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Guidance on Practice for Level Instruments

GP 30-15

BP GROUP
ENGINEERING TECHNICAL PRACTICES

Foreword

This is the first issue of Engineering Technical Practice (ETP) GP 30-15. It is based on parts of heritage documents of the merged BP companies as follows:

Amoco

A PC-LI-00-E	Process Control—Level Instruments—Selection, Specification, and System Design; Specification (October 1997).
A PC-LI-00-G	Process Control—Level Instruments—Guide (October 1997).
A PC-LI-NUC-P	Process Control—Level Instruments—Nuclear Type—Supply Specification.

BP (Pre-1999)

RP 30-1	Instrumentation and Control, Design and Practice (September 1993).
RP 30-2	Instrumentation and Control, Selection and Use of Measurement Instruments, Section 4 Liquid Level Measurement (September 1993).
RP 30-2	Instrumentation and Control, Selection and Use of Measurement Instruments, Section 6 Storage Tank Measurement (September 1993).
RP 30-12	Instrumentation and Control, Field Instrumentation for Chemical Processing Plant (February 1997).

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1. Scope

This BP Engineering Technical Practice (ETP) provides guidance for the selection, design, and application of level instruments used in production and process plants, storage facilities, pipelines and other installations.

For guidance on practice for storage tank level instrumentation, refer to **GP 58-XX** Storage Tanks.

2. Normative references

The following normative documents contain requirements that, through reference in this text, constitute requirements of this technical practice. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this technical practice are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to apply.

American Petroleum Institute (API)

API RP 551 Process Measurement Instrumentation, Section 3 Level.

BP

GP 12-60	Guidance on Practice for Hazardous Area Electrical Installations.
GP 30-05	Guidance on Practice for Pressure Instruments.
GP 30-25	Guidance on Practice for Common Field Instrument Issues.
GP 30-76	Safety Instrumented System (SIS) – Process Requirements Specification.
GP 30-80	Guidance on Practice for Safety Instrumented Systems (SIS) – Implementation of the Process Requirements Specification.
GP 30-90	Guidance on Practice Commissioning of Instruments and Control Systems.

British Standards Institute (BSI)

BSI BS 3463:1975 Specification for Observation and Gauge Glasses for Pressure Vessels.

International Electrotechnical Commission (IEC)

IEC 60529 Degrees of protection provided by enclosures (IP Code).

National Electrical Manufacturers Association (NEMA)

NEMA 250 Enclosures for Electrical Equipment (1000 Volts Maximum).

3. Symbols and abbreviated terms

DN	Nominal diameter.
NPS	Nominal pipe size.
P&ID	Piping and Instrument Diagram.
PTFE	Polytetrafluoroethylene.
SIS	Safety Instrumented Systems.



4. Common requirements

4.1. General

- a. This GP provides guidance that is unique to level instruments. Guidance on level instruments that is common with other instruments is provided in GP 30-05, GP 30-25 and GP 30-90.
- b. Installation and general application of instrumentation for indicating, recording, and controlling liquid and solid levels and liquid-liquid interface levels shall be specified in accordance with API RP 551 Section 3.
- c. Requirements for diaphragm seals shall be specified in accordance with GP 30-05.
- d. For Safety Instrumented Systems (SIS), level instruments shall comply with GP 30-80.
- e. Instrument's electronic housing for outdoor use shall, as a minimum, comply with IEC IP 66 in accordance with IEC 60529 (NEMA 4X in accordance with NEMA 250).

In aggressively corrosive environments, SS enclosures may be required.

- f. Instruments in hazardous (classified) areas shall comply with GP 12-60.
- g. Protection required for radio frequency interference (RFI) shall be discussed and agreed upon with manufacturer.

The effect of RFI may need to be considered as part of the overall installation.

4.2. Local indication

- a. Local level gauges shall span the full working range of the vessel and the level instrumentation mounted on it.
- b. Local indication of level should be provided by:
 1. Local gauges for vessels and small tanks.
 2. Gauge glasses with overlapping connections to provide continuous measurement over the working range of the vessel for larger vessels.

Gauge glasses do not provide easy indication if the fluid is dirty. If a local visual measurement is required, purging a lighter liquid between the vessel isolating and level gauge isolating valves or the use of magnetic type gauges should be considered.

