaningless. The follow'ing steps may be taken to provide an acceptable installation:

(a) If a temperature gauge (shown as TI local on theP &: ID) or a TW is inaccessible check to see if it can be deleted or relocated.

(b) If the above alternate is not possible, see if the Control Systems engineer can change the TI or TW to a thermocouple (TI mounted on panel) or a remote temperature indicator of the bulb and capillary type, since the connections for thermocouples or bulbs generally do not have to **be** accessible. However, this should be checked with both project and Control Systems engineers

(c) If neither of the above steps is acceptable the piping layout must be revised or a platform/ ladder installed to provide accessibility.

NOTE: It is important not to ignore these temperature points as the client often insists that these points be made accessible when conducting construction inspection of the plant. This leads to expensive field changes.

The orientation of orifice flange connections should conform to std. dwg. L-550 or L-504 depending on job requirements. When pipe rack spacing *is* tight the liquid/ steam services may sometimes be rotated to 45° below horizontal if job specs permit. Orientation of connections for venturis, flow nozzles, corner taps, and full flow orifice taps should follow the same principles as for flange taps, i . e. vertical (or 450 upward) for gas, and hori2ontal (or 45° downward) for steam and liquid. Pitot tubes and annubars may be installed vertically for all services if the horizontal plane cannot be used (if job specifi- cations permit).

Anyflow element in the pipe rack is generally con- sidered accessible. The flow elements on piping that branch off the pipe rack should be dropped down to an elevation accessible by a portable ladder (check client standards for maximum allowable height of portable ladder) if they are not otherwise accessible.

(3) Responsibilities: The Plant Design Group shall pro- duce or thogi·aphic drawings or model representations of all connections for instrumentation and isometrics of the associated piping.

The designer should refer to the following documents in order to properly fulfill his responsibilities:

Document	Purpose
Std. spec. L-502 Std. dwg. L-550 and 504	Background Orientation, size, and type of orifice flange
Piping specifications	Detail for press and temperature connections, material for all connections shown on isometrics
P & ID	Number and category of connections
Instrument data sheets	Type and size of connections for specials, i.e.; analyzer, miscellaneous, flow other than orifice flange
Instrument details for special installations	Design guide

The designer is also responsible for taking off bolts, nuts, gaskets for all flanged instrument connections and marking these on the appropriate isometric.

1333 3 <u>Instruments (Valves and Meters) Mounted In-Line</u>

The most common instruments mounted in-line are:

- Control valves
- Relief valves
- Flow meters

    Orifice flanges

    Rotameters

    Turbine meters

Magnetic fl.owmeters

Positive displacement flowmeters

- Conductivity and pH cells

(1) Connections: Connections of these valves and meters often vary from the standard pipe connections listed on the pipi.ng specification. This occurs either because the valves and meters are not available in the connection types shown on the piping specification or because the design requirements do not permit use of these standard connections. The designer must check instrument data sheets to verify the type and size of connection.

The pipe diameter of these valves and meters is often different fr01n the piping diameter and should be noted on the P &; ID. However, it is good practice always to check the instrument data sheet.

(2) Installation: Special attention should be given to the installation of. relief valves since .the centerline-to-face dimensions vary according to the actual valve selected. For example a 4- by 6-inch valve with a 300 pound RF outlet flange has different dimensions depending on the orifice size as shown below:

Centerline-to-Face, in.		Size, in,	Orifice
Inlet	Outlet		
7 1/16	7 1/8	4 x 6	L
7 3/4	8 1/4	4x6	N

Relief valves should not be mounted remote from the primary connection unless specific approval is obtained. from both project and Control Systems engineers. Extended lengths of inlet piping change the data for sizing the relief valve.

Inlet piping to the relief valve must be equal to or larger than the inlet diameter of the relief valve. Outlet piping should generally be one diameter larger than the outlet diameter of the relief valve, The diameter of long lengths of either inlet or outlet piping should be checked with project and instrument engineers.

Control valve manifolds should be installed in accordance with std. dwg. L-538 and job standards. Bypass vah es are installed in accordance with job standards and are not automatically used with each control valve. The designer should follow the requirements as shown on the P & ID.

Certain control valves are designed to reduce the noise level which may require the installation of baffle plates, silencers, special restriction orifices, or special piping arrangements. The Control Systems engineer shall be consulted to outline these special requirements. No mention of these requirements is made on the early P & ID issues.

