WSRC-MS--91-469

DE92 013192

INSPECTION OF STORAGE TANKS AT THE SAVANNAH RIVER SITE (U)

by

P. R. Vormelker
Westinghouse Savannah River Company
Savannah River Site
Aiken, South Carolina 29808

J. B. Elder
Westinghouse Savannah River Company
Savannah River Site
Aiken, South Carolina 29808

A paper proposed for presentation at the
2nd International Symposium on Aboveground Storage Tanks
Houston, Texas
January 14 - 16, 1992

and for publication in the proceedings

M9110021i

Inspection of Storage Tanks at the Savannah River Site

Phillip R. Vormelker and James B. Elder

Westinghouse Savannah River Company
PO Box 616
Aiken, South Carolina 29808

Abstract

Inspections have been performed on over 200 storage tanks since the startup of the Savannah River Site in 1955. The tanks contain a variety of fluids, including alum, fuel, oil, waste oil, sodium hydroxide, chlorine, sodium hypochlorite, and sulfuric acid. Many inspection methods have been developed over the years, starting with visual and progressing to manual, straight-beam ultrasonic thicknesses at specific tank locations and then to automated ultrasonic thickness mapping. This paper will review the current inspection methods and the uses of new inspection technology at the Savannah River Site, show where inspections can be used to find potential problems before they occur, and show what problems may occur when inadequate attention is given to inspections or inspection results.

Introduction

The Savannah River Site (SRS) is a 300-square-mile site in South Carolina where defense materials are manufactured for the United States Department of Energy (DOE). SRS is a multi–plant site comprised of many different facilities such as nuclear reactors, coal–fired boilers, chemical separations facilities, waste storage, and waste consolidation. Each of these plants has individual requirements for materials containment. This paper will review the inspection of these storage tanks which contain non–nuclear materials.

Inspections on more than 200 storage tanks have been proceeding since the startup of SRS in 1955 due to standards established by the original site contractor, E. I. du Pont de Nemours and Company, Inc. In the same year, Du pont established a specific standard for inspection of pressure vessels that required periodic inspection and testing. Normally, storage tanks are not considered pressure vessels; but this specification included any vessel with severe service conditions and whose failure could endanger personnel or adjacent equipment. Westinghouse Savannah River Company (WSRC), the current contractor since 1989, has continued these inspections in their Quality Assurance programs.

The typical storage tank at SRS is constructed of welded carbon steel, painted, and is mounted horizontally above the ground on concrete supports, as depicted in Figure 1. Fluids contained include fuel, new oil, waste oil, dry gaseous chlorine, sulfuric acid (66 degree baumé, approximately 96% concentration), alum (8% $AlSO_4$ concentration), or sodium hydroxide (50% concentration). The sodium hydroxide tanks are the only ones that are heated; the others are exposed to ambient temperatures. All but the chlorine tanks are stationary, which are filled by a vendor and returned to the site. The tanks are designed per American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel codes. In the past, however, a code stamp was not required because South Carolina

The information contained in this article was developed during the course of work under Contract No. DE–AC09–89SR18035 with the Department of Energy.

is not a code state. The chlorine tanks were ASME stamped. Recently, DOE has required that all national codes and standards be followed at SRS, including those of the ASME and the National Board. It is assumed that all new tanks will be code stamped. There are also vertical, epoxy-coated steel tanks for neutralized well water, steel reinforced gunite tanks that provide service water for fire protection and boiler feedwater, and epoxy-lined fiberglass tanks for containment of sodium hypochlorite. The capacities range from 2000 gal (7570 L) waste oil tanks to the 200,000 gal (757,000 L) service water tanks.

Inspections of these tanks are performed either externally or internally, depending on whether or not the tanks are insulated. Each of these methods is explained below along with information on personnel certification, inspection frequency, and acceptance criteria.

Discussion

External Inspection

External inspection methods are primarily visual and volumetric and can be performed easily since the majority of these vessels are not insulated. A general visual inspection is first performed to obtain information about the general condition of the vessel. Examining the overall condition is necessary to determine

- the condition of the exterior coating
- if corrosion is evident
- if the tank or its nozzles are leaking
- if there are any areas of mechanical damage to the vessel and its supports (e.g., dents in the sides or heads, gouges, bent nozzles, bent supports, deformed flanges, etc.)
- if welds are visibly cracked
- if there is distortion, such as bulging, contour change, and dimensional or other physical change that might occur from overpressurizing or overheating
- if the vessel is physically locked out to stop inlet/outlet liquid flow that could prove hazardous to the inspector (If interior inspection is to be performed, then an oxygen check is necessary to determine if toxic gases are present.)

After determining the general condition of the tanks, ultrasonic thickness measurements are taken at 90° intervals on the outside diameter of the vessel at locations near the circumferential welds or the supports in the pattern displayed in Figure 1. Locations slightly above or below the liquid level and at the bottom usually show the most signs of corrosion. The outside diameter inspection pattern is repeated at each end of the vessel and in the middle of the vessel. Additional inspection areas may be added, depending on the size of the vessel. The locations are recorded and marked on the tank. On large vessels with multiple circumferential welds, inspections are performed on both sides of each weld. The thickness of the vessel heads are measured at a minimum of four positions (Figure 1). One disadvantage of ultrasonic thickness testing is the difficulty in finding pitting or concentrated areas of corrosion away from the tested areas. A frequent inspection program is necessary to establish whether corrosion thinning is occurring. When significant corrosion has been found, areas of inspection will be increased.

Internal Inspection

Normally, insulated vessels are inspected internally to avoid insulation removal. There was a time when the insulation was removed to get rid of asbestos and the vessels were inspected externally.

Now, however, the current non-asbestos insulation is not removed unless conditions warrant it. Most internal inspections are performed on sodium hydroxide tanks that are insulated. The tank is drained, flushed when possible, and then valves are locked out to prevent further flow. The tank is opened up and oxygen levels are measured prior to sending personnel inside. The inspector(s) dresses out in a full body-protected plastic suit with attached breathing air hoses to prevent contamination from any remaining liquid or leftover sludge. The inspector will record any unusual conditions inside the tank, perform thickness measurements, measure pit depths, and photograph any corroded areas.

Inspection of fiberglass and steel tanks, which have an epoxy lining, is somewhat different than metal tanks because degradation of polymeric coatings may occur by delamination, blistering, discoloring, softening, stress cracking in holes, etc. Most of the polymer degradation can be observed visually. There is, however, an established test method for lined steel tanks called the Holiday Test, ASTM G–62.[1] In this test, a fine wire brush (connected to a voltage source) that can detect thinned coatings and pinholes is swept over an area to be inspected. When a pinhole or any other penetration to the metal surface is found, grounding occurs and an electrical spark is generated. Ultrasonic thickness measurements are difficult on fiberglass tanks because of the signal reflections from the glass fibers.

Certified Personnel

All personnel performing these inspections are qualified per American Society for Nondestructive Testing (ASNT) Standard, TC–1A,[2] by an internal training program that follows ASNT guidelines. All inspections are performed by level I and II personnel. These people are part of an onsite inspection group that is in a quality control organization.

Inspection Frequency

The current inspection frequency for the sulfuric acid tanks is every year; every two years for the caustic tanks; and every five years for all others. This schedule is based on prior plant experience in handling these fluids.

Acceptance Criteria

The vessels are permitted to continue in service as long as the following criteria are met:

- Fifty percent of the original corrosion allowance is remaining.
- Localized areas of greater corrosion may be accepted, provided that the maximum penetration is not greater than one–half of the original wall thickness (not including corrosion allowance).
- The total area of corrosion is less than 7 $in.^2$ (45 cm^2) within any 8–in.(203 mm) diameter circle and the sum of their dimensions along any straight line in this circle is no greater than 2 in. (50 mm).

If these conditions are not met, an engineering evaluation is required prior to continued service. This service requirement is equivalent to the National Board Inspection Code.[3]

Inspection Problems

In 1982, an 18,000 gal (68,000 L) horizontal sulfuric acid tank collapsed after being filled (Figure 2). Luckily, no one was injured and no damage was done to surrounding equipment or the environment. Upon review of the inspection history,[4] it was found that the thinning had been noted in the past; however, the thinnest section on the bottom of the buckled tank was near the edge of the concrete support and not within a previously inspected area. There was enough thinning in the measured areas (50% below nominal) that should have caused alarm to both the equipment custodian and the inspectors after the prior inspection in 1975. In this case, lack of adequate communication was probably the root cause. Also, acceptance criteria had not been pre-established at the time of the inspection; therefore, the inspector was not able to inform the equipment custodian of whether or not the tank thickness measurements were within acceptable limits. This case also points to the fact that the most significant corrosion does not always occur at the inspection location.

A caustic tank was also inspected in 1982 because of repeated failures in repaired steam inlet nozzles. This tank was insulated and required an interior inspection. The visual inspection revealed extensive pitting (greater than 50% through the cross section of the weld) in the longitudinal and girth welds, general corrosion at the varying liquid level interfaces, and stress corrosion cracking in the heat-affected zone of the welded thermowell nozzle. Failed welds were also observed in the steam heater and liquid level indicator guide tube supports (Figures 3, 4, 5, 6, and 7). Previous inspections had been performed around the nozzles where corrosion had been expected. This tank was immediately repaired and eventually replaced.

The two previous examples indicate problems with finding the most significant corroded areas on tanks where previous inspection areas did not reveal the total problem. One solution to this may be the automated inspection method in which prior single-point thickness measurements can be greatly expanded.

Automated Ultrasonic Inspections

There are several good automated ultrasonic systems currently in use in the industry and many similarities exist between most systems. While being somewhat alike, there are differences in data collection and display, scanning speed, data analysis features, system operating environments, as well as other variables that should be considered when choosing an automated system. SRS has experience with both the Intraspect® 98 and the P-SCAN® system. Experience with other systems at SRS has been limited; therefore, they will not be mentioned. They may, however, be well suited to other inspection needs.

WSRC has recently purchased an automated ultrasonic testing (UT) inspection system. The particular system type has been used at SRS since 1984 for performing automated UT weld inspections on critical piping welds. The automated system was able to find intergranular stress corrosion cracking using shear wave UT methods. Scanning cracks is more difficult than determining thicknesses. Plans have been made to use the same system for UT thickness mapping as well as weld inspections. Automated inspection systems were mentioned previously in the First International Symposium on Aboveground Storage Tanks in 1990.[5]

There are many advantages to using an automated UT inspection system for thickness mapping instead of performing manual UT when inspecting storage tanks. One of the main advantages is that complete coverage is obtained in the area of interest. This provides the highest probability of finding areas of pitting and localized corrosion, which are often the causes of failures. The use of an automated scan, such as the one shown in Figure 8, minimizes the possibility of an unexpected failure occurring (i.e., like that of the sulfuric acid tank mentioned earlier). Due to the layout that is normally used for manual UT, it is highly unlikely that areas of pitting or localized corrosion would be located. A conservative layout for manual UT is to use a 2-in.(5 cm) grid and take measurements at the intersections. When performing automated thickness mapping or T–scan, a 10 in. x 10 in. (25 cm x 25 cm) area is scanned. Normally, these consecutive 10 in. x 10 in. areas result in a 10–in. wide area for the entire circumference or length of a tank or pipe. Our system records well over 10,000 thickness measurements for each 10 in. x 10 in. area compared to less than 40 measurements when using the manual grid. Figure 8 shows a comparison of typical manual thickness reading locations and automated scan locations.

Another major advantage of using automated UT systems is that a permanent record of the examination results is produced. The system records and stores all of the UT thickness readings. This not only provides a more credible permanent record, but it also gives the equipment owner the advantage of being able to re–analyze the data to different acceptance criteria.

The system in use at SRS is a four-channel automated UT inspection system. The inspector is able to scan with up to four different transducers at the same time. This means that a dual element thickness probe (most sensitive to pitting) and two angle beam transducers can be run at the same time. The advantage of this setup is that with one scan of the area, wall thickness can be measured, pitting and localized corrosion located, and laminations and pitting differentiated. The angle beam transducers can be used to locate "stair stepping" between laminations, grain boundary deterioration, and cracking.

There is a procedure where painted components can be inspected using automated UT and still obtain accurate metal thickness readings. This is performed without secondary paint thickness measurements. Therefore, paint removal is not necessary when the paint is in good condition.

The system produces a visual display of the thickness readings in the form of a topographic map or top view. This top view is accompanied by a projection view from the side and end of each part.

The system also generates valuable statistical information. The software calculates the minimum, mean, and maximum values on each scan area. The system is generally set to display the data using eight color levels. Each color level can be adjusted to show which thickness values are significant for a given inspection (e.g., one at nominal, one at nominal minus 12.5%, one at the calculated minimum, etc.). This software also shows what percentage of the scan area is within each thickness level. This information is very useful in making engineering evaluations of the integrity of a given tank. The data can also be joined with an extreme value analysis (EVA) program, which can accurately predict the minimum thickness of the entire tank while only scanning a small percentage of the total area.

Inspection Standards

Another problem revealed in the above examples is the lack of an organized method to determine inspection frequency and adequate acceptance standards. Details such as this are generally determined by experience with the equipment and addressed by individual company standards. Current state and federal environmental regulations require strict reporting requirements on leakage such that stricter industry-wide inspection standards may be necessary.

In the nuclear industry, inspections of nuclear equipment are governed by Section XI of the ASME Boiler and Pressure Vessel Code. This document provides details on which individual components are to be inspected, where inspection takes place, the inspection method, the frequency of inspection, and acceptance criteria. However, there is no national code covering the inspection of storage tanks or similar equipment. There are inspection codes covering the petroleum industry storage vessels,[6,7] but not in such detail as in ASME, Section XI.

ASME's Center for Research and Technology Development, along with other project sponsors, is supporting a program that began in 1988 to develop risk-based inspection guidelines for non-nuclear equipment.[8] These guidelines will aid in identifying system boundaries, establish an initial qualitative risk assessment (failure modes and causes, consequence of failure), assist in performing a quantitative risk analysis by looking at failure probabilities versus consequences, and create a risk-based ranking of components. An inspection program can then be established based on failure probabilities.

Conclusion

Based on the above examples and discussion, it seems apparent that the use of an automated UT inspection system and risk-based inspection methods may have identified the thinning–and allowed repair or replacement–prior to the catastrophic failure of the sulfuric acid tank. Furthermore, if insulation could have been removed, recognition of the caustic tank corrosion may have been easier with an automated inspection system.

References

1. "Test Methods for Holiday Detection in Pipeline Coatings," American Society for Testing and Materials, Standard No. G–62, 1987.

2. "Recommended Practice," American Society for Nondestructive Testing, Standard No. SNT–TC–1A, August 1984.

3. "National Board Inspection Code: A Manual for Boiler and Pressure Vessel Inspectors," ANSI/NB–23, 20th ed., Columbus, OH.

4. WSRC Internal Reports.

5. G. Avarado, "Corrosion Assessment of Above Ground Storage Tanks Using Computerized Ultrasonics and Statistical Analysis," presented at the First International Symposium on Aboveground Storage Tanks, National Association of Corrosion Engineers, Houston, TX, June 28, 1990.

6. "Tank Inspection, Repair, Alternation, and Reconstruction," API–653, 1st ed., American Petroleum Institute, January 1991.

7. "Pressure Vessel Inspection Code," API–510, 6th ed., American Petroleum Institute, June 1989.

8. "ASME Risk Based Inspection Guidelines Information," presented at the ASME Section XI Meeting, San Diego, CA, February 6, 1991.

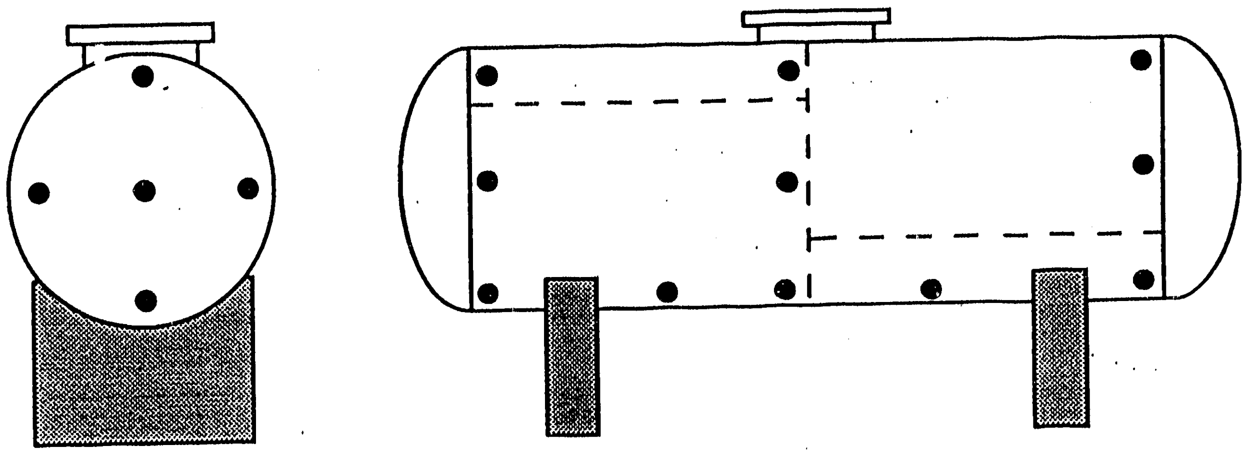


Figure 1. Typical Horizontal Storage Tank Mounted on Concrete Supports

