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Revision Memo

- 12/01** Deleted typical ranges (Table 1) since emerging technologies are ever-changing the range choices. Expanded description of d/p, displacer, and ball float to address material and configuration options. Added the introduction to pressure signal difference as an alternative to d/p. Other minor changes for the purpose of clarification. Added **Figure 4B**.



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SCOPE

This section covers the aspects of level measurement and control that are of importance to process design and operation and that are considered and decided in preparing a Process Design Specification.

Descriptive material on the main types of level equipment used is included, with coverage of their influence on vessel connections.

REFERENCES

GLOBAL PRACTICES

GP 3-6-1	Piping for Instruments
GP 15-5-1	Level Instruments
GP 15-6-1	Electronic and Pneumatic Instruments

TYPES OF LEVEL MEASURING DEVICES AND THEIR USES

LEVEL INSTRUMENTS FOR PROCESS UNITS

Differential Pressure Type

This is often known as the “d/p cell” or “d/p transmitter” type. **Figure 1** shows the basic construction and application. The vessel connections are required to be 2 in. (50 mm) flange as a minimum vessel connection. The use of diaphragm seals (see below) also requires a minimum connection size of 2 in. (50 mm). Since there is negligible displacement of liquid in the cell from zero to full range, there is no flow in the connecting lines. Therefore, seal pots are not required for accuracy in level measurement. Seal pots are an expanded piece of pipe in the lead lines from the process connection to the instrument that create a liquid barrier between the process and the instrument. Seal pots can be filled with process fluid or immiscible seal fluid. However, seal pots may be required for other reasons, such as freeze protection, or to provide a “wet leg” for measurement accuracy.

- ◆ In corrosive services (caustic, etc.), fouling services (asphalt, fluidized solids), or services where maintaining fluid in the wet leg / keeping the dry leg empty is difficult, diaphragm seals are used. These consist of a flange with a thin metal diaphragm that isolates the d/p connection from the process. A capillary containing an inert fluid such as silicone, or oil is used to transmit the pressure to the d/p cell. Care must be taken to assure the two capillaries are routed together. If a temperature difference causes the fluid in one capillary to expand more than the other errors are introduced into the level reading. Care must also be exercised to ensure that the seal diaphragm and fill material are compatible with the process service; e.g. fill fluid vapor pressure will limit the process temperature allowable, diaphragm material must avoid permeation in hydrogen service, and diaphragm material may require special coatings or optional material to avoid corrosion by the process fluids.
- ◆ The d/p range may be any value from 1 in. (0.25 kPa) of water and up. However, problems associated with the effects of the connecting piping/tubing increase with decreasing range, so it is usually best to avoid the lowest ranges when possible. Practical minimum and/or maximum ranges are difficult to establish due to service, installation, and fluid properties, however, most concerns except variation of fluid gravity can be addressed. Manufacturers typically use a series of two to four models to cover a wide range of calibrations. **Advances in transmitter technology have introduced many improvements in regard to accuracy, diagnostics, expanded range, and lower costs. D/p transmitters can and should be investigated for services traditionally covered by other level devices.**

Figure 1 shows some of the possible variations in the application of d/p cells to level measurement. The upper connection (the “wet leg”) is liquid filled with condensed vessel vapors or an introduced seal liquid, such as ethylene glycol (**Figure 1B**). The upper connection will be dry (**Figure 1A**) when air or gas is purged (e.g., cat cracker services) or if there is no condensation of vessel vapors in the leg. A dry upper connection is sometimes heated and insulated to prevent such condensation.

- ◆ It should be apparent with a dry leg (**Figure 1A**) that the upper connection can be located at the 100% level range point or anywhere above that point. In contrast, the upper connection of a wet leg (**Figure 1B**) is limited by the amount of bias adjustment (also known as zero suppression) available, which varies with range and manufacturer. However, most manufacturers will allow the wet leg bias (length times density of the wet leg liquid) to be up to the maximum upper range limit less the minimum span.
- ◆ The bias adjustment limits available for the arrangement shown in **Figure 1A** (also known as zero elevation) also vary with range and manufacturer. The limits are usually the same as for the wet leg arrangement.

