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Operational Experience in Mitigating Flammable Gas Releases from Hanford Site Tank 241-SY-101

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ABSTRACT

Flammable gases consisting of hydrogen, nitrous oxide, ammonia, and methane are periodically released from Hanford Site waste tank 241-SY-101 at concentrations above the flammable limit. A large mixer pump installed in the tank in 1993 has effectively mitigated this problem by continuously releasing small amounts of the flammable gases at the rate they are generated.

BACKGROUND

Since its original fill in 1980, Hanford Site high-level underground waste tank 241-SY-101 has periodically released flammable gases as a result of a buoyant rollover of the lower viscous layer of waste. At intervals of approximately 100 to 150 days, the flammable gases hydrogen, nitrous oxide, ammonia, and methane evolve episodically from the tank at concentrations above the flammable limit. Because of the potential consequences of ignition, this problem has received a high national priority for mitigation.

In July 1993, a large mixer pump was installed in tank 241-SY-101 to test whether mixing could mitigate the episodic hydrogen releases. The results of initial testing were reported in February/March at Waste Management '94 by Lentsch et al. (1994). In April 1994, a series of full-scale tests were completed, and the pump was placed into routine operation.

TANK AND MIXER PUMP

Hanford Site tank 241-SY-101 and the mitigation mixer pump are shown schematically in Figure 1. The tank is 23 m (75 ft) in diameter and contains 4,163,953 L (1.1 million gal) of caustic sodium nitrate/nitrite/aluminate waste with 3% to 5% organic complexants. Approximately 3 million curies of radioactive Cs^{137} in the tank generates 40,946 Btu/hr (12 kW) of decay heat, resulting in an average waste temperature of approximately 49 °C (120 °F). Overall waste depth is 1,016 cm (400 in.); the lower 635 cm (250 in.) consists of non-convective settled solids with a specific gravity of 1.7, covered by approximately 254 cm (100 in.) of convective saturated solution with a specific gravity of 1.4. A 102 to 127-cm (40 to 50-in.) layer of solid crust floats on top of the waste.

Prior to mixer pump installation, gases formed by radiolysis were retained in the lower (non-convective) waste layer. Every 100 to 150 days, the gas inventory built up to the point where the lower waste layer was less dense than the upper layer. The waste would then "roll over" or "burp," releasing the gas inventory to the dome of the tank, over a period of a few minutes, at concentrations above the lower flammability limit.

The mixer pump shown in Figure 1 is a 150-hp, submersible, centrifugal unit that draws waste from the middle of the tank at 660 cm (260 in.) and discharges it through opposing 7-cm (2.6-in.)-diameter converging nozzles at 71 cm (28 in.) off the bottom at a maximum velocity of approximately 20 m/sec (65 ft/sec) and flow rate of 10,599 L/min (2,800 gal/min). The pump nozzles can be rotated through a 360-degree sweep. The mixer pump is located in a tank riser located 3 ft off center in the tank. Two multi-function instrument trees (MITs) are located at distances of 8.5 and 9 m (28 and 30 ft) from the pump to measure the vertical temperature profile of the waste at .30 to .61-m (1 to 2-ft) intervals. These two MITs provide the best measure of the degree of mixing taking place in the tank.

Tank 241-SY-101 is also equipped with multiple high-sensitivity gas monitoring systems and level detection systems to measure the quantity of gas that is retained in and released from the waste.

TEST AND OPERATIONAL RESULTS

The best measure of the effects of pump mixing on gas retention in the waste is waste level. A graph of the waste level before and after mixer pump operation is shown in Figure 2. Prior to pump installation, the waste level grew at a rate of about 0.25 cm (0.1 in.)/day as gas accumulated. Following the rollovers, or burps, the waste level dropped 0.30 m (1 ft) or more after the gases were released. Then the cycle took place again. This behavior has not occurred since the pump was installed in July 1993. The first 4 months after the pump was installed, it was only operated for 5 to 10 minutes per day maximum. This operation was adequate to keep the pump nozzles from clogging with the viscous waste at the bottom of the tank. During this period, the waste level grew 5 to 8 cm (2 to 3 in.), but at a reduced speed. As more aggressive mixing was performed (up to 3 hours per day with 360-degree sweeps of the tank), the tank level was knocked down to a historical low value of 400 in.