3. Float type instruments for large tanks if fiscal-quality measurement is unnecessary.

If the fluid is viscous, a displacer instead of a float should be considered. Alternatively, a close-coupled differential pressure instrument should be the next consideration.

4. Static head pressure measurement.

4.3. Point level detection

- a. Continuous measurement is preferred. If point level detection is required, the guidance in this section shall apply.
- b. Ball float operated instruments are preferred for point level detection.

On low-level applications and if sludge could be a problem, a displacer should be considered rather than a float operated device. Although the effect of increased weight caused by sedimentation affects both float and displacer, the effect on buoyancy is less severe.



- c. Other point level types (e.g. capacitance, vibration, tuning fork) may be considered if they offer advantages over ball float devices.
- d. Microwave level switches side mounted may be used to detect a point level measurement.
- e. For dual point level detection, adjustable displacers mounted on a single support wire may be used on small vessels in non-process applications (for example, sumps).

A dual displacer mounted on a support wire allows higher differential levels to be controlled than a single level switch. This is especially useful if access is restricted.

4.4. Design

4.4.1. General

- a. Calibration equipment shall comply with GP 30-90.
“Rodding” a float device to test operation is unacceptable because crushed floats are not detected.
- b. Level instruments shall be isolated from the vessel during hydro-testing or other procedure that may exceed the pressure rating of the instrument internals.
Internal floats are easily collapsed by overpressure.
- c. Level instruments installed in hazardous areas shall comply with GP 12-60.
- d. The top instrument connection should be at least 25 mm (1 in) above the maximum interface level and the lower connection at least 25 mm (1 in) below the minimum interface level.
- e. Local level control should be avoided. If local control is required, displacer type instruments are preferred for applications over small ranges.
- f. Alarms or controls activated from auxiliary contacts on gauges are not recommended.
- g. Level gauges should cover the complete range of measurement associated with level controls, alarms, shutdown devices, and transmitters.
- h. Standpipes (bridles) and gauges in vaporising services should be oversized to accommodate the dynamic state within them.
The dynamic state occurs from the boil-off/condensation occurring within the body and pipe work.
- i. If feasible, standpipes (bridles) and gauges in vaporising services shall be insulated.

4.4.2. Manufacturer calculations

- a. Detailed calculations associated with specifying level instruments should be provided by manufacturer.
- b. Calculations should be in an editable electronic format (for example, MS Excel or Word).
- c. Calculations should be one per page or one per electronic file.
- d. Calculations should include a sketch that shows:
 1. Physical installation, including distance between taps and any other relevant distances.
 2. The zero mark.
 3. Specific gravity of process, including upper and lower fluids for both liquid/liquid and liquid/gaseous interfaces.
 4. Fill fluids and their specific gravity.



4.4.3. Boiler plant drums

- a. Level measurement for boiler plant drums (including waste heat boilers and fired heaters) shall comply with the relevant statutory requirements.
- b. Externally mounted level instruments shall include a lagged condensing device. The lagging of the condensing device shall be as recommended by the manufacturer or supplier of the boiler steam drum and condensing device.

Device is to ensure that the water in the measuring instrument is as near as possible the same temperature as that in the drum.

The lagging of the condensing chamber can have a critical effect upon level transmitter performance, particularly where the condensate chamber is subject to widely varying ambient temperatures. In addition, a certain amount of heat loss is desirable in order to encourage condensation within the chamber and thus replenish heat lost from the chamber. The requirements for lagging are very dependant upon the condensate chamber design.

- c. In extra high pressure boilers [98 bar(g) (1 421 psig) and above], if water surging can occur:
 1. At least two sets of level measurements and switches, with one on each side of the drum should be used.
 2. The chosen configuration for trip initiation shall conform to the Safety Integrity Level (SIL) requirements for the SIS interlock and in accordance with GP 30-80.
 3. Additional transmitters may be required for control.

5. Selection**5.1. General Criteria**

- a. Level measurements should be designed with the maximum practical range.

Often level nozzles are placed 350 mm. (14 in.) apart even when the vessel may have additional capacity. For added accuracy and controllability, the entire available capacity should be spanned with the level instrument.
- b. The selection and installation of level measuring devices should be such that:
 1. Measurement is reliable and reproducible.
 2. Installation, maintenance, and testing are as simple as feasible.
- c. Selection of level instrument for a specific application shall require a comparison of the following:
 1. Compatibility with process fluids.
 2. Functionality.
 3. Suitability.
 4. Maintainability.
 5. Operability.
 6. Cost.
- d. Level measurements should use electronic transmitters.

