Applying Tank Farm Safety Standards for Petroleum Storage Tanks in India

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Introduction

Like other process industry operations, petroleum tank farms present difficult challenges for automation and safety technology. Tank farms, storage areas and loading/unloading sites all need effective safety solutions to protect personnel, assets and the environment. The consequences of incidents at these facilities can be enormous.

The tank farm environment, being a hazardous area, requires continual monitoring of critical process parameters. Accurate and reliable tank level monitoring is especially important to prevent overfill situations. Some overfills are small and easily contained, but the accumulation of product from repeated overfills or a single large spill can cause significant soil and ground water contamination.

Worse yet, recent catastrophic incidents at tank farms and terminals can be traced to ineffective safety technology leading to loss of level control and, ultimately, to loss of containment.

Tank farm operations benefit from a holistic approach to industrial safety, which integrates advanced technology at all plant protection layers - and the people who interact with that technology - to help end-users achieve their safety objectives.

Overview

This white paper describes various standards and recommendations as per international and Indian publications addressing safety in petroleum storage tank farms. It also discusses possible technologies/solutions, which can be used to comply with industry guidelines and create a safe work environment.

Applicable Standards

- IEC 61511, Part 1, 2 & 3
- IEC 61508
- API 2350
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- Fire Protection and Prevention Act (NFPA)
- Oil Industry Safety Directorate (Government of India) Guidelines
- Buncefield Recommendations
- MB Lal Committee Recommendations

**Applying Major Standards**

Indian tank farm owners/operators adhere to the following standards and recommendations when implementing systems for tank overfill protection:

**IEC 61511 & IEC 61508**
IEC 61511 defines the safety standard end-users, safety instrumented system (SIS) designers and system integrators follow when implementing certified safety equipment. IEC 61511 applies when equipment meets the requirements of IEC 61508 or if Section 11.5 of IEC 615111 (prior-use or proven-in-use) is integrated into an overall system used for process sector applications.

IEC 61511 clearly states that manufacturers of equipment used on SIS must follow the requirements of IEC 61508 Section 2 and 3 unless the end-user has met the requirements of Section 11.5 “Prior-Use.” As such, equipment certified for safety loops with adequate SIL is a solution. A reasonable level of SIS must be used based on the studies. TUV-certified SIL2 instrumentation (e.g., radar or servo gauges) on tanks adequately meets these requirements.

**API 2350**
API 2350 Clause 1.3.4 (a-e), Integrated and Independent Level Detectors, stipulates that high-level detectors and high-high-level detectors must be independent. The use of an auto tank gauging system for high-level detection is allowed.

Applying this clause:

- The radar gauge portion of the tank inventory system combining high-level switching meets the independently certified (i.e., TUV) requirements for SIL2. In addition, servo level gauges for high-high-level switching (i.e., overfill safety switch) meet the independently certified (i.e., TUV) requirements for SIL2.

API 2350 Clause 1.3.4 (f) indicates that independent level detectors can be servo level gauges, radar level gauges, or a hydrostatic level gauging system.

Applying this clause:

- Radar gauges and servo gauges are both available as the most reliable solutions.

API 2350 Section 4.3, 4.3.1.2 and 4.8, Test Provision for Detectors, stipulates that testing procedures be as simple and replicate an actual alarm condition as realistically as possible. It states that an overfill protection system should be checked upon initial installation, and then retested frequently enough to determine its reliability and develop data establishing the testing, maintenance and inspection schedules. System electronic integrity operational tests should be done 24-hours prior to pipeline transfers, or weekly if pipeline receipts are very frequent.
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Applying this clause:

- Switches such as capacitance/vibrating forks or even radar gauges cannot simulate alarm conditions realistically, since they either need to be removed from installation and tested by touching the probe tips, or by giving commands for only the relay operation (radar gauges) checking. Hence, electronic integrity, together with operational mechanism proof testing, is not achieved and requires more labor-intensive methods. Servo gauges should employ operation-checking mechanisms, as per the API recommendations. As a continuous measurement device, these gauges require testing on a frequent basis. This provides an advantage over switches designed to operate when the alarm condition is reached.