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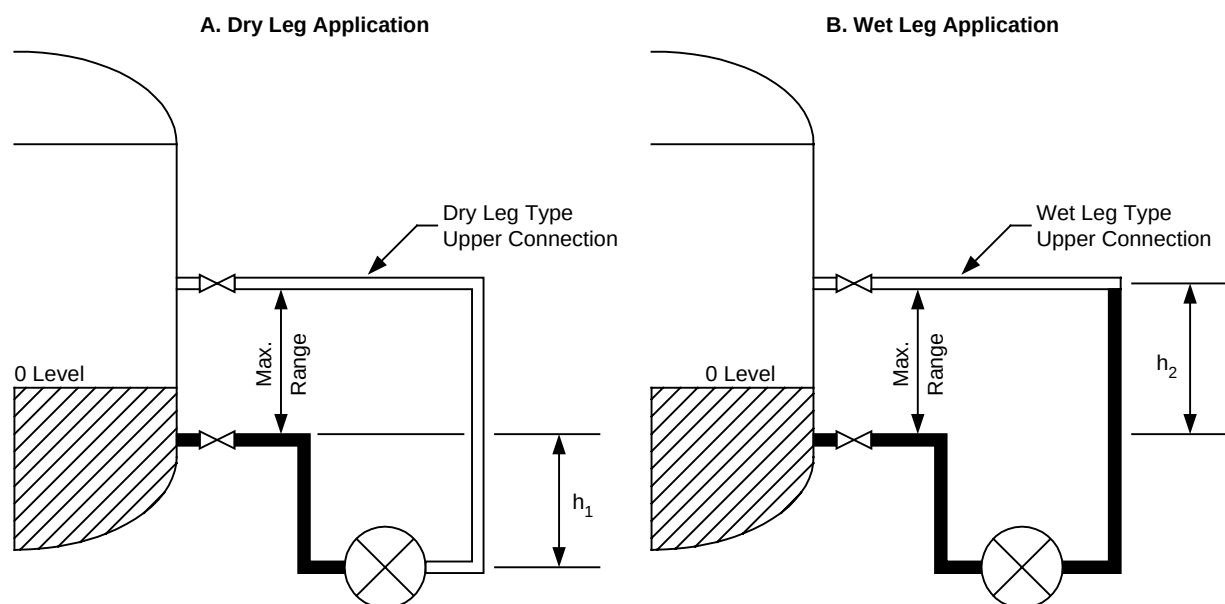
TYPES OF LEVEL MEASURING DEVICES AND THEIR USES (Cont)

The preferred installation arrangement is to mount the centerline of the d/p transmitter at the same level as the lower vessel connection and use a dry leg upper connection. This will provide the highest possible accuracy and minimize the difficulties of calibration that zero elevation or suppression introduces. If a dry leg is not possible for process reasons (condensing vapors, for example), a wet leg filled with the liquid in the process vessel and the transmitter mounted level with the lower connection is the second choice. Also, if the process temperature is higher than the rated instrument capability, the d/p transmitter is mounted below the process tap to provide a wet leg to insulate the transmitter from the high temperatures.

The wide variation in available ranges, the field adjustability for variations in operating conditions and in installation, the higher accuracies available, and the overall costs of equipment and installation make the d/p cell one of the most popular types of level measuring devices.

Emerging technology for pressure transmitters, (e.g. better accuracy and stability, "smart" devices, inherent diagnostics, and lower cost) is leading toward generating differential pressure by difference in two pressure transmitters. This greatly reduces concerns due to installation effects. Limits of accuracy are still a major consideration for this technique, but improved reliability due to simplified installation makes it worth evaluation. Achievable accuracy can be determined by comparison of the manufacturer's quoted accuracy (operating at pressure) and the desired d/p range. This method lends itself more to large level ranges in low pressure vessels.

FIGURE 1
BASIC CONSTRUCTION AND APPLICATION OF DIFFERENTIAL PRESSURE LEVEL MEASURING DEVICE



Note:

Heads h_1 (which adds to the true signal—"zero elevation") and h_2 (which subtracts from the true signal—"zero suppression") are biased out so transmitter gives a 0% level signal for the level at the lower tap.