Electronic transmitters are preferred so that the output can be directly sent to the control centre.



5.2. Differential pressure instruments

- a. Differential pressure level measurement instruments may be used for most applications.
- b. For ranges below 350 mm (14 in) consider using displacer type level instruments.

The concern is that for such small range, any variation in density causes a significant error in the indicated level.

- c. Selection of differential pressure instruments should include consideration of the following advantages and disadvantages:

Advantages:	Disadvantages:
Lower cost.	Maintaining the low-pressure leg either empty or full.
Ease of use.	Affected by density changes.
Ease of maintenance.	Need for diaphragm seals with capillaries to protect the differential pressure from severe environment.

5.3. Displacement type level instruments

- a. Displacement type instruments should be considered for liquid interface level measurement if the specific gravity difference is greater than 0,10.

A common level measurement device is a displacer with torque tube and electronic head.

- b. For ranges below 350 mm (14 in), displacement type instruments are preferred for level measurement.
- c. Displacement type level instruments should not be used in the following conditions:

1. In severely turbulent, dirty, foaming, or fouling service.

These conditions make displacement type level instruments unreliable.

2. In liquid-liquid interfaces if the two fluids form an emulsion or do not have a clean interface (rag layer).
3. In liquid-liquid interfaces with specific gravity difference less than 0,10.
4. In liquid-liquid or liquid-gaseous services where either the upper or lower fluid specific gravity is not relatively constant.

- d. Selection of displacement instruments should include consideration of the following advantages and disadvantages:

Advantages:	Disadvantages:
Wide range of temperature and pressure.	Sensitive to turbulence in the displacer chamber.
Suitable for interface level.	High maintenance cost.
	Difficult to calibrate for interface.

5.4. Magnetic level instruments

- a. Magnetic level instruments should be used for high pressure, high temperature, and toxic or hazardous duties.
- b. Magnetic level gauges shall be used in most applications, if feasible.

Magnetic level instruments have particular advantages over glass gauges as shown in the advantages/disadvantages table.

- c. Magnetic type gauges may be used for environmental, personnel safety hazard elimination, or if corrosiveness of process fluid precludes feasible application of gauge glasses.



- d. Selection of magnetic type level instruments shall include consideration of the following advantages and disadvantages:

Advantages:	Disadvantages:
Construction involves fewer joints giving greater mechanical strength in a single length than the standard reflex or transparent sections. They can be built to almost any length, eliminating the need for multiple devices on vessels with long spans. They are less sensitive to fluid density changes than differential pressure or displacer devices. They have an integral local indicator and transmitter or switch. Larger size nozzles make them less prone to clogging. They can be direct mounted to vessels (a standpipe is not required). There is significant field experience with very good performance. Same technology can be used for either total level or interface level. They can continue to function even if several degrees off of true vertical.	They need to be heat traced in services that have paraffin buildup. (This is however true of most devices.) They are not available in all alloys. Only nonmagnetic materials can be used. Incorrect procedure for placing in service can damage or collapse the float. Magnetic gauges tend to accumulate ferric scale on the float.

5.5. Nucleonic level instrumentation

- a. Subject to BP approval, nucleonic level instrumentation should be considered for both point and continuous applications if reliable measurement by other means is impractical.
- b. Nucleonic level instruments of two basic types should be considered:
1. Gamma ray absorption.
 2. Neutron backscatter (a newer technique).

Because neutron backscatter is a relatively new technique, a summary of neutron backscatter technology follows:

Fast neutrons are emitted from a source typically mounted on the outside of the vessel. The neutrons easily penetrate the vessel wall and interact with the contents in the immediate vicinity of the entry point. The neutrons are slowed (moderated) primarily by collisions with hydrogen atoms. These moderated neutrons are either absorbed by other atomic particles or "backscattered" out of the vessel. The measure of moderated neutrons (typically made with a device adjacent to the source) is proportional to the hydrogen concentration of the contents. This can then be related to the level in the vessel.

Neutron backscatter devices can penetrate thicker walls than gamma ray radiation. Thus, a neutron backscatter level instrument should be considered whenever a gamma ray device would not penetrate the walls.