Following demonstration testing in 1993, gas was allowed to regrow into the waste during early 1994 to show that mixing had not altered the waste or created any safety issues. During February-April of 1994, full-scale testing was performed. Daily test sequences of 5-minute, 1-hour, and 3-hour runs and 360-degree directional sweeps were performed to determine the minimum pump operation necessary to control gas releases, and to assess how deep the pump jets were penetrating into the waste.

From the full-scale tests and experience gained since then, it has been determined that the mixer pump should be operated at a speed of 1000 rpm for 25 minutes three times a week. Figure 2 shows that since the summer of 1994, the waste level has been closely controlled at 1,013 to 1,016 cm (399 to 400 in.) by this pump operating frequency. This frequency has also been shown to effectively prevent clogging of the pump nozzles.

Figure 3 shows a plot of hydrogen release data during a typical month of pump operation. Hydrogen is measured continuously with electrochemical cells and with gas chromatographs. Each 25-minute operation of the pump typically causes an increase in hydrogen concentration of 50 to 200 ppm. These values are not only controllable, but are far lower than the concentrations of up to 50,000 ppm that were seen during the naturally occurring, uncontrollable burps prior to pump operation.

Since September 1994, a steady state has been maintained using mixer pump operation. An average of approximately 3 m^3 (100 ft^3) of total gas is released each day. This amount corresponds with the approximately 100 ft^3 of total gas that is estimated to be generated by radiolysis in the tank.

Concentrations of other gases in the tank dome exhaust are measured continuously with a Fourier transform infrared analyzer. Concentrations of the oxidizer gas nitrous oxide show close correlation with hydrogen at approximately 1.5 times higher values than hydrogen. Ammonia, on the other hand, shows a more steady release of roughly 35 to 50 ppm with only small increases of 10 to 15 ppm during pump operation. Much higher concentrations of ammonia (to 2,000 ppm) were seen during burps prior to pump installation). Only trace amounts of methane have been detected at concentrations of 1 to 2% of the nitrous oxide concentration.

JET PENETRATION

Waste temperature profiles were used to measure how deep the pump jets are penetrating into the waste. Figure 4 shows graphs of waste vertical temperature profiles from the thermocouples of one of the MITs (this tree is located 8.5 m [28 ft] from the pump). Profiles are shown for a date prior to pump installation, and for a recent date during steady state pump operation. The parabolic temperature profile shows that prior to pump installation, the lower 635 cm (250 in.) of waste are unmixed (non-convective). With pumping, only the lower 4 ft of waste is non-convective. Further, when the pump is running, the temperature reading on the very lowest thermocouple on this tree (10 cm [4 in.] from the tank bottom) clearly increases when the warmer pump jet passes by.

The other MIT, located 30 ft from the pump in the opposite direction, shows less than 41 cm (16 in.) of unmixed waste. However, each successive operation of the pump further reduces the thickness of the unmixed waste.

Recent operation of a newly-developed instrument for measuring the fraction of gas voids in the waste has confirmed the mixing depth inferred from the MITs. Also, infrared photogrammetry of the primary tank wall was performed from the tank annulus. The tank wall temperature was shown to be vertically uniform before and during pump mixing. From this and thermal calculations it has been inferred that the waste is vertically well mixed all the way out to the cylindrical tank walls, at a distance of 10 to 12 m (34 to 40 ft) from the pump.

The mixer pump cannot be operated continuously due to thermal operating limits. However, the continued systematic operation at 3 days per week is expected to eventually mix all of the tank waste all the way to the bottom in all directions.

PUMP REPLACEMENT

Because of the proven success of the mixer pump for mitigating tank 241-SY-101 flammable gases, keeping a pump operating in this tank at all times has become essential. Thus, a spare pump has been fabricated and is ready for installation in case the current pump fails. The estimated lifetime of the current pump is approximately eight years, based on its current duty factor, operating temperature, and radiation exposure.

Removal of the current pump, in case of a failure, is expected to be a difficult task involving radiation levels up to 50 R/hr. The pump is nearly 21 m (70 ft) long and weighs approximately 9,072 kg (20,000 lb). Remote equipment to decontaminate, monitor, and contain the pump during withdrawal is currently being tested, and a special shielded container and hydraulic trailer assembly have been built to contain and transport the pump after removal. Detailed plans and training are being developed to assure that a failed pump can be removed and a new pump installed within 30 to 60 days of a failure, before hydrogen builds back up to unacceptable quantities.