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Bubbler-Type D/P Cell

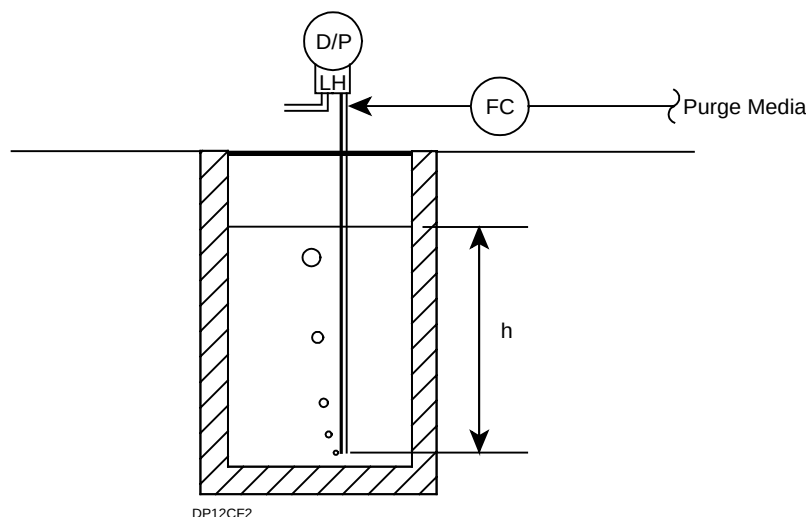
One variation of d/p cell level measurement is the bubbler (see **Figure 2**). A bubbler is used when access to the bottom level connection is not possible, for example, an underground sump; or when other level measurement devices will not work (such as a subsurface molten sulfur storage tank). A bubbler consists of a d/p cell with the low pressure port connected to the top of the vessel (or vented to atmosphere in the case of atmospheric vessels) and the high pressure port connected to a dip tube extending down through the liquid being measured to the lowest level to be measured. Also connected to the high-pressure port is a purge stream compatible with the process, which provides a constant low flow rate of the suitable purge gas (e.g. hydrocarbon, air, nitrogen, steam). A constant flow controller or a variable-area flow meter is usually used to maintain a constant flow. The pressure required to force the purge gas out the bottom of the dip tube is the hydrostatic head of the liquid above the bottom of the dip tube – a direct measurement of the level (for a constant gravity fluid).



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TYPES OF LEVEL MEASURING DEVICES AND THEIR USES (Cont)

FIGURE 2
BUBBLER-TYPE D/P LEVEL MEASUREMENT



Displacer Type

Principle of Operation

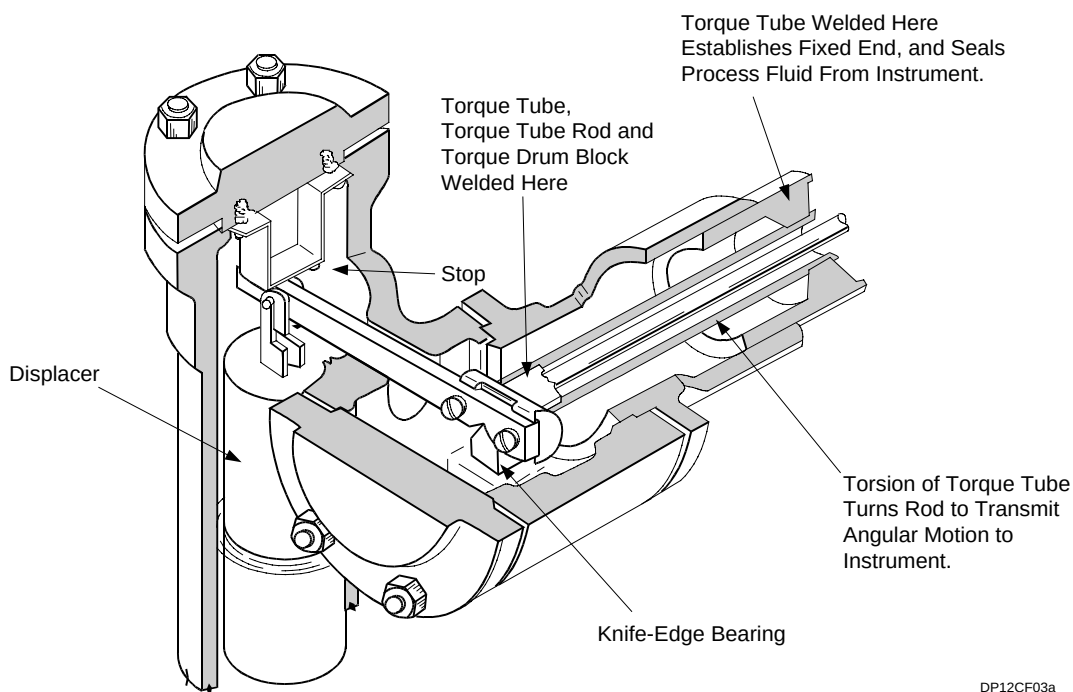
By definition, displacer density will be greater than the liquid and will act as an immersed body. Operation of the displacer is based on the measurement of the change in buoyancy of the displacer as the level changes over its length. Buoyancy is equal to the weight of the volume of liquid displaced. By varying the cross-section of the displacer (volume per unit length) the linear change in level can be measured for a variety of ranges. **Figure 3** illustrates the basic construction. The term "float" is frequently used to signify a displacer, but as explained above, measurement is dependent on the displacer acting as an immersed body. If released, the displacer would actually sink.

