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EVALUATION OF BUBBLER/DIAPHRAGM
TECHNIQUES TO MEASURE SURFACE
LEVEL IN THE WASTE STORAGE TANKS

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SUMMARY

This report describes the results of tests conducted at the Pacific Northwest Laboratory (PNL) to determine if a bubbler technique can be used to determine the surface level in the waste tanks. Two techniques were evaluated. The first technique is a standard bubbler system in which a tube is placed below the surface of the liquid to be measured and air pressure inside a tube is increased until bubbles begin to become emitted from the tube. The air pressure then is a function of the pressure at the bottom of the tube. The second technique involves a system similar to the standard bubbler technique, but instead of bubbles being released into the material to be gauged, air pressure is increased against a diaphragm until enough pressure is applied to overcome the pressure of the liquid at the given depth, at which time the air then flows in a return loop back to a vent. The advantage of the diaphragm system is that it is a sealed system; thus no air is released into the waste tank materials, and it is not possible for the waste tank materials to get into the air flow. In both of these techniques, the density of the material needs to be known in order to determine the surface level. By using two or more of these devices at a known vertical separation from each other, the pressure difference between the two devices can be used to determine the density of the liquid.

A liquid is required in order for these devices to operate. For these tests, water was used first to determine the ideal operation of the devices, and then the devices were placed in a 101-SY waste tank simulant. The simulant had a density of 91.7 lb/ft^3 (1.47 gm/cm^3) and had a consistency similar to the convective layer in the 101-SY waste tank.

The results of the tests indicate that the devices could measure the surface level accurately (approximately $\pm 0.06 \text{ in.}$) in both water and simulated waste tank material providing that the waste tank material did not adhere to the exit port of the bubbler or the diaphragm. However, both the bubbler and diaphragm techniques exhibited inaccurate readings when placed in the simulant over a period of time. The standard bubbler clogged after one day in the simulant, resulting in variations in the reading of the level of $\pm 0.5 \text{ in.}$ The diaphragm system also exhibited variations in reading of the level of ± 0.16

in. after approximately five days in the simulant. Flexing the diaphragm by turning the air supply off and on several times resulted in the gauge properly reading changes in the level and returning to a normal ± 0.08 in. variation in the reading, but inaccurately reading the absolute level. This was probably due to the settling of the simulant material in the test tank and/or the deposit of material on the diaphragm. The diaphragm developed an offset in the level reading in both the water and the simulant when the gauge operated over a period of time which appears to be caused by variations in the air flow.

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BACKGROUND

The surface level of the contents of the waste tanks has been measured for several years using a Food Industry Corporation (FIC) electrical contact probe, manual-weighted tape, and zip cords. All of these devices exhibit problems in determining the distance to the waste surface. When the FIC probe contacts a liquid surface, electrical contact is registered and the liquid level is determined by measuring the amount of cable that was extended into the tank when electrical contact occurred. The desired accuracy for measuring the surface level is ± 0.25 in. (± 6.4 mm). The surface level is automatically recorded using a data acquisition system at predetermined times depending on the status of the tank. With the manual tape, a weight is placed at the end of a steel tape. The tape is lowered until a current meter connected between the tape and the riser shows a full-scale deflection. The level reading is taken from the tape. With the zip cord, the prestretched cord is lowered through a riser until the operator detects slack in the cord. The amount of cord that is released until slack is noted in the cable is used to determine the surface level.

One of the problems with measuring surface level using the contacting FIC probe, as well as the manual tape, is that crystals form on the probe or weight as it is withdrawn from the liquid material. This leads to inaccuracies in subsequent measurements made with the device. Another problem with the FIC probe and manual tape is that it cannot determine the level of solid materials if the surface dries out and it becomes nonconductive. Also, the weight of the probe or weight at the end of the FIC probe or manual tape eventually may pound a hole into the solid material, resulting in a false reading. Finally, because the dried-out sludge level can be uneven and the salt cakes may shift, the probe may produce false readings of the actual (average) level of material in the tanks. The manual tape can also give inaccurate readings due to thermal expansion of the steel tape. The level measurement with the zip cord is dependent on the subjective determination of slack by the operator.