Servo gauge operation checking is simple and can be performed from tank-side indicators, or even from the control room. The displacer is physically raised till the alarm levels and the operation of output (e.g., analog output to ESD systems) and relay contact changeover to the safety PLC can be checked. The entire testing operation takes approximately 10 minutes to complete.

API 2350 Section A3.4, Overfill Protection System Installation, stipulates that when two-stage detector systems are used (e.g., high-high overfill detector and high-level detection), they should be designed such that failure of any component in the first stage (e.g., high level) does not interfere with or incapacitate the operation of the second stage (e.g., high-high detection).

Applying this clause:

- Clearly, the selection of two different types of equipment such as radar for high-level detection and an independent high-high detector (e.g., servo gauge) meets this requirement.

**Buncefield Recommendations**

Competent authorities/operators at Buncefield-type sites should develop and agree upon a common methodology to determine SIL requirements for overfill prevention systems in accordance with the principles set forth in Part 3 of BS EN 61511.

Applying this recommendation:

- The Buncefield Recommendations call for a single, consistent methodology for terminal safety analysis. The IEC 61511 standard provides such a common methodology for functional safety, including analysis and determination of the SIL. The use of one common approach for terminal safety analysis allows for a more transparent overview of the various applications and safety requirements — resulting in a widely accepted and adopted method. This approach is also more cost-effective to maintain and easier to audit by authorities.

Operators of Buncefield-type sites can protect against loss of containment of petrol and other highly flammable liquids by adopting a high-integrity, automatic overfill prevention system (or a number of such systems, as appropriate) physically and electrically separate and independent from the tank gauging system.

Applying this recommendation:

- For adequate overfill detection, users should select a device developed by a certified hardware and software designer that is independent from the level gauge used as a primary level indicator, and employing a different method of level measurement.

The process industries have a long and successful practice of applying redundant process control and safety systems to operate their critical processes. Redundant process control systems and safety systems have achieved superior reliability and high availability through the application of a very important architectural first principle known as the
“separation principle.” The design criterion behind this principle is simple: separate safety and control. A radar- or servo gauge-based continuous level monitoring system, and a servo gauge-based independent overfill device with continuous monitoring and proof testing mechanisms, fulfills this requirement.

All elements of an overfill prevention system should be proof tested in accordance with validated arrangements and procedures, and on a sufficiently frequent basis, to ensure the specified safety integrity level is maintained, in practice, in accordance with the requirements of Part 1 of BS EN 61511.

Applying this recommendation:

- Imagine a petrol tank that requires an overfill prevention system with a SIL2 requirement. Just after the installation, commissioning and testing of the equipment, one can assume the SIL is 2 at that time. But what will it be at a later time; for example, after six months? Conducting a proof test will guarantee the hardware and software still do the intended job. Typically, a proof test will simulate overfill and verify the overfill detection and prevention systems are still able to function on demand.

For systems that can guarantee high diagnostic coverage, the proof test intervals can be extended to a period satisfying the safety demands. The use of two level measurements based on different principles, and comparing the results, will increase safety and improve the proof test interval.

**MB Lal Committee Recommendations**

These recommendations stipulate the SIL of the tank level control must be improved, with independent overfill protection meeting the requirement of Part 1 of EN 61511 in place. For this purpose, radar gauges should be provided at least in Class A tanks along with existing positive displacement level indicators/controls. In addition, MOVs serving as the primary items for cut off should be kept in proper working order, and the SIL level of the entire interlock loop should be raised to meet the requirements of EN 61511.

Applying this recommendation:

- In real life, the aforementioned recommendations will mean that pump shutdown loops are to be the SIL level of EN605111. For level measurement/control 1, radar/displacer type gauges with SIL2 certification should be used. For level measurement/control 2, independent overfill protection devices are necessary apart from the main level measurement 1. This recommendation emphasizes the use of radar gauges for Class A tanks, but it contradicts the need to apply proof testing standards for the overfill device. However, the decision regarding the application of all standards ultimately lies with the user.