- c. Nucleonic level instrumentation shall meet applicable statutory regulations governing the handling and use of radioactive sources.
- d. Subject to BP approval, nucleonic type detector level instruments may be used in applications that require non-contact level measurement.



- e. Selection of nucleonic level instrumentation shall include consideration of the following advantages and disadvantages:

Nucleonic advantages: Nucleonic level instruments are particularly well suited if there is a change of fluid properties, such as density or phase (for example, a well-stirred reactor that has both liquid and gas phases.) Non-intrusive.	Nucleonic disadvantages: Nucleonic type level detectors are relatively expensive compared to other types of level measurement used in the industry. Special handling and maintenance requirements. Source decay and ultimate disposal.
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5.6. Capacitance and resistance probes

- a. Capacitance and resistance probes should be considered only for:
1. A secondary measurement as a backup for other type level systems.
 2. Dirty fluids if purges are not feasible.
 3. Powders.
Weigh systems are typically preferred for measuring solid materials such as powders and pellets in vessels and silos.
 4. If the fluid may be subject to density changes, either overall or at the interface.
 5. If a purge is not practical or process-acceptable.
 6. If the vessel is below grade.
Capacitance techniques are used for both solids and liquids.
- b. Capacitance and resistance probes may be used in applications where a small, lightweight probe may be mounted vertically through a top connection.
- c. Capacitance and resistance probes shall not be used in a service if the dielectric constant of the measured liquid changes.
Capacitance level instrument accuracy is a function of the liquid dielectric constant. Care should be taken to determine the dielectric constants of the fluids being measured over their full range of possible compositions and operating conditions.
- d. Selection of capacitance and resistance type level instruments shall include consideration of the following advantages and disadvantages:

Advantages: Relatively low cost. Can detect interfaces accurately. Small nozzle requirement. Suitable for high-pressure applications.	Disadvantages: Adversely affected by dielectric constant changes in the fluid. Probe subject to coating. Very application specific. Difficult to calibrate and check in the field. Probes mounted directly in the vessel typically cannot be replaced with the vessel in service.
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5.7. Ultrasonic devices

- a. Ultrasonic devices should only be considered for:
1. Powder duties.
 2. Storage vessels.
 3. Effluent pits.



The use of an external chamber for process type measurements is more feasible than the ultrasonic device.

- b. In corrosive service or if maintenance is difficult to perform, level instruments should be non-contact sonic instruments.

If the sonic instrument is not in contact with the liquid, it is unaffected by the corrosive and electrical properties of the fluid.

- c. The use of ultrasonic type level instruments is severely restricted due to the diameter of the chamber required to accommodate the beam angle (typically 0,12 radians (7 degrees)).
- d. Ultrasonic devices should not be used in vessels where hydrocarbon vapours given off can vary the density above the liquid.

Varying density vapours can interfere with signal wave transmissions.

- e. Selection of Ultrasonic type level instruments shall include consideration of the following advantages and disadvantages:

Advantages:	Disadvantages:
Non-contact.	Adversely affected by density changes in vapour.
Above fluid level instrument location.	Ultrasonic transducer head subject to coating.
Relatively low cost.	May be lower accuracy than other devices.

5.8. Bubbler tubes

- a. Bubbler tubes should be considered for the following applications:
1. In sumps and below grade tanks if the level instrument should be above the fluid level.
 2. For solids bearing, corrosive, or viscous fluids.
 3. For fluids that are subject to coking or solidification.
 4. If the measured equipment is at atmospheric pressure or below 0,07 bar(g) (1 psig).

These systems are normally only used on atmospheric pressure and freely vented systems.

- b. Selection of bubbler type level instruments shall include consideration of the following advantages and disadvantages:

Advantages:	Disadvantages:
Simple operation.	Requires a constant flow of process compatible bubbling media.
Above fluid level instrument location.	Head type measurement accuracy is affected by varying density of fluid.
Relatively low cost.	

5.9. Radar level instruments

- a. If costs and risks of malfunction, verification, and maintenance are high, radar level instruments may be considered for the following applications:
1. Applications that cannot be easily handled by other instruments.
 2. Toxic or hazardous applications.
 3. Sanitary applications.



- b. Selection of equipment for liquid-liquid interface measurement applications shall take account of the differential density of the two fluids, and the possibility of emulsion layers forming under normal or abnormal process conditions.
- c. Selection of radar type level instruments shall include consideration of the following advantages and disadvantages:

Advantages:	Disadvantages:
Non-contact measurement.	Relatively high cost.
High accuracy.	Low dielectric constant products may cause detection problems.
Low maintenance.	Feed horn coating in "dirty" vapour services.
Long spans of 1.5 m to 60 m (5 ft to 200 ft).	May be temperature limited.
They can be direct mounted to vessels (a standpipe is not required).	
There is significant field experience with very good performance.	
Low sensitivity to changing fluid temperature or varying composition.	

6. Gauge glasses

6.1. General

- a. Gauge glasses shall comply with BSI BS 3463 and the following:
 - 1. Glass tube gauges shall be subject to BP approval.
Due to their frailty and susceptibility to damage, glass tube gauges should be considered only for atmospheric vessels and clean, non-hazardous liquids at ambient temperatures. The gauge length should be restricted to 750 mm (2 ft 6 in).
 - 2. Each gauge shall be stamped with the maximum working pressure and temperature.
 - 3. Gauges other than those in vacuum service shall be fitted with safety shutoff ball checks.
 - 4. Through vision and reflex gauges shall be fitted with toughened glass.
 - 5. Compensation shall be made for expansion and contraction of gauges used on hot or cold liquids.
- b. Gauge glass gasket material shall be compatible with the process fluid.
- c. Pressure rating (at maximum temperature of the service) for gauge glass shall be at least twice the maximum operating pressure of the service.
This safety factor is necessary because gauge glasses may be subjected to repeated thermal and pressure cycling that fatigues the materials over a long period of time.
- d. Gauges on services below ambient temperatures shall be of the non-frosting type.
- e. Armoured tubular gauge glasses should be used only on equipment under atmospheric pressure, 2,5 m (8 ft) high or less, containing non-hazardous fluids at temperatures below 60°C (140°F). Tubular gauge glasses shall not be acceptable for any other use.
Tubular gauge glasses should not be used in process service or in severe utility service because they are susceptible to breakage from mechanical, temperature, and pressure stress.
- f. Armoured tubular gauge glass shall have a maximum length of 460 mm (18 in).
- g. Gauge glasses in services with temperatures greater than 260°C (500°F) or pressures greater than 7 000 kPa (1 000 psig) shall use Belleville type spring washer construction.



- h. The operating length of a sight glass shall represent the full physical working range of the vessel. Associated instrument level measurement should be calibrated to indicate over the same length.

6.2. Selection

- a. Reflex gauges should be used only on clean, non-viscous fluids that are not corrosive to glass.
- b. Through vision type gauge glasses should be used for the following:
 - 1. Interface.
Reflex gauges cannot detect a liquid interface.
 - 2. High viscosity fluids.
 - 3. Acid or caustic.
 - 4. Steam and condensate above 2 100 kPa (300 psig).

6.3. Glass surface shields

- a. Gauge glass shields shall be KEL-F, or an equivalent material subject to BP approval.
KEL-F (a registered trademark of 3M) is a common material used for gauge glass shields.
The pressure rating of non-shielded gauge glasses has approximately a 50% decrease in original pressure rating if shields are installed in the field.
- b. To resist gauge glass deterioration and possible gauge leakage:
 - 1. A system pH of 8,0 should have mica shields on gauge glasses operating in 2 100 kPa (300 psig) and above.
 - 2. A system pH of 9,5 should have mica shields on gauge glasses operating in 700 kPa (100 psig) and above.
Pressures for using mica shields for steam and condensate service is dependent on pH levels of the system. These shields protect the gauge glass from breaking.
- c. Caustic and acid services should have internal protective shields.
- d. If shields are installed, design pressure of assembly shall be reduced as recommended by the manufacturer.

6.4. Valves

- a. Gauge glass valves shall be angle pattern, offset design, with internal ball checks for ease in cleaning.
Internal ball checks prevent process leakage in case of glass breakage.
- b. Gauge glass valves directly connected to vessels shall have flanges.
- c. If extremely hot or corrosive fluids may contact the stem threads and cause the valve to malfunction, gauge valves (straight through or offset) should be Outside Screw and Yoke (OS&Y) type.

6.5. Connections

- a. Top/top, bottom/bottom gauge connections are preferred.
Top/top and bottom/bottom gauge connections allows rotation of gauges for best viewing, except in welded construction.