A radar gauge was installed in the 101-SY waste tank as a noncontacting method to measure surface level. However, its accuracy was affected by the changing surface conditions.

Thus, a better method needs to be found to determine the level of the surface. Bubbler systems have been used for a long time in measuring the surface level in liquid storage tanks. The purpose of this project was to evaluate whether such a method could be used to measure the surface level in the waste storage tanks at Hanford. A bubbler system could not be used on a tank that contains a hard surface. Even the tanks that are liquid in nature generally do not contain a viscous liquid like water, but contain sediments, like sludge, that could clog a bubbler system. The advantage of a bubbler system is that no electronic parts are placed in the waste material. Hence, the electronics are not exposed to high radiation fields. The only thing that is placed in the waste materials is a tube, and easily obtainable tubing materials will withstand the caustic and radiation environment of the waste tank. The tube in the bubbler system would need to be braced if it is placed inside a tank whose contents shift or burp in order to prevent the bubbler tube from bending, which would affect the air flow through the tube.

THEORY

Bubbler systems have been used to measure liquid level since the advent of compressed air and are commonly found on the Hanford site in applications where corrosion, plugging, and freezing are not a problem.

The theory of bubbler operation is shown in Figure 1. A "dip tube" is installed in a vessel with its open end about three inches from the bottom. A flow of air passes through the tube; and when the pressure of the air in the tube equals the hydrostatic head of the liquid, bubbles begin to escape from the end of the tube (hence the name "bubbler"). As the liquid level varies in the vessel, the pressure in the dip tube changes proportionally. With an appropriately calibrated pressure transducer, level can be read out directly from this pressure signal. The pressure at the bottom of the tube is a function of both the depth of the liquid above it and the density of the liquid. The density of the liquid can be determined by placing another bubbler a known vertical distance from the first tube and reading the pressure difference between the two bubblers.

The dip tube is normally fabricated from 1/4-in. or 1/2-in. tubing compatible with the process liquid, with an angle or groove cut at the bottom to allow the bubbles to escape more easily. Plastic tubing, tubing runs longer than 6 feet, and tubing in agitated tanks require continuous mechanical support. The purge gas pressure is kept about 10 psig higher than the highest hydrostatic pressure to be gauged, and the flow rate is kept small so that there is no appreciable pressure drop in the tube (about 1 SCFH or 500 ml/min). Usually the purge media is air or inert gas, but liquid can also be used.

At Hanford, the pressure signal is normally monitored with a differential pressure transmitter which uses the tank vapor space as a reference, since it may be at a different pressure than the atmosphere. The transmitter then usually sends a 4-20 mA signal to a remote display which indicates the level.

Like any other measurement system, the bubbler has advantages and disadvantages. It is a simple and inexpensive technology; and by using an

FIGURE 1. Typical Dip Tube Bubbler

explosion-proof transmitter, a bubbler can be installed in Class 1 hazardous areas. No electronic parts are placed in the radioactive and corrosive environment of the waste tank. However, it has several disadvantages, including limited accuracy, nonlinearities due to changes in purge flow rate with level, and introduction of gas or liquid into the process. If the purge media fails, not only is the readout lost, but the system is exposed to the process material, which can cause dip tube plugging, corrosion, or freezing.

There are at least two improvements which can be made to reduce or eliminate some of the problems associated with the simple bubbler. One improvement is to use an automatic flow regulating valve to ensure constant flow through the dip tube regardless of level. Another improvement is to use a diaphragm to provide a flexible barrier between the process and the purge media, therefore isolating the purge media from the liquid to be measured.

Both of these improvements are implemented in the bubbler system shown in Figure 2. The hydrostatic pressure exerts an upward force on the diaphragm proportional to the process liquid level. Pressure from the purge media (usually air) is then applied above the diaphragm until the hydrostatic pressure is just equal to the air pressure. As the air pressure is increased

FIGURE 2. Typical Diaphragm Bubbler

further, the diaphragm bulges slightly downward and away from the end of the tube, allowing the air to escape through the vent hole to atmosphere. This pressure and flow are then automatically kept constant as the process liquid level varies.