The type of control valve shown on P & ID should always be checked against the instrument data sheet. Often a ball valve is changed to a butterfly, or a globe valve to an angle valve without the P & ID being revised to show this change.

The installation of orifice flanges requires detailed study and planning in order to provide the straight pipe-runs referred to in spec. L-502 and standard instrument installation details .J-F -0101 through .J-F-0108. This straight run varies from 8 to 40 diameters upstream and from 3 to 5 diameters downstream. This requirement for upstream run in larger diameter pipes sometimes cannot be met due to space limitations. Where the modification to the piping arrangement would be very expensive, a venturi or flow nozzle can be substituted for the orifice flanges.

This does not require as long a straight piping run. Both project and Control Systems engineers must agree to such a substitution.

The specifications for some projects require the installation of a fabricated meter run which is usually designed and purchased by the Control Systems Group. This meter run generally consists of orifice plate and flanges, and the necessary lengths of piping up- and downstream to provide for the straight run piping. These pipes and flanges are welded in the shop and delivered to the jobsite as an assembly. The piping must be designed to allow for the installation of these meter runs.

During the preliminary stages of the project, the Control Systems Engineers should size orifices to confirm the pipe diameter of the orifice run. Frequently the diameter of the orifice run must be increased to one size larger than the line diameter specified on the line tables. Generally, such line size increases occur when pipe diameter is 8 inches and larger. Orifice runs are usually limited to a minimum size of 2 inches in diameter. Thus, all orifices in 1- and 1-1/2-inch lines should be referred to the Instrument Engineer.

The requirements for straight run piping on orifice runs also apply to pitot tubes and annubars. Shorter runs may be used for some venturis, flow nozzles, turbine meters, magnetic flowmeters, and positive displacement flowmeters (consult the Control Systems Engineer).

Both turbine meters and positive displacement flowmeters require special strainers to be installed upstream of the meter (Consult the Control Systems Engineer).

Conductivity and pH cells installed in the lines are always special applications requiring a joint design effort of both piping and instrumentation. Generally, a globe or butterfly valve is installed in the main line with a bypass around this valve in which the cell is installed.

Rotameters, like displacement level connections, have a variety of connection arrangements; e.g., theinlet may be at the bottom or side and the outlet may be at the top or side. The flow through a rotameter is upward. Therefore, the body of the rotameter must be installed vertically with inlet at the bottom or bottom-side connection. Like a control valve, rotameters shall be installed with a bypass if flow must be maintained even if rotameter is damaged or out of service. Such bypasses shall be shown on the P & ID.

(3) Accessibility: All valves and meters except orifice flanges must be accessible from grade, platform, or permanent ladder. Accessibility from a portable ladder is not permitted.

One of the major design tasks is to assure that there is enough clearance to allow removal of valves and meters from the line. This is particularly important in designing control valve manifolds and piping since the topworks (yoke and actuator) must be removed from the valve so that the valve internals may be removed or repaired in place. Check vendor prints or control valve catalog for dimensions of these topworks.

(4) Responsibilities: The Plant Design Group shall produce orthographic drawings or model representations of all these valves and meters and isometrics of the valves, meters, and piping.

The designer should refer to the following documents in order to properly fulfill his responsibilities:

Document	Purpose
Std. spec. L-502 Std. **dwg.** L-538 Std. details J-F-0101 to 0108	Background
Piping specifications	Orifice flanges, connecting flanges, and material for bolts, nuts, and gaskets
P & ID	Number, types, and sizes of valves and meters
Instrument data sheets	Confirmation of types and sizes; also connection type and ratings
Job standards	Minimum orifice size, use of fabricated meter runs, control valve bypass criteria, type of strainers for flowmeters, if vertical orifice runs are permitted, if control valve connection are same or different than piping specs

13.3.4 Purging and Tracing

(1) Purging: When instruments require purging (symbol O on P & ID) the Plant Design Group shall design a header within 10 feet of the instrument to be purged. Provision must be made for a block valve at the end of this purge line for each instrument requiring purge. The type of fluid to be used for purging shall be dietated by the Control Systems Engineer. The pipe specification of the piping where the purge fluid originated shall be used as the piping specification for the purge