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EPA **Project Summary**

Fail-Safe Devices for the Prevention of Hazardous Materials Spills

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Many hazardous material spills can be prevented by the use of automatic container-filling procedures to determine when maximum capacity is reached. This project assessed current fail-safe technology, conducted laboratory tests of automatic devices and monitored performance of on-site automatic level controllers.

In the assessment of current technology, available data on devices used to prevent tank overflow were identified and reviewed. Fourteen types of devices were investigated to determine their potential for automatic container-filling control. Although most of the fourteen level detectors could measure for either wet or dry products, some could measure both wet and dry products. The detectors were activated by electrical, electric/pneumatic, pneumatic, or mechanical action. The fourteen types of level detector devices are pressure devices, float level controls, capacitance level detectors, conductive level measurements, thermal probes, sonic-echo level monitors, inductive-level detectors, rotating-paddle level detectors, vibration-level detectors, automatic sounding, light and sight glass measurement, radiation-level measurement, microwave-level measurement, and pressure tape.

Three different types of industrial plants, each having an overfilling problem with a different material, cooperated in the field testing phase. The three level control devices tested were ultrasonic, vibrating tines, and magnetic-coupled-float types, respectively.

Two of the units were activated by electricity and the third was activated pneumatically. One unit controlled dry powder, the second, a viscous liquid, and the third, an aqueous liquid. Each location required an explosion-proof system. All three units were installed without significant revisions to existing containers, and all operated well for an extended period under severe weather conditions. The proper controller configuration must be compatible with the environment and must also incorporate requisite safety features and demonstrate corrosion fouling and weather resistance.

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Introduction

Hazardous material spills which pollute water resources and the atmosphere constitute a peril to human and environmental health. Prevention of accidental spills is essential to environmental protection. An earlier report, *Hazardous Material Spills: A Documentation and Analysis of Historical Data* (EPA-600/2-78-066), established that the chief cause of hazardous material spills was the overfilling of containers (tank overflow).

Many such spills can be prevented by using automatic container filling procedures which employ remote, automatic level detectors as fail-safe devices. Although numerous types of level and volume control devices are commercially available, caution in choosing and operating the devices will assure that they will function adequately and safely within the process to be controlled.

In this project, the current technology in level control devices was assessed to determine the kinds of controllers available and their ability to control different types of hazardous materials spills automatically, and to evaluate their potential for use with wet and dry materials. From this assessment, three different types of fail-safe level control devices were selected for field use, one each at three different industrial sites. Each fail-safe level controller was to be tested for an extended period to demonstrate its spill-prevention properties. The field studies were also to determine the environmental conditions in which a device must operate.

Technology Summary

During the technology assessment, many methods of measuring the level of stored material in a container were identified, ranging from extremely simple to very complex. Most of the available level detector-controllers also can be used for remote, automatic sensing to assure safety and continuity of measurements of hazardous materials in pressurized vessels. The transducer mechanism within the various detectors is generally dependent on one of the following conditions or devices: pressure, capacitance or conductance changes; float, displacer or paddle switches; weight and tape sensors; ultrasonic echos; inductance, thermal or light sensors; radiation and weight sensors. Activation of a signal from within each type of transducer can be initiated with an electrical, electric-pneumatic, pneumatic or mechanical trigger. A brief description of each of the fourteen categories of level controlling devices follows.

Pressure Devices

Generally employed for measuring liquid levels, pressure devices can range from simple bubble tubes that use atmospheric or inert gases to differential pressure devices and pressure-diaphragm devices. Pressure devices can be used with other types of mechanical or electrical connectors to integrate electrical signals to control fill pumps, valves, etc. These systems are generally simple and can be used in hazardous atmospheres. Disadvantages can include clogging, corrosion of, or introduction of foreign matter into a process.

Float Level Control Devices

These indicators monitor liquid levels and may employ either ball type floats, surface floats or displacer floats, generally mounted in a container at the top or sides, in a standpipe (open or caged), to activate pumps, valves, or other devices by means of mechanical linkage, electric switches, or pneumatic transmitters.

Capacitance Level Detectors

These indicators can be used with liquids. A variable capacitor is formed when an electrode is mounted in a tank with metal walls or, if the tank is not conductive, another electrode is mounted at a distance from the first electrode. The capacitance between the electrodes varies with changes in the depth of liquid in the tank, and these changes more or less expose the surface of the electrodes. Thus, as the level of material in the tank rises, the dielectric constant varies accordingly. The capacitance is measured, and readout meters are calibrated for the container depth. These detectors can be point or continuous types. The electrodes may need to be sheathed if the liquid is conductive. Capacitance detector systems may occasionally be coated with adhering material, yielding false readings.