This system also has its disadvantages. The diaphragm is not a perfect conductor of pressure fluctuations, and as such, has a somewhat more restricted linear range. In addition, each time the liquid level varies, the diaphragm experiences small oscillations, which can cause an extended response time.

The tests described in this report were intended to explore the accuracy and repeatability of waste simulant level measurement, using these two bubbler configurations.

TEST RESULTS

TEST SET-UP

Figure 3 shows the apparatus which was designed to test a simple dip tube bubbler and a diaphragm-type bubbler (see Appendix A for material list).

The major constituents of the waste simulant used in this test are shown in Table 1. The density of the simulant was measured to be 91.7 lb/ft³ (1.47 gm/cm³).

Because of the caustic nature of the simulant and the amount of simulant available, the test vessel volume was minimized as much as possible. The vessel was made out of a 5-foot section of 4-in. clear PVC pipe which held approximately 3 gallons of liquid. Visual liquid level was determined with standard tape measure, fastened lengthwise along the side of the test vessel. A 1-in. valve was provided at the bottom of the vessel to facilitate draining during calibration and between tests. All components and materials which came into contact with the simulant (or the simulant vapors) were made of stainless steel, polyethylene, or PVC.

TABLE 1. Chemical Components of Simulant

Component	Weight Percentage (%)
H ₂ O	31.83
NaNO ₂	17.95
Na _{1.21} AlO ₂	15.53
NaNO ₃	12.31
NaOH	6.45
Na ₃ PO ₄	4.48
Na ₃ HEDTA	3.38
Na ₂ CO ₃	2.79
NaCl	2.02
Na ₄ EDTA	1.65

FIGURE 3. Bubbler Test Apparatus

Compressed air was used as the purge medium. The lab air supply was regulated down from 95 psig to approximately 15 psig (a pressure gauge was used to verify the regulated pressure level). When performing the dip tube bubbler tests, a rotameter and needle valve were used to adjust air flow. When performing the diaphragm bubbler tests, a differential flow relay was used to regulate air flow.

A differential pressure transmitter was used to measure the air pressure, with the low pressure port vented to atmosphere. Care was taken to ensure that the top of the vessel was vented to maintain atmospheric pressure in the vapor space above the liquid. The differential pressure transmitter provided a 4-20 mA output proportional to the measured pressure difference, which was calibrated to read out as level on a digital display. A quick disconnect and flexible tubing were used to connect the air supply and differential pressure transmitter to each bubbler test apparatus.

The bubbler system and the diaphragm system were tested first in water, to determine the accuracy, precision, and repeatability of the system, and then in simulated waste tank material, to determine the operation of the measurement systems in an media containing various particulates.

CALIBRATION

A relative calibration was used to ensure consistency between tests and to make maximum use of the accuracy and adjustable range of the differential pressure transmitter. A re-calibration was performed each time the process liquid or bubbler apparatus was changed.

The calibration for each test consisted of four steps: setting the transmitter zero, setting the transmitter span, setting the digital display zero, and setting the digital display span. The circuit used in setting the transmitter zero and span is shown in Figure 4, and the circuit used for setting the digital display zero and span is shown in Figure 5. Since the calibration steps vary markedly between the two bubbler types, the calibration procedures for the two types are described separately in the following two sections.

The level displayed by the gauge is measured from the 4-20 mA output of the transmitter. This current could be set for different levels depending on the density of the fluid, the amount of material available, and the size of the tank. Table 2 summarizes the range setting of the current output for the different test conditions. Because the 4-20 mA output was set for different measurement spans, the accuracy and repeatability of the tests are presented in this report not only in the value of one standard deviation of the measurements but also in a percentage of the measurement span.

TABLE 2. Measurement Spans for Different Test Conditions

Test Condition	Setting Position		Span Length
	Current Output 4 mA	20 mA	
1. Bubbler in Water	3.37 in.	55.00 in.	51.63 in.
2. Bubbler in Simulant	3.37 in.	37.42 in.	34.05 in.
3. Diaphragm in Water	3.62 in.	55.00 in.	51.38 in.
4. Diaphragm in Simulant	3.00 in.	40.00 in.	37.00 in.