**OISD Guideline 152**

Clause 4.2.12

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4.2.12 STORAGE TANKS

Following safety instrumentation shall be provided in line with OISD-STD-108:

(i) Tanks shall be provided with at least two numbers of level instruments working on different principles. One of the above shall be used for High-High and Low level alarms.

(ii) Automatic isolation of tank receipt line based on High-High Level sensing device should be considered for tanks receiving at high flow rates (unloading from ship/pipeline receipt etc.).

(iii) Low-low level switch from the primary level instrument to stop transfer pump (optional).

(iv) High temperature alarm should be provided wherever required.
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Applying this clause:

- OISD Guideline 152 stipulates the use of radar and servo gauges employing different principles for level measurement in storage tanks, with servo gauges serving as the high-high detector switch (even low-level detection is possible). For high-speed transfers into and out of storage tanks, it is necessary to use a level detector with a 40 mm per minute capability.

OISD new guidelines:

Tanks must have at least two types of level instruments, with one having a local display and the other located in the control room. In addition, high/low-level alarms with independent primary sensing devices should be provided. This includes a high-level alarm from the radar gauge and a high-high-level alarm from a separate tap off.

Applying this clause:

- Radar and servo gauges use different principles for level measurement in storage tanks. Radar gauges should have built-in indication on the tank top, as well as remote indication in the control room for high-level detection. Servo gauges should have tank-side indication with a proof testing facility, and be used as an overfill detector (i.e., high-high detector). These level detectors should be installed in two different locations (i.e., tap-offs) on the tank top.

Tank Gauging Solutions

Honeywell Enraf has been committed to making precision instruments since 1925. The company introduced automatic servo level gauging technology in the 1950s, and soon after released the first automatic level gauge used in bulk-liquid storage facilities to assess holding tank content and manage tank inventories.

Honeywell Enraf provides a comprehensive range of products and systems for tank farm safety applications such as tank level gauging, tank overfill monitoring, and floating roof monitoring. These solutions are compliant with all major international standards.

Servo Level Gauge

Serious accidents at tank farms and terminals have shown the potential for loss of life and economic impact when overfill is not effectively monitored and stopped. Overfill protection also prevents the legal ramifications that can impact companies in countries with overfilled tank penalties.

Thanks to Honeywell Enraf's level measurement solutions, tank farm operators can significantly improve the performance of overfill monitoring. The company’s servo level gauge is equipped with a new servo auto test feature for overfill protection loops requiring SIL2 or SIL3 solutions to prevent spillage.

The increased diagnostics of the servo level gauge allows it to detect failures inside the device or in the application, and report these problems to higher-level systems for further action — thus mitigating the possibility of mechanical failure.
Main features:

- $\pm 0.4$ mm accuracy
- Custody transfer gauge
- Indian W&M approval
- Overfill protection by two-relay contact
- TUV approved for SIL2
- OIML certification
- MTBF 40 years
- Proof-testing through the tank-side indicator and/or from the control room
The integrated keyboard on the Honeywell Enraf tank-side indicator provides the proof testing facility and password-protected use, thus preventing unauthorized operation.

Typical installation:

![Figure 4: Typical servo level gauge installation.](image)

**Servo Gauge**

The Honeywell Enraf servo gauge is a very reliable, versatile and accurate automatic tank gauge. The instrument is designed for measurement of all kinds of liquids in any type of storage tank. It is a multi-functional instrument, provided with microprocessor boards. The first or master board provides the backup and a number of user interfaces such as the display; communication channels including IR and BPM; 4-20 mA analog output; and 2x SPDT relay contacts. The servo gauge is SIL2 certified by TUV.

With the Honeywell Enraf servo gauge design, the displacer is positioned in the liquid, which produces buoyancy; in other words, an upward force equal to the weight of the displaced product (Archimedes principle). The apparent weight is the weight of the displacer minus the buoyancy. The heart of the servo gauge is a force transducer and a motor unit. The force transducer is an accurate weighing balance that continuously measures the apparent weight of the displacer. The motor unit is able to
position the displacer very precisely to any position in the tank. For level measurement, a set point is programmed to
correspond to the apparent weight with the displacer partly immersed. The measured apparent weight is compared with the
set point and the displacer is positioned up or down until equilibrium is obtained. The displacer is then at level. With falling
level, the buoyancy will decrease so that the force transducer experiences an increase in the apparent weight. The servo
controller will then lower the displacer until equilibrium is achieved. The gauge follows the falling level, and the process is
reversed at rising level.