Conductive Level Measurement Detectors

In these detectors, two probes a conductive fluid with a device to measure the flow of current can sense the point level of the contents of a tank. Usually, the tank serves as the grounded electrode, and both a high-level and a low-level electrode are needed. The outputs are connected in order to control pump start-up at the low level and shut-off at the high level. Splashing, foaming, turbulence, temperature and conductivity must be measured to avoid false readings.

Thermal Probes

A thermal probe is a point-level indicator using a self-heating glass bead thermistor as a sensing element. Since the heat dispersion is greater in a liquid environment than in a gaseous environment, a large voltage change occurs when a liquid level rises to envelop the sensing element. The thermistor probe is a negative-coefficient resistor in which resistance increases proportionally to the decrease in temperature; therefore, with greater heat dispersion in a liquid, the sensor cools, and a greater voltage signal is sent to the amplifier, which, in turn, operates relays that control valves and pumps.

Sonic-Echo Level Monitors

These devices consist of a pulse generator, transmitter, receiver, amplifier, and control circuit. They are ultrasonic, sonic and sonar echo devices which measure the time a pulse takes to travel from a transmitter to a reflecting surface and back to the receiver. The measured time is a reflection of the distance between the surface of the material and the transmitter/receiver. The signal received can activate valves or pumps to control tank filling and emptying. Ultrasonic and sonic systems are non-tactile, and sonar systems are usually immersed in the material being measured.

Inductive Level Detectors

Inductive systems can detect the level of conducting metal objects. As the metallic object enters an electromagnetic field produced by an oscillator, it disrupts the field. This disruption varies a voltage-sensitive circuit which operates a relay that activates a control system. Only under special conditions are induction systems used to monitor levels. These systems are more often used in process lines to detect tramp metal in order to prevent damage to process machinery.

Rotating Paddle Level Detectors

In these detectors, rotating paddles detect the presence or absence of bulk material at a specified level in a tank. They are used for point level detection. A small electric motor provides constant paddle rotation while the paddles are clear of any solid material. When the vessel is filled to the level of the rotating paddles, the paddles stall and a switch is actuated, signaling a cessation of rotation at the level caused by the material in the tank. Paddles may be used for high-point, low-point, or any other level detection.

Vibration Level Detector

Tuning fork, vibrating paddles, and vibrating probes used as point-level detectors all work on the same principle. When the vibrating element comes in contact with a bulk material after exposure to gas (air) or when two bulk materials of different densities are encountered, the vibrating frequency either stops or changes. All vibration detectors must be used in dry bulk that does not arch or bridge and is not sticky. Any cavity formed by the vibrations or any material adhering to the surface will produce false readings.

Automatic Sounding Detectors

Automatic soundings are made with a weight (for bulk materials) or float (for liquids) and employ a cable device to measure the level of materials in silos, bins, or tanks. This device has a motor-operated drum which may be actuated manually or automatically to obtain a continuous record of the amount of material in the vessel. When the motor is actuated, a measuring cable with the float or weight at the end runs out, producing an electrical pulse at regular intervals. The number of pulses counted is an inverse indication of the quantity of material stored in the vessel. When the weight or float contacts the surface of the medium, the drum rewinds the tape. Consequently, set points for automatic control of stored materials are easily established.

Light and Sight Glass Measurement Detectors

A light-beam breaker system can be used as a method of point determination. It consists of a light source and photo cell connected to light conducting plastic probes which protrude into the tank space and are separated by a gap. When the stored material interrupts the light path, a relay activates control circuits. When the material falls below the probes, the relay is deactivated or another relay is cut in and other control circuits take over. In a similar approach, a directional light source is focused on a phototransistor. As a filling liquid immerses the light source, the change in refraction inactivates the phototransistor, triggering a signal. The basic sight glass is a tube between a pair of valves used for visual checks of amounts of material in a tank.

Level Detectors Using Radiation

When properly installed, isotope source-level controls present no hazard to plant personnel and are cost effective. Both source and detector(s) are mounted externally and are able to monitor almost any liquid or solid. These instruments are used for point- or continuous-level detection.

For point-level detection, a radioactive source produces a gamma ray beam which penetrates the vessel walls and, when there is no product intervening, strikes a detector. The detector produces an electrical impulse in relation to the gamma photons received. When the material in the vessel rises to intercept or scatter the photon path, a different intensity of impulses is produced by the detector. For full-range level indication and control, the source has a wider angle of emission and a continuous level detector is used. Atomic Energy Commission licensing is not required for these systems because the radiation is minimal.

Microwave Level Detectors

Microwaves may be used when a non-tactile control device is required. The system consists of a transmitter, oscillator and directional antenna; and a receiver, directional antenna, amplifier, pulse coding network, voltage comparator circuit and a relay driving circuit. Microwaves emitted from the directional antenna are picked up by the directional receiver.