Bubbler System

In general, the recommended air flow rate for a dip tube bubbler is approximately 1 SCFH (500 ml/min) (Lipták, 1982, p. 188). However, due to the small size of the test vessel, this flow rate caused such turbulence that a reliable visual level measurement could not be made. Since Lipták recommends using a very low flow rate to reduce pressure drop through the dip tube, the flow rate was reduced to approximately 0.2 SCFH (100 ml/min). This reduction in flow rate still produced several bubbles per second, and the turbulence was reduced to a tolerable level.

During these series of tests, the air flow for the bubbler was initiated by fully opening the needle valve until bubbles began to escape from the bottom of the tube. The amount of flow was then was adjusted downward to the desired level based on readings from the rotameter.

In an actual tank installation, the bubbles would not be visible, so a rotameter (or other flow indicator) would have to be used as the exclusive

indicator of flow. To set the flow to appropriate level is slightly more involved in this case because it takes a finite amount of time for air to push the water column entirely out of the dip tube. This time would be quite pronounced in an actual waste tank because the dip tube might be as much as 25 to 30 feet long, and the flow rate is very low. As the needle valve is opened, the rotameter will indicate flow, and the liquid will start to be pushed out of the dip tube. After some amount of time, if the valve is not open enough to allow sufficient pressure to build inside the dip tube, an equilibrium point will be reached where the dip tube is only partially evacuated and the air flow stops. The valve must then be opened incrementally until the flow no longer stops after pausing an appropriate amount of time. The flow would then be adjusted upward to the desired setpoint.

For the water tests, the vessel was filled with water to 55.00 in., and the transmitter circuit was set up as shown in Figure 4. Since there is no differential pressure between the high and low ports of the transmitter when the liquid level is lower than the end of the dip tube, an empty vessel was simulated by opening the equalizing valve between the high and low ports. The transmitter zero was then set at 4.00 mA. The needle valve was adjusted to achieve the proper air flow rate, the equalizing valve was closed, and the dip tube was allowed to pressurize and produce bubbles. After a stable flow rate was established (a few seconds), the transmitter span was adjusted such that the ammeter read 20.00 mA.

The circuit was then changed to that shown in Figure 5. An empty vessel was simulated by using the equalizing valve, and the digital display coarse zero was adjusted until it read 3.37 in., which was the distance from the end of the dip tube to the bottom of the vessel. The equalizing valve was then closed; and after bubbles appeared, the digital display coarse span was adjusted until it read 55.00 in. The coarse zero adjustment was then repeated, followed by an iterative adjustment of the fine zero and span.

The same basic procedure was used for the simulant tests; but to compensate for the change in density (and corresponding change in pressure gradient), the span was set at the water height (55.00 in.) divided by the

FIGURE 4. Calibration Circuit

FIGURE 5. Test Circuit

density (91.7 lb/ft^3 or 1.47 gm/cm^3), which was 37.42 in. In this way, the same pressure range was measured in both the water tests and simulant tests.

Diaphragm System

The manufacturer's recommended flow rate range for the diaphragm bubbler is 0.5 to 1.5 SCFH (Moore Products Company, p. 2), so the flow regulator was valved in, and the flow rate was set at approximately 0.9 to 1.0 SCFH (450 to 500 ml/min).

For the water tests, the vessel was filled to a level of 3.62 in., and the transmitter circuit was set up as shown in Figure 4; the transmitter zero was set at 3.62 in. because the diaphragm was located 1.62 in. above the bottom of the vessel, and the manufacturer states that the minimum output is at 2 in. of water (Moore Products Company, p. 1). Once the transmitter zero was set, the vessel was filled to a level of 55.00 in., and the transmitter span was set.