The success of the displacer is due to the development of a suitable torque tube, which translates the resultant buoyancy into an upward movement and allows the motion of the displacer [less than 1 in. (25.4 mm)] to be transmitted outside the process pressure zone without a stuffing box or similar seal. The twist of the torque tube, which is also the rotation of the shaft that actuates the level instrument, is only about 5 angular degrees.

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TYPES OF LEVEL MEASURING DEVICES AND THEIR USES (Cont)

FIGURE 3
A. CONSTRUCTION OF DISPLACER TYPE LEVEL MEASURING DEVICE



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Standard Ranges

In principle, a displacer could be made for almost any range. The main requirement is to adjust the diameter of the displacer so that the selected range gives the standard displacement, in order for the torque shaft rotation, in turn, to be standard. [Note: The 14 in. (356 mm) range uses a 3 in. (75 mm) diameter "float."] However, since most displacers are external and thus need a chamber for the "float," this would require much custom work. The choice should, therefore, be limited to the available standard lengths of 14, 32, 48, 60, 72, 84, 96, and 120 in. (356, 813, 1219, 1524, 1829, 2134, 2438, and 3048 mm). Per **GP 15-5-1**, either d/p or displacer is the preferred level measurement device for ranges up to 48 in. (1219 mm). Note that since the prices increase rapidly above 48 in. (1219 mm), the differential type transmitter is preferred for any of the larger sizes, due to lower cost.

Displacer Material of Construction

Displacers can and have been fabricated from a variety of materials compatible with the fluid density and severity. A displacer can be selected compatible with fluids, which are hostile to most standard materials. Displacers can also be fabricated in special configurations to produce multiple functions from one level device, e.g. "deadband" control, sump pump control, multiple setpoint switches, etc.