Testing is also underway to determine what amount of dilution of tank 241-SY-101 would be required to "passively" mitigate the tank (thinning the waste to the point where it no longer retains gas). A 1:1 dilution (diluent: waste) might be needed. At this time, there is insufficient tank capacity in the West area at Hanford to accommodate the additional waste volume that would result from dilution.

CONCLUSIONS

The mixer pump in Hanford Site tank 241-SY-101 has been in operation for 20 months. It has effectively eliminated the episodic release of flammable quantities of hydrogen and other gases. Although the pump is only operated about 1% of the time, it has been shown to mix most of the viscous settled solids in this tank. A steady state has been reached where the pump releases gases at the same rate as they are generated.

REFERENCES

J. W. Lentsch, H. Babad, C. E. Hanson, N. W. Kirch, 1994, *Progress Toward Mitigation of Flammable Gas Tank 241-SY-101,* Proceedings of the Symposium on Waste Management at Tucson, Arizona, February 27 - March 3, 1994 (pp. 397 - 398).

Figure 1. Tank 241-SY-101 Hydrogen Mitigation Test Pump.

Tank 241-SY-101 Hydrogen Mitigation Test Pump

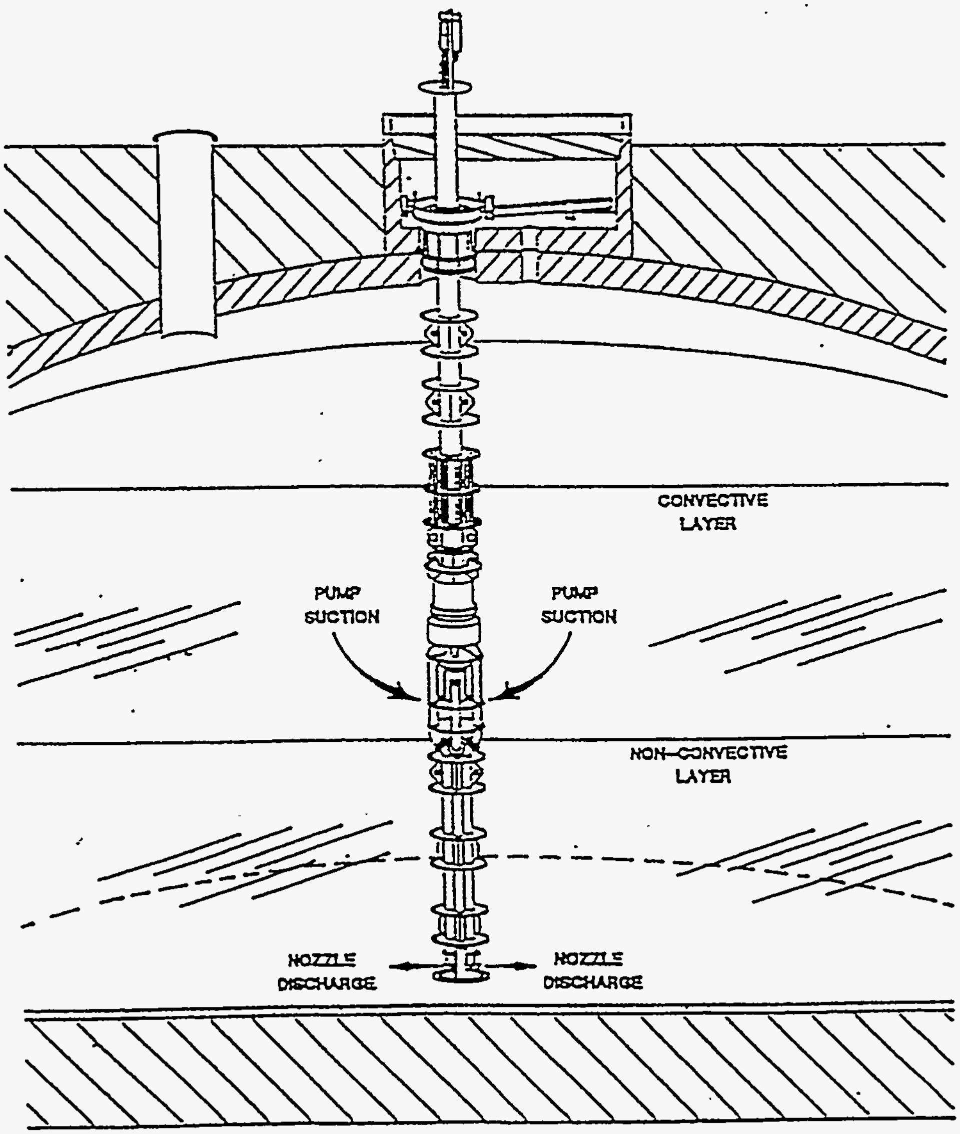
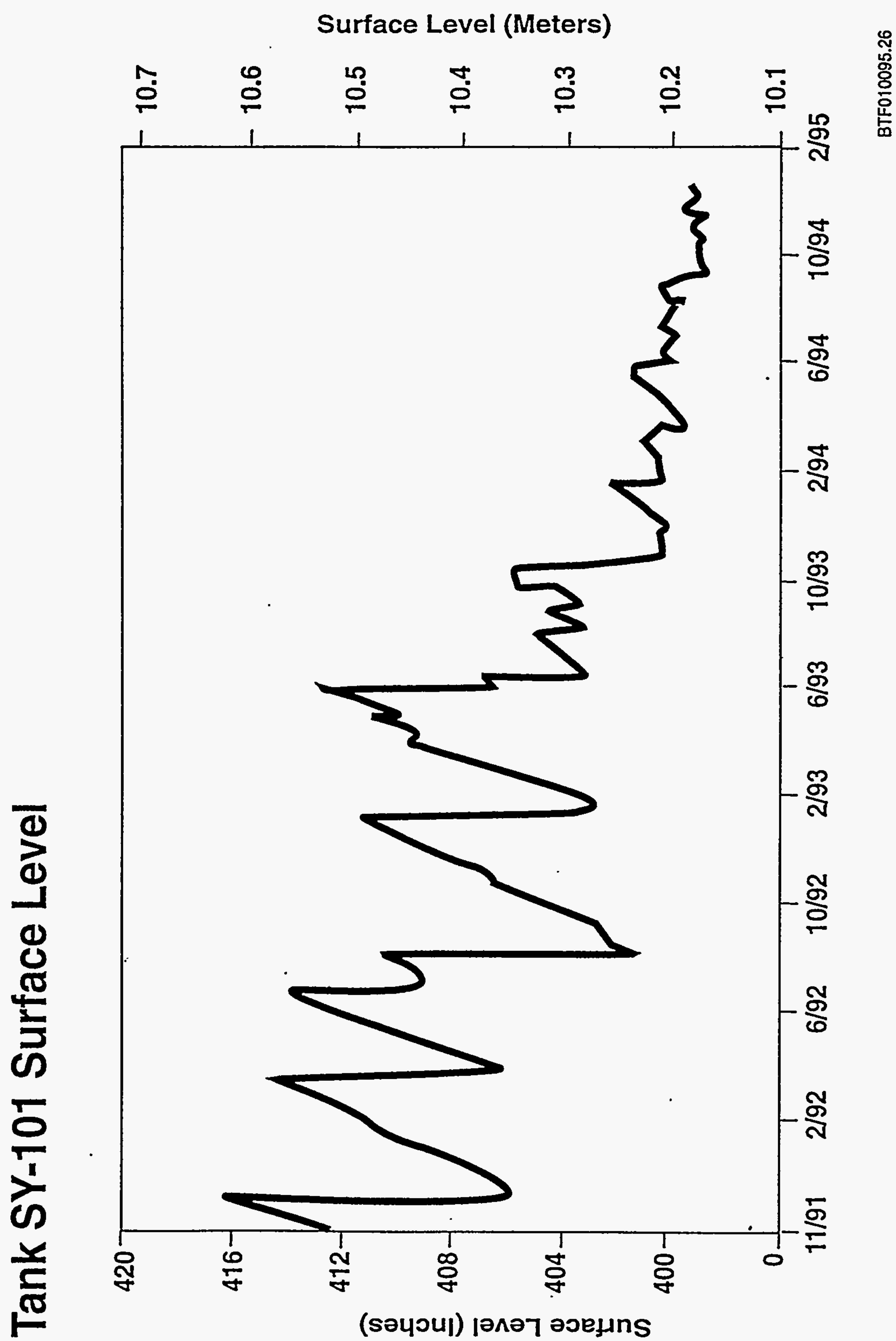


Figure 2. Tank SY-101 Surface Level.