The circuit was then changed to that shown in Figure 5. The vessel was emptied to a level of 3.62 in., and the digital display coarse zero was adjusted until it read 3.62 in. The vessel was then filled to a level of 55.00 in., and the digital display coarse span was adjusted until it read 55.00 in. The coarse zero adjustment procedure was then repeated, followed by an iterative adjustment of the fine zero and span.

The same basic procedure was used for the simulant tests; but to compensate for the change in density (and corresponding change in pressure gradient), the zero was set at 3.00 in., and the span was set at 40.40 in.

DISCUSSION OF TESTS

Bubbler System

Water

The test of the bubbler system in water are shown in Table 3. Two test runs were conducted in order to determine the repeatability of the device. The results indicate that the system was accurate to ± 0.04 in., which is $\pm 0.08\%$ of the set-up distance for the 4-20 mA span of the analog output, up to about a depth of 17 in. Then the measurement system became less accurate,

TABLE 3. Test of Bubbler System In Water

Run 1			Run 2		
Measured Level (in.)	Displayed Level (in.)	Difference (in.)	Measured Level (in.)	Displayed Level (in.)	Difference (in.)
55.06	55.06	0.00	55.00	55.04	-0.04
54.12	54.10	0.02	54.19	54.25	-0.06
53.00	53.02	-0.02	53.44	53.51	-0.07
48.31	48.26	0.05	48.06	48.08	-0.02
47.06	47.04	0.02			
			46.62	46.67	-0.05
45.69	45.67	0.02	45.56	45.61	-0.06
44.44	44.38	0.06			
41.19	41.16	0.03			
40.44	40.44	0.00	40.75	40.77	-0.02
39.62	39.56	0.06	39.62	39.65	-0.03
34.44	34.43	0.01			
			38.12	38.18	-0.06
33.69	33.65	0.04	33.50	33.59	-0.09
			32.06	32.16	-0.10
27.50	27.55	-0.05			
27.00	26.99	0.01	26.88	26.96	-0.08
26.06	26.10	-0.04			
			25.19	25.32	-0.13
			23.94	24.04	-0.10
			22.19	22.31	-0.12
			20.31	20.48	-0.17
19.88	19.94	-0.06			
19.00	19.08	-0.08	18.88	19.02	-0.04
18.19	18.27	-0.08			
			17.12	17.29	-0.17
			16.00	16.24	-0.24
			14.00	14.26	-0.26
			13.00	13.25	-0.25
12.19	12.42	-0.23			
11.06	11.28	-0.22			
10.12	10.33	-0.21	10.19	10.45	-0.26
			8.44	8.72	-0.28
6.93	7.20	-0.27	6.69	6.99	-0.30
6.44	6.70	-0.26			
5.69	6.00	-0.31			

with an average offset of about 0.25 in. This occurred in both tests. The repeatability of the device was ± 0.07 in. ($\pm 0.14\%$ of the span).

Simulant

The test results of the bubbler system in simulated waste tank material is shown in Table 4. Two test runs were conducted in order to determine the repeatability of the device. The accuracy of the device in the simulated waste tank material was measured to be about ± 0.10 in. ($\pm 0.29\%$ of the span) in the first test, and ± 0.06 in. ($\pm 0.18\%$ of the span) in the second test. The repeatability of the device was ± 0.07 in. ($\pm 0.21\%$ of the span). A larger error did not occur as the level approached the bottom of the tank, as was seen when the bubbler was tested in water. Instead, the largest error in the accuracy of the device occurred in the middle of the range in both of these tests.

However, the bubbler did exhibit erroneous readings when allowed to monitor the level over time. With an air flow of 0.2 SCFH (100 ml/min.), the reading of the level decreased 4.23 in. overnight, even though the level did not change.