The conductivity of the material being measured determines the signal attenuation. Metal tanks and hoppers reflect microwaves, and storage vessels using this method of measurement must be provided with windows of materials such as high-density polyethylene. Air transmits microwaves with little or no loss, whereas water-based materials (or those materials with a significant water content, such as grain or wood) absorb them. As the air space in the microwave beam becomes filled with material, the transmitted microwaves are either cut off from the receiver or sharply reduced. This method can be used for point level indication or to drive a control system.

Pressure Tape Detectors

In these devices, a tape made up of a loop of resistance wires or contact points, normally held apart, is inserted in the vessel to be measured. As the product is introduced into the vessel, pressure on the tape forces the wires into contact. As the vessel fills, the wires touch or the contact points close, shortening the resistive path of an electric current. The resistance measured varies inversely with the level of product stored. This type of instrument continually measures the level in the vessel and can activate relays at preset points to control process, fill, and discharge.

Field Evaluations

After the assessment of the state of the art technology was completed, three different types of level control devices were chosen for field evaluation in an industrial environment: ultrasonic, vibrating tines and a magnetic-coupled float unit. Each of the units was installed at one of three different industrial plants, each experiencing a problem with a different material.

An ultrasonic controller was installed at one plant to prevent overfilling of an outdoor grease tank which had a history of small spills. This unit, with its non-tactile properties, was chosen to prevent grease overflow. An ultrasonic transducer was mounted on the tank and connected to controls in the pump room. The controls had high and low set points and a direct meter readout showing the amount of grease in the tank. In operation, these controls shut off the fill pump when the level of grease in the tank reaches a predetermined level or if a loss/signal occurs due to transducer clogging or electronic failure. Although several minor operational problems occurred, these were corrected and the unit operated successfully for more than three years, after which it was removed and installed at another plant to monitor the levels of wood pulp in a paper pulp chest supplying a paper machine. After two years of successful operation in this role, the unit was removed for laboratory examination. After 5½ years operating in harsh environments, this unit was found to function well.

At another plant, two sets of vibrating forks were used to monitor the filling of containers with a dry powder, PVC. A system was designed to indicate the high cutoff point and a low refill point. A series of panel board lights was used to indicate the relative fullness of the containers. Although minor operational problems were encountered during rapid filling, the system worked well for plant personnel. The unit had been in operation for five years before it failed due to a defect in a relay and a damaged tine assembly.

At a chemical plant, a pneumatic, diaphragm-type level sensor was installed to control filling of a tank holding acids or potentially explosive solvents. The unit produced a pneumatic signal that was 3 psi when the tank was empty and 15 psi when the tank was full. Two pressure switches in a remote control room were activated by this pneumatic output signal. When activated, these switches interrupted signals to solenoid valves. Thus, if a tank was filled to produce a 15 psi pressure, the fill valve was closed and filling ceased. The second pressure switch was designed to activate at a pressure of 3 psi or less in order to close the fill valve. This served as a fail-safe device in case of a shutdown of the pneumatic system. The device was installed and operated over a 5½ year period, during which time several mechanical and other malfunctions of the device occurred. However, the malfunctions were not considered unusual or excessive within the harsh operating environment, and design changes might well eliminate the problems.

Conclusions

The level of material in a container, tare weight, contents, the volume occupied by the material, pressure exerted by a fluid, emissions of gas or radioactivity may all be used for monitoring a quantity of material. The method of transferring this information may be by mechanical linkage, electric signal, hydraulic or pneumatic pressure. The readout may be continuous, representing the total range of the container capacity, or it may be for one or more points. Continuous signals may be used to set limits on the contents of the container, and the point signals may be placed in the container to act as limit points. In this way, low-level, high-level, and other alarms may be obtained. The signal activating the alarms can also be used to start or stop pumps and to open or close valves.

The type of level detector or controller must be carefully chosen to be compatible with the material being monitored and the environment in which it is placed. Chemical and physical requirements govern the choice of equipment to be used. Although some level detectors will work well with either wet or dry and both wet and dry materials, others are made only for wet or dry materials. Dangerous, explosive, flammable, caustic materials in the container or in the vicinity determine the types of level indicators and controllers to be chosen. The material composition of the level indicator in contact with the contained material and the surrounding atmosphere must be carefully considered when choosing a level sensing or control device. The mode of action of the transducer must also be compatible with the material and tank atmosphere (e.g. explosion-proof relays). When appropriate automatic level detection fail-safe devices are chosen and installed, they have been demonstrated to virtually eliminate spills resulting from overfilling of containers.

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The complete report, entitled "Fail-Safe Devices for the Prevention of Hazardous Material Spills," (Order No. PB 85-138 642; Cost: $11.50, subject to change) will be available only from:
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