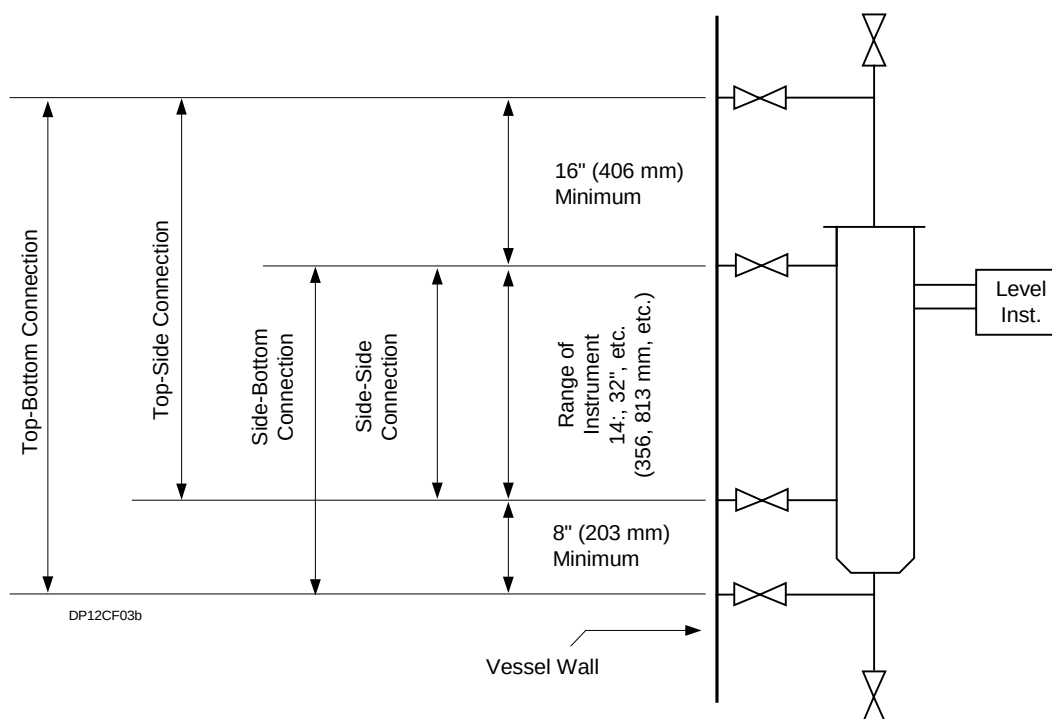
Connections

The lower connection can be made into the chamber bottom or side, and the upper connection can be made into the chamber top or side. Thus, four combinations are possible and available. Side-Bottom connections are "preferred" and Side-Side are "acceptable". More precise location of mating vessel nozzles are required for Side-Side connections. The center-to-center dimensions of the Side-Side connections are the same as the displacer level range [14, 32, 48 in., etc. (356, 813, 1219 mm, etc.)]. These dimensions plus minimum additional dimensions required for proper top and bottom connections are given in **Figure 3B**.

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FIGURE 3 (Cont)
B. VESSEL CONNECTION DIMENSIONS FOR THE FOUR POSSIBLE ARRANGEMENTS FOR EXTERNAL DISPLACER



The choice of the arrangement to use (**Figure 3B**) is governed by several major considerations besides the mechanical ones involving the process vessel itself. Due to the manometer effect, the weight of the liquid in the external leg must balance that of the column of liquid inside the process vessel. If these two liquids have different densities (e.g., because of cooling of the external leg or condensation of light material in the upper part of the external leg), then the external and internal liquid levels will not be the same. The magnitude of the error introduced by such level differences depends on the locations of the connections.

The lower the external leg starts below the float in the displacer, the greater the error is in the indicated level due to density differences. For a liquid-liquid interface service, a similar analysis would show that the error due to density changes increases as the distance between the top connection and the float and the bottom connection and the float increases.

Due to the ease and flexibility of installation and maintenance, the Side-Bottom connection arrangement is preferred (see **GP 15-5-1**). To minimize error due to density changes, the length of the bottom leg should be kept to a minimum. Side-Side connection arrangements are also permitted. All level interface applications should be reviewed by an Instrumentation expert.

Vessel connection is a 2 in. (50 mm) flange. Connections into the bottom of a process vessel should be avoided, where possible, because the piping traps water and sediment. If for some reason a bottom connection must be used, an enlarged (3 in.) bridle should extend at least 3 in. (75 mm) into the vessel, to minimize the water and sediment problem. The bridle arrangement shall include the piping and valving to blowdown the piping "trap" created by the bottom connection. (See discussion of the use of bridles below.)

Top process vessel connections should be avoided if the drum is liquid-filled, to avoid trapping gas in the upper piping which will cause an inaccurate level reading. In addition, the top displacer chamber connection is inconvenient when maintenance of the displacer internals ("float") is required.

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TYPES OF LEVEL MEASURING DEVICES AND THEIR USES (Cont)

Drain and vent connections should be provided for any of the connection combinations, to provide for displacer calibration without removing the instrument from the vessel.

CAUTION: Connections should not be made into lines that can have flow to or from the vessel (inlet, outlet, drain, etc.), since the velocity head effects of such flow can cause errors that exceed the entire range of the instrument.