TABLE 4. Test of Bubbler System In Simulant

Run 1			Run 2		
Measured Level (in.)	Displayed Level (in.)	Difference (in.)	Measured Level (in.)	Displayed Level (in.)	Difference (in.)
34.00	34.03	-0.03	34.38	34.50	-0.12
32.88	32.83	0.05	33.00	33.05	-0.05
30.75	30.66	0.09	31.12	31.15	-0.03
29.12	28.97	0.15	29.06	29.05	0.01
27.00	26.81	0.19	27.00	26.95	0.05
25.00	24.83	0.17	25.06	25.01	0.05
23.06	22.90	0.16	23.12	23.07	0.05
21.00	20.82	0.18	21.06	21.00	0.06
19.06	18.96	0.10	19.00	18.99	0.01
17.06	16.93	0.13	16.94	16.94	0.00
15.06	15.00	0.06	15.00	15.03	-0.03
13.12	13.05	0.07	12.94	12.99	-0.05
10.94	10.97	-0.03	10.94	11.01	-0.07
8.94	9.00	-0.06	8.94	9.05	-0.11
7.00	7.14	-0.14	7.00	7.14	-0.14

In addition, the instantaneous reading of the level by the bubbler gauge was fluctuating approximately ± 0.5 in. The air flow was then increased to 1 SCFH (500 ml/min.), which is the maximum air flow that could be run on the test system. The system was left running overnight at this flow rate and the gauge indicated that the level increased 0.84 in. The instantaneous fluctuations was only ± 0.03 in. at this air flow. It was noted that a small amount of the material was attached to the end of the tube when the bubbler was taken out of the simulant.

Diaphragm System

Water

The test of the diaphragm system in water is shown in Table 5. Two test runs were conducted in order to determine the repeatability of the device. The results indicate that there was an offset in the accuracy of the device of about 0.25 in. in the first test, and 0.12 in. in the second test. The reason for this offset appears to be variations in the air flow. The calibration was not changed between the two tests. If the offset is corrected, then the accuracy of the device is about ± 0.04 in. ($\pm 0.08\%$ of the span) in both tests. The repeatability of the device was ± 0.06 in. ($\pm 0.12\%$ of the span). The offset could occur due to fluctuations in the air supply, which would also occur in the field. A change of 0.17 in. was noted in the displayed level when the system was left on overnight, even though the level of the water did not change.

Simulant

The test results of the diaphragm system in simulated waste tank material is shown in Table 6. Again, two test runs were conducted in order to determine the repeatability of the device. Unlike the testing of the diaphragm in the water, the results in the simulated waste tank materials did not indicate an offset in the level measured by the gauge. The accuracy of the device in the simulated waste tank material was measured to be about ± 0.04 in. ($\pm 0.11\%$ of the span) in the first test, and ± 0.05 in. ($\pm 0.14\%$ of the span) in the second test. The repeatability of the device was ± 0.06 in. ($\pm 0.16\%$ of the span). A variation of ± 0.05 in. ($\pm 0.14\%$ of the span) was noted in the displayed level when the system was left on overnight, even though the level

TABLE 5. Test of Diaphragm System In Water

Run 1			Run 2		
Measured Level (in.)	Displayed Level (in.)	Difference (in.)	Measured Level (in.)	Displayed Level (in.)	Difference (in.)
55.25	54.95	0.30			
53.00	52.82	0.18			
51.06	50.90	0.16			
49.00	48.83	0.07			
46.94	46.72	0.22			
45.00	44.74	0.26			
42.94	42.69	0.25			
40.94	40.67	0.27			
39.06	38.78	0.28			
36.62	36.35	0.27			
34.94	34.67	0.27			
32.94	32.68	0.26			
31.06	30.76	0.30			
29.00	28.71	0.29			
26.94	26.66	0.28			
25.06	24.76	0.30			
23.00	22.71	0.29	23.06	22.86	0.20
21.00	20.73	0.27	21.06	20.89	0.17
19.00	18.74	0.26	19.00	18.85	0.15
17.00	16.77	0.23	17.00	16.88	0.12
14.94	14.67	0.27	15.00	14.90	0.10
13.00	12.74	0.26	13.00	12.92	0.08
11.06	10.84	0.22	11.00	10.89	0.11
9.06	8.81	0.25	9.00	8.90	0.10
6.88	6.66	0.22	7.00	6.90	0.10

of the water did not change. The system was left on over a weekend, the accuracy of the device was measured to be ± 0.07 in. ($\pm 0.19\%$ of the span). Some separation of the simulant was noted in this test. After five days, however, the accuracy of the gauge degraded to ± 0.16 in. ($\pm 0.43\%$ of the span). The accuracy of the system returned to ± 0.08 in ($\pm 0.22\%$ of the span) when the air supply to the diaphragm was turned off and on a few times to flex the diaphragm. However, the gauge continued to indicate that the level was 0.78 in. lower than the actual level of the simulant in the tank. The density of the simulant was measured to be 98.0 lb/ft^3 (1.57 gm/cm^3) at the bottom of the tank.