Hydrogen Releases from Tank SY-101 During Mixer Pump Operation

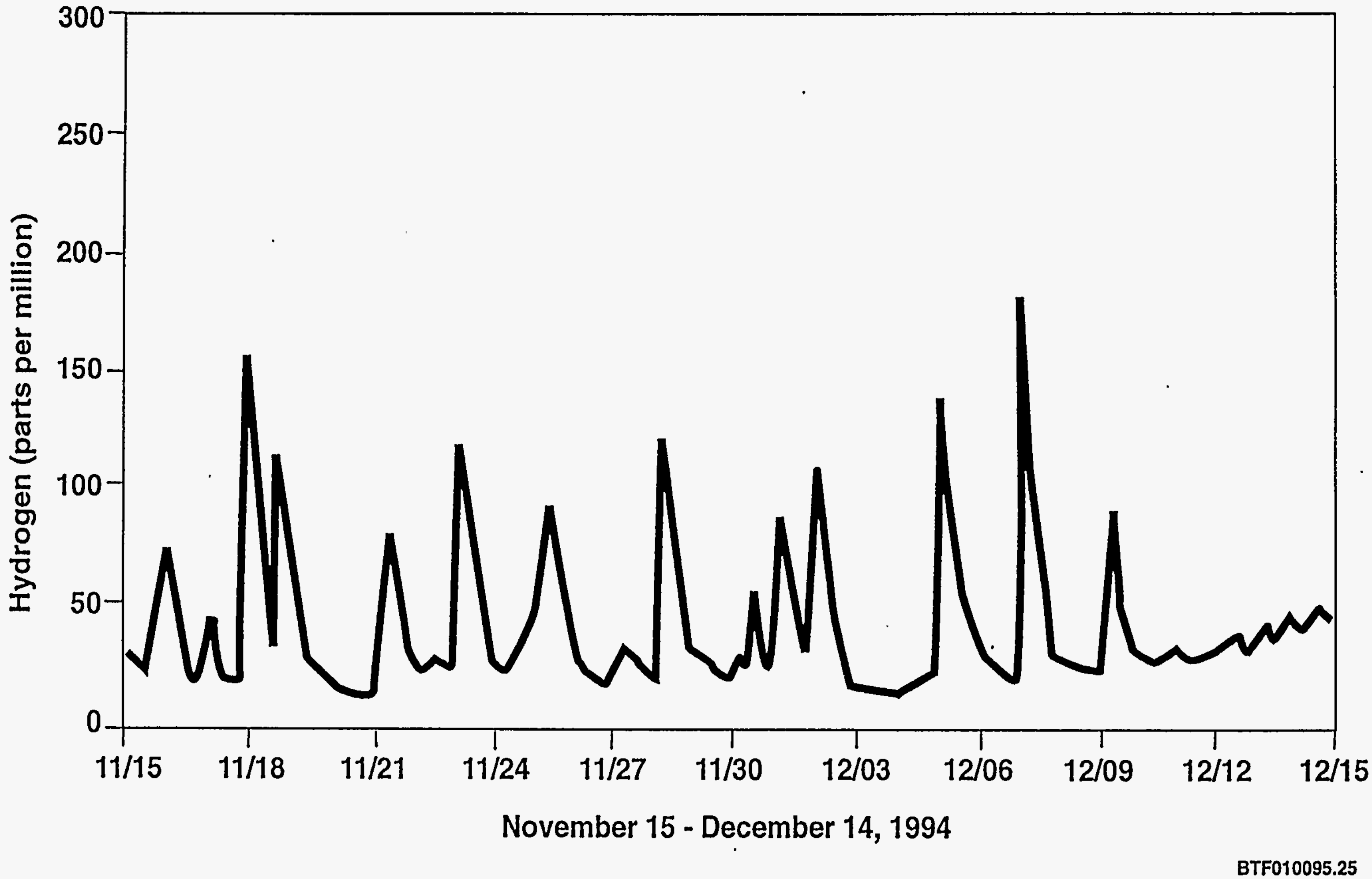


Figure 3. Hydrogen Releases from Tank SY-101 During Mixer Pump Operation.

Tank 241-SY-101
Multi-Instrument Tree Riser 17B Temperature Profile

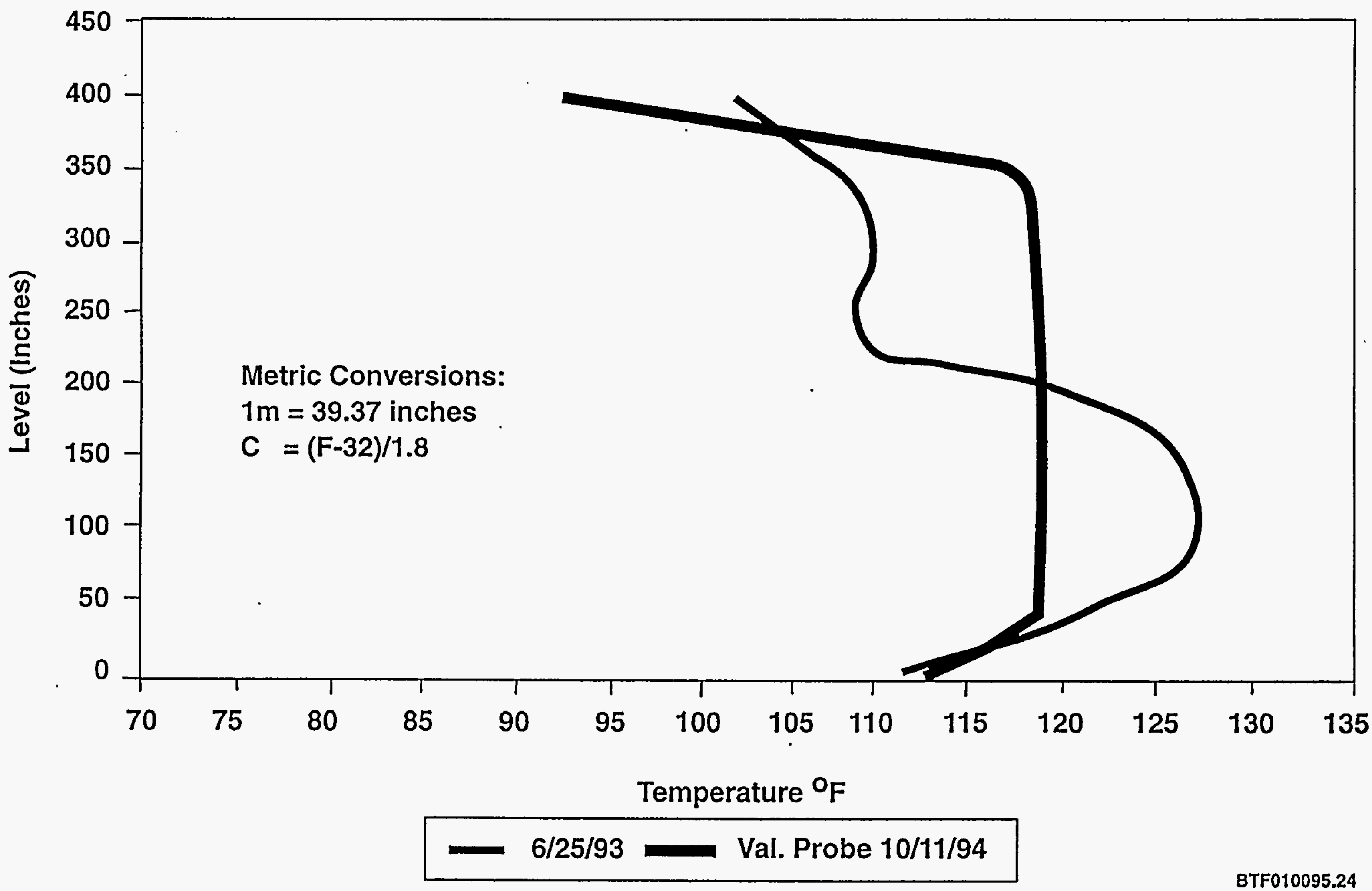


Figure 4. Tank 241-SY-101 Multi-Instrument Tree Riser 17B Temperature Profile.