Displacers may be mounted on a single nozzle on the top or side of the vessel [4 in. (100 mm) is normal], with the displacer member inside the vessel. These are called internal displacers. Internal displacers are used when connection plugging or boiling in the displacer chamber annulus is anticipated.

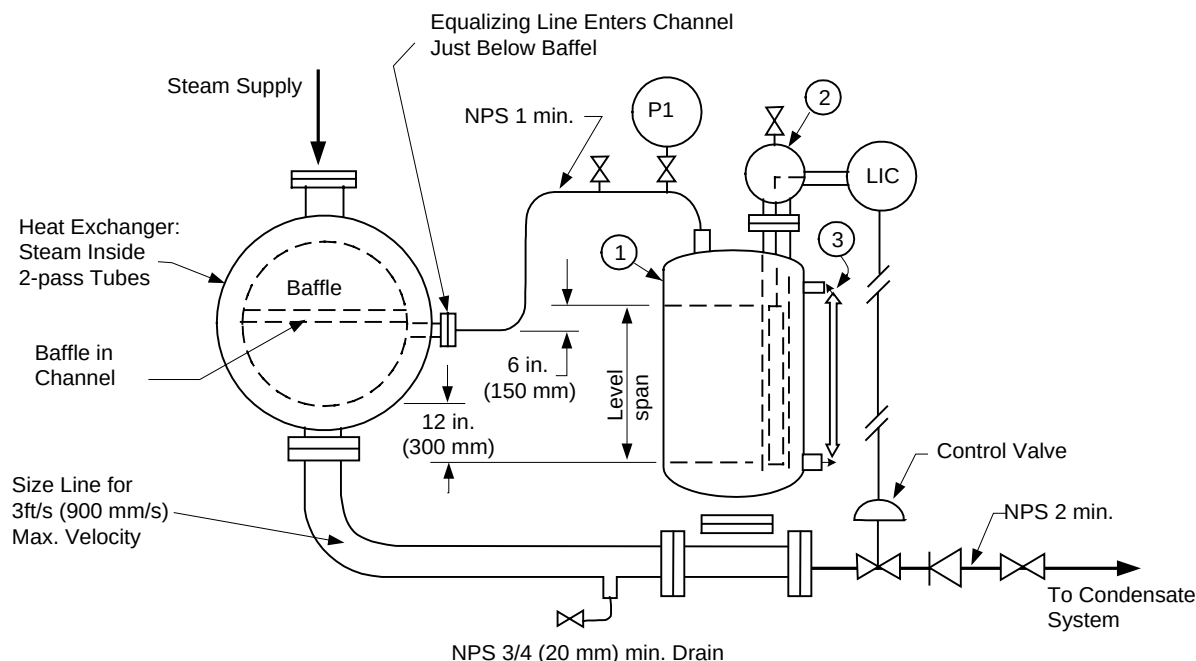
GP 3-6-1 calls for a stilling well to be installed on all internal displacer applications or any other application where process agitation can affect the level measurement. The problems mentioned above must be of sufficient probability to prevent a normal external displacer from working. The major disadvantage of using an internal displacer is being unable to service the instrument without removing the vessel from service.

Example of special application of displacer:

Figure 4 shows a unique use of the displacer technology to accomplish several purposes and serves as a good example of the installations methods mentioned in the above sections. This arrangement provides a positive method of condensate removal and the ability to modify the effective exchanger area. For further discussion on this application, see **DP Section XII-E**.

Where steam is used as a heating exchange medium with process hydrocarbon, steam traps shall not be used in the condensate lines. Steam condensate vessels with displacer-type instruments shall be installed.

FIGURE 4
STEAM CONDENSATE VESSEL WITH DISPLACER-TYPE INSTRUMENT



Legend:

1. Condensate pot 16 x 30 in. (400 x 760 mm) with NPS 4 nozzle and slotted internal guide pipe for level displacer, if internal.
2. Pneumatic internal displacement type of level controller, flange mounted. External displacement type of level controller may be used as an alternative.
3. Level gage with velocity check gage valves.

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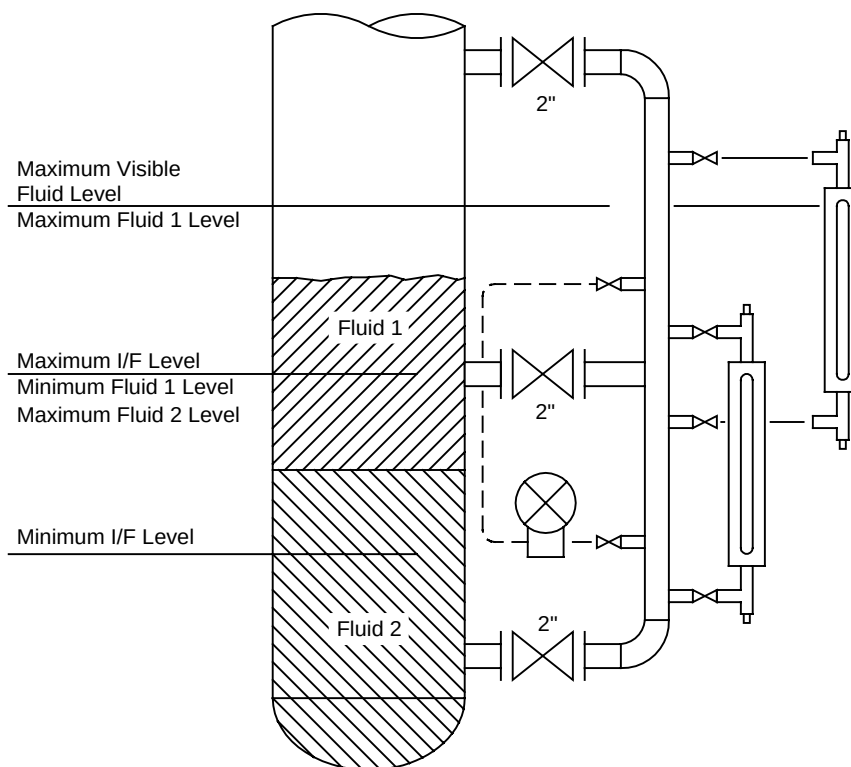
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Use of External Bridles

To minimize the number of connections into a vessel for economic and safety reasons, an external bridle is frequently used (see **Figure 5**). A bridle consists of a vertical section of pipe, usually 2 - 4 in. (50 - 100 mm) diameter, with block valves to isolate it from the vessel for maintenance. Multiple level instruments, such as level switches, level transmitters, and gauge glasses can be mounted on connections to the bridle. This is especially beneficial for lined vessels, vessels constructed of materials difficult to weld, or vessels which must be stress relieved. For additional information, see **GP 15-5-1**. **Independent valving shall be provided for the multiple level devices connected to the bridle. If the bridle includes separate control functions on the same bridle, (e.g. switch and control transmitter) then the common isolation valve for the bridle connection to the vessel shall be tagged or sealed to avoid inadvertant isolation of multiple functions at the same time.**

FIGURE 5
USE OF EXTERNAL BRIDLE FOR LEVEL INSTRUMENTS



Note:

In a three-fluid system (normally two liquids plus a gas), it is necessary that the bridle opposite the liquid interface connect into the middle fluid. The line must be located so the point where it connects to the vessel is covered by the middle fluid for all expected fluctuations of the middle fluid levels. If this cannot be achieved by one balance line, additional balance lines must be used.

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Ball Float Type

Acceptable designs of ball float devices use a principle similar to the torque tube in the displacer or a magnetic coupling to eliminate the stuffing box. One such type is shown in **Figure 6**. These are widely used for on-off service, operating valves or alarms in applications such as high levels in compressor and fuel gas knock-out drums and distillate drums, where dependable action at infrequent intervals is necessary. The flattened section of the ball arm allows sufficient motion to be transferred out of the pressure zone to operate a pneumatic or electric switch.

Level instruments using a ball float on a lever arm operating a standard controller or switch require a stuffing box, and are now considered obsolete. They have generally been replaced by the displacer or d/p cell. However, a specially designed internal ball float is still used for Alky Plant Settler level control. This device requires a 10 in. (250 mm) flanged connection.