TABLE 6. Test of Diaphragm System In Simulant

Run 1			Run 2		
Measured Level (in.)	Displayed Level (in.)	Difference (in.)	Measured Level (in.)	Displayed Level (in.)	Difference (in.)
39.31	39.26	0.05	39.50	39.55	-0.05
36.75	36.75	0.02	36.75	36.74	0.01
35.00	34.94	0.06	34.50	34.42	0.08
33.12	33.07	0.05	32.50	32.47	0.03
30.50	30.38	0.12	30.94	30.89	0.06
28.81	28.71	0.10	28.69	28.62	0.07
26.75	26.65	0.10	26.88	26.80	0.08
24.94	24.78	0.16	25.00	24.91	0.09
23.12	22.99	0.13	23.00	22.88	0.12
21.10	20.86	0.14	21.00	20.86	0.14
19.06	18.90	0.06	19.06	18.94	0.12
16.75	16.61	0.14	17.00	16.86	0.14
14.94	14.79	0.15	15.00	14.91	0.09
13.00	12.82	0.18	12.75	12.67	0.08
11.06	10.94	0.12	11.06	10.99	0.07
9.00	8.90	0.10	9.00	8.96	0.04
6.88	6.80	0.08	6.81	6.76	0.05

Because the diaphragm was located 1.62 in. from the bottom of the tank, it is possible that this offset was due to the settling of the simulant material. When the gauge was taken out of the simulant, some build up of material was noted on the diaphragm, as well as some oil on the back of the diaphragm (even though a filter was placed in the air line). Thus, it is also possible that the offset error shown in Table 7 is related to the build up of material on the diaphragm. However, this offset error did not effect the ability of the gauge to track changes in the level, as shown in Table 7. The error in tracking changes in the level was measured to be ± 0.07 in. ($\pm 0.19\%$ of the span).

This offset error does not appear to be related to discontinuing and reapplying the air to the gauge. In a separate test, when the system was calibrated, the accuracy of the device did not change significantly when the air supply was disconnected to the diaphragm and then reconnected. The measured error for this test condition was ± 0.06 in. ($\pm 0.16\%$ of the span). The only significant error that was noted with the diaphragm occurred when

TABLE 7. Test of Diaphragm System After Two Weeks In Simulant

Measured Level (in.)	Displayed Level (in.)	Difference (in.)	Change in Measured Level (in.)	Change in Displayed Level (in.)	Difference (in.)
36.38	35.45	0.93	----	----	----
35.00	33.94	1.06	1.38	1.51	-0.13
32.88	31.82	1.06	2.12	2.12	0.00
31.00	29.90	1.10	1.88	1.92	-0.04
29.06	28.00	1.06	2.06	1.90	0.16
24.94	23.80	1.14	4.12	4.20	-0.08
23.00	21.87	1.13	1.94	1.93	0.01
21.00	19.80	1.20	2.00	2.07	-0.07
19.00	17.84	1.16	2.00	1.96	0.04
16.88	15.73	1.15	2.12	2.11	0.01
15.00	13.83	1.17	1.88	1.90	-0.02
13.06	11.90	1.16	1.94	1.93	0.01
11.00	9.90	1.10	2.06	2.00	0.06
9.00	7.92	1.08	2.00	1.98	0.02
7.00	5.87	1.13	2.00	2.05	-0.05

pressure was suddenly restored to it after the air supply was cut-off. A whistling noise and vibration was noted in the gauge when air was suddenly reapplied to the gauge. The gauge also misread, as shown in Table 8. The accuracy of the gauge in this situation was ± 0.22 in. ($\pm 0.59\%$ of the span). Thus, it is important that if air flow is lost to the gauge, it be restored slowly.