Honeywell Enraf servo gauges have the following I/O options for use in overfill detection:

- 2x SPDT relay contacts
- 4-20 mA output
- IS output for connections to tank-side indicator
- Power input: 110 V-240 VAC
- Optional output to tank inventory system

Deployment of the servo gauge for overfill protection is as follows:

- **Normal Operation** – The servo gauge is first commissioned by qualified engineers trained on the equipment, and its
  functionality is demonstrated to the user. Initial proof testing is done after the commissioning. The owner of the
  installation is trained in proof testing of the gauge via a live demonstration using the tank-side indicator and handheld
  terminal.

- **Periodic Proof Testing** – As per the frequency dictated by the installation, operators test the servo gauge using push
  buttons on the keyboard of the tank-side indicators, or through the remote test facility of the handheld terminal/TFMS
  (in case the gauge is connected to the control room on digital transmissions).

- **Continuous Online Integrity Testing** – The servo gauge analog output, which is connected to the PLC system,
  continuously monitors level information from the gauge. Also, the PLC connected to the tank inventory system has
  the flexibility of continuous monitoring and verifying servo gauge functions. An additional alarm of suspected
  malfunctioning of either the tank inventory or overfill gauge is generated when the SIL3 PLC detects a difference of
  more than 3 to 4 cm. In the event of such alarms, operators must follow emergency precautions and immediately
  verify the servo gauge using a defined proof testing procedure. In addition, they should check the tank inventory
  system/level gauge for proper operation.

Servo auto test features for additional safety checks include:

- Testing feature in gauge software
- Mechanical system monitoring: displacer, wire, drum, magnet coupling, main shaft, motor-block and force transducer
  Tests:
    - Free movement of displacer
    - Level repeatability before/after test
    - Successful completion of tests
- Automatic:
  - At start-up
  - Periodic (configurable; one-minute default)
- Delayed after last movement (filling or emptying)

Radar Gauge
By combining entirely new software algorithms with Honeywell Enraf’s advanced planar antenna technology, SmartRadar FlexLine gauges ensure the levels of precision demanded for custody transfer accuracy. Enhanced performance signal processing makes it possible to provide accurate level readings even when a free space antenna is installed close to the tank shell. Honeywell Enraf gauges use the OneWireless™ universal mesh network to seamlessly integrate any supervisory system to optimize plant productivity and reliability, improve safety and security, and ensure regulatory compliance. The FlexLine is also approved by TUV for SIL-rated loops. As such, the radar gauges can be used in overfill protection loops to prevent spillage.

Main features:

- Custody transfer accuracy
- Indian W&M approval
- Overfill protection by two-relay contact
- TUV approved for SIL2
- OIML certification
- MTBF 40 years
- Proof testing possible through tank-side indicator and/or from control room

Figure 6. Servo gauge auto test.

Figure 7. Radar level gauge.
A. Smart View Tank Side Indicator

Main features:

- Loop power from the radar gauge
- Two-line, 16-character, backlit display
- Configuration of radar gauge through integral keyboard
- Proof testing commands to radar gauge

![Figure 8. Installation of tank-side indicator.](image)

B. Overfill Protection Using Radar Gauge

Honeywell Enraf radar gauges have the following I/O options for use in overfill detection:

- 2x SPDT relay contacts, SIL2-certified by TUV (additional two-relay contacts for alarms at other levels)
- 4-20 mA output
- IS output for connections to tank-side indicator
- Power input: 110 V-240 VAC
- Optional output to tank inventory system

The Honeywell Enraf FlexLine radar gauges can be used for specific Safety Instrumented Function (SIF) applications requiring SIL1 or SIL2 certification. If installed in a redundant arrangement, the gauges can be applied in loops needing SIL3.
C. Proof Testing Using Radar Gauges

During proof testing, the alarm condition indicating over- or under-fill can be simulated by initiating "Start Proof Test " from the Smart View indicator or from the control room through software.

Proof test operation activates the relays by simulating alarm conditions; the results can be seen physically at terminals or the control element, or viewed in the software as “status.” The proof test can be terminated by initiating "Stop Proof Test " from the Smart View indicator or from the control room through software. Plus, the test can also be configured for automatic termination without manual intervention.
Figure 10. Safety implementation – petroleum storage facility.

<table>
<thead>
<tr>
<th>Primary Sensing</th>
<th>Signal Transmission</th>
<th>Control</th>
<th>Final Control Element</th>
<th>Essential Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radar Gauge</td>
<td>FR Cable (Multi drop allowed)</td>
<td>For Process &amp; SAP</td>
<td>Second Tank Body Valve for Operation</td>
<td>Only for Inventory Mgt</td>
</tr>
<tr>
<td>Radar Gauge’s SIL 2 Level switch set for High Alarm</td>
<td>FR Cable (Direct for Line monitor)</td>
<td>For Safety Control to SIL 3 PLC</td>
<td>ROsov First Tank Body Valve</td>
<td>Additional Direct High Alarm in Safety PLC, Close ROsov from CR</td>
</tr>
<tr>
<td>Servo Level Gauge on a separate Tap off</td>
<td>FR Cable</td>
<td>Backup for Safety Control to SIL 3 PLC</td>
<td>ROsov First Tank Body Valve</td>
<td>Generate Soft HH Alarm in Safety PLC, Close ROsov</td>
</tr>
<tr>
<td>Servo Level Gauge’s SIL 2 Level Switch for HH Alarm</td>
<td>FR Cable (Direct for Line monitor)</td>
<td>For Safety Control to SIL 3 PLC</td>
<td>ROsov First Tank Body Valve</td>
<td>Generate HH Alarm in Safety PLC, Close ROsov</td>
</tr>
</tbody>
</table>

Figure 11. Overfill protection subsystem.
Other Overfill Protection Solutions

Depending upon the user’s design requirements, Honeywell Enraf can provide a solution beyond those suggested in this white paper. One such solution could be a level switch providing relay contact changeover at overfill level. However, proof testing of these probes often invites operational challenges such as increased frequency of testing.

The level switch operates on a two-crystal pulsed or “transmit-receive” principle, which applies a high-frequency electronic burst to the transmitted crystal. The signal is then converted into ultrasonic energy and transmitted across the sensing gap towards the receiver crystal. When there is air in the gap, the high-frequency ultrasonic energy is attenuated, thereby prohibiting the energy from being received. When there is liquid in the gap, the ultrasonic energy propagates across the gap and the current shift or relay output will indicate a reception of the signal.
Specifications

- Relays with two-output connections: one DPDT contact and one alarm contact
- Proof test simulation relay level alarm (dry or wet) and separate test simulation alarm relay
- Power supply: 102-265 VAC
- Flange connection: 1” to 2” and 150# to 600#
- Usable for liquids with no calibration required
- Configurable for high/low-level failsafe
- Ultrasonic level switches (pulse signal technology)
- Continuous self-test
- LED indications for process alarm, errors, wet and dry status
- SIL2 according IEC 61508 – SFF > 90%
- Push-button for manual testing and error signal
- Unaffected by:
  - Shifting dielectric, density, or pH of the liquid
  - Presence of foam, turbulence or visible vapors
  - Fast drain/fill rates
  - Vacuum conditions
- Broad range of viscous to light liquids
- IP66 enclosure
- ATEX II 1/2G EEx d IIC T6
References

1. Recommendations on the design and operation of fuel storage tanks (MIIB) [http://www.buncefieldinvestigation.gov.uk/index.htm].
6. OISD Guideline 152 – Safety Instrumented System Std 152 SE.
7. MB Lal Committee Recommendations.

More Information
To learn more about Honeywell Enraf’s Tank Farm Safety Solutions, contact your Honeywell Enraf account manager or visit [www.honeywellenraf.com](http://www.honeywellenraf.com)