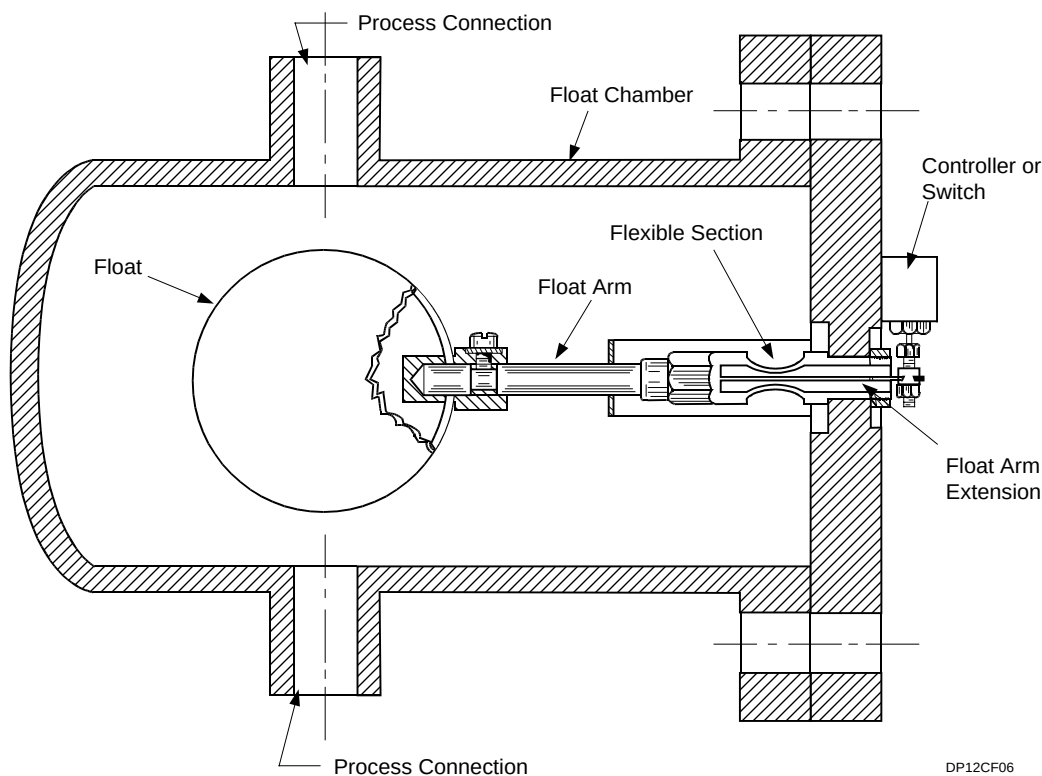
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TYPES OF LEVEL MEASURING DEVICES AND THEIR USES (Cont)

FIGURE 6
BASIC CONSTRUCTION OF ONE TYPE OF BALL FLOAT LEVEL DEVICE
USED FOR EMERGENCY AND ALARM SERVICE



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Ball float switches are sometimes used in those services where large gravity changes in the liquid being measured could affect the calibrated range of a displacer-type level switch, and prevent the switch from operating safely. This is especially significant on compressor suction drums and fuel gas knockout drums, where failure of the high level shutdown switch can cause destruction of a compressor or cause liquid hydrocarbon to be injected into a gas-fired burner.

All known makes and types of ball float switches in external chambers can be installed on 2 in. (50 mm) vessel connections on 24 in. (600 mm) centers. Deviations from these dimensions in a specification would require knowledge of the specific make and type switch to be used.

Ball floats can be fabricated with a variety of materials and geometric shapes to meet special process needs.

Gauge Glasses

Gauge glasses are normally specified for all level instruments as a means of checking operation of the instruments. The gauge glasses should cover the range of any level instrumentation on a vessel which should include any surge capacity specifically added for design reasons, such as the added 3 minutes of capacity below the low liquid level (LLL) on fired heater feed services. Exceptions may be made when there is a very large surge volume outside the normal control range (see **Figure 7**). Gauge glasses may also be specified to cover other levels of interest, such as start-up inventory seal legs.