TABLE 8. Test of Diaphragm System In Simulant When Air Is Suddenly Reapplied to the Gauge

Measured Level (in.)	Displayed Level (in.)	Difference (in.)
38.62	38.39	0.23
36.88	36.62	0.26
34.81	35.52	0.29
32.94	32.70	0.24
30.88	30.60	0.22
28.81	28.42	0.39
27.06	26.62	0.44
24.75	24.46	0.29
23.00	22.57	0.43
20.94	20.44	0.50
19.12	18.59	0.53
17.12	16.64	0.48
15.12	14.64	0.48
13.00	12.44	0.56
11.12	10.68	0.42
9.00	8.53	0.47
7.00	6.49	0.51

CONCLUSIONS

Bubbler systems enable simple, economical level measurement in areas such as waste water handling and food processing. Although the bubbler and diaphragm systems tested in this program exhibited better than the ± 0.25 in. accuracy desired for waste tank applications, the testing indicates that both the bubbler and the diaphragm system exhibited inaccurate readings when placed in simulated waste tank material for an extended period of time. These results are consistent with the past experience of the personnel at Hanford who maintain the bubbler systems. They indicate that there are many problems with using this type of technology (or any contact technology) in the waste tanks.

One of the most obvious problems with the dip tube bubbler is the tendency for the dip tubes to plug. Although the dip tubes would ideally never be filled with waste, during calibration and instrument air compressor failures, the dip tubes can fill up to the level of the waste in the tank. In fact, there have been instances in the past where instrument air compressor problems and poor system design have actually caused a momentary "suck back" on dip tubes. Several years ago one such case caused a great deal of contamination in the Pipe Gallery at B-Plant. Bubblers are still used in some waste tanks (like 102-AW in 200-E), but only in instances where the waste is highly water soluble. In these installations, a water drip system is used inside the dip tube to reduce build-up. This has some obvious disadvantages over the long term, since the addition of water changes the volume, density, and other properties of the tank contents.

In instances where the waste is not highly water soluble, steam is sometimes effective in clearing dip tubes. However, some installations at B-Plant actually required the periodic use of a metal "ram rod" to keep the dip tubes open. This is obviously not a viable option in a radioactive waste tank.

Although bubbler technology is simple and proven, the maintenance issues alone would seem to preclude them as viable options for use in the waste tank level measurements.

RECOMMENDATIONS

Based on the results of the tests conducted in this program, it appears that the bubbler and diaphragm systems that were tested could not be used for accurate measurements of the level in the waste tanks. Both exhibited deposits of simulated waste tank material at the end of the devices which affected the ability of the gauge to accurately determine the level. By flexing the diaphragm, the gauge was able to accurately determine changes in the surface level even though the measured value of the level was inaccurate. Further investigations into the cause of this inaccuracy may be warranted. Alternate diaphragm materials may improve the performance of this gauge.

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APPENDIX A

MATERIAL LIST

MATERIAL LIST

EQUIPMENT	SPECIFICATION OR RANGE	MANUFACTURER AND MODEL NO.
Differential pressure transmitter	0-300 in. H ₂ O, Hastelloy C-276 diaphragm, viton o-ring, 4-20 mA output	Bailey Controls Model PTDDE121200D010
Digital display	4-1/2 digits, 4-20 mA input	Omega Engineering Model DP3002-P
Rotameter	Shielded, 20-2100 cc/min	Omega Engineering Model FL-212
Pressure gauge	0-30 psi	Marsh
Pressure regulator	0-160 psi	ARO Model 127112-000
Submersible level transmitter	2" - 200" H ₂ O (at $\leq \pm 0.5''$ accuracy)	Moore Products Co. Type GC-19A, Model 19L1
Differential relay	0.06 to 1.8 SCFH with integral rotameter	Moore Products Co. Type GC-62, Model 62-VNA
Digital multimeter (ammeter)	-	John Fluke Mfg. Co. Model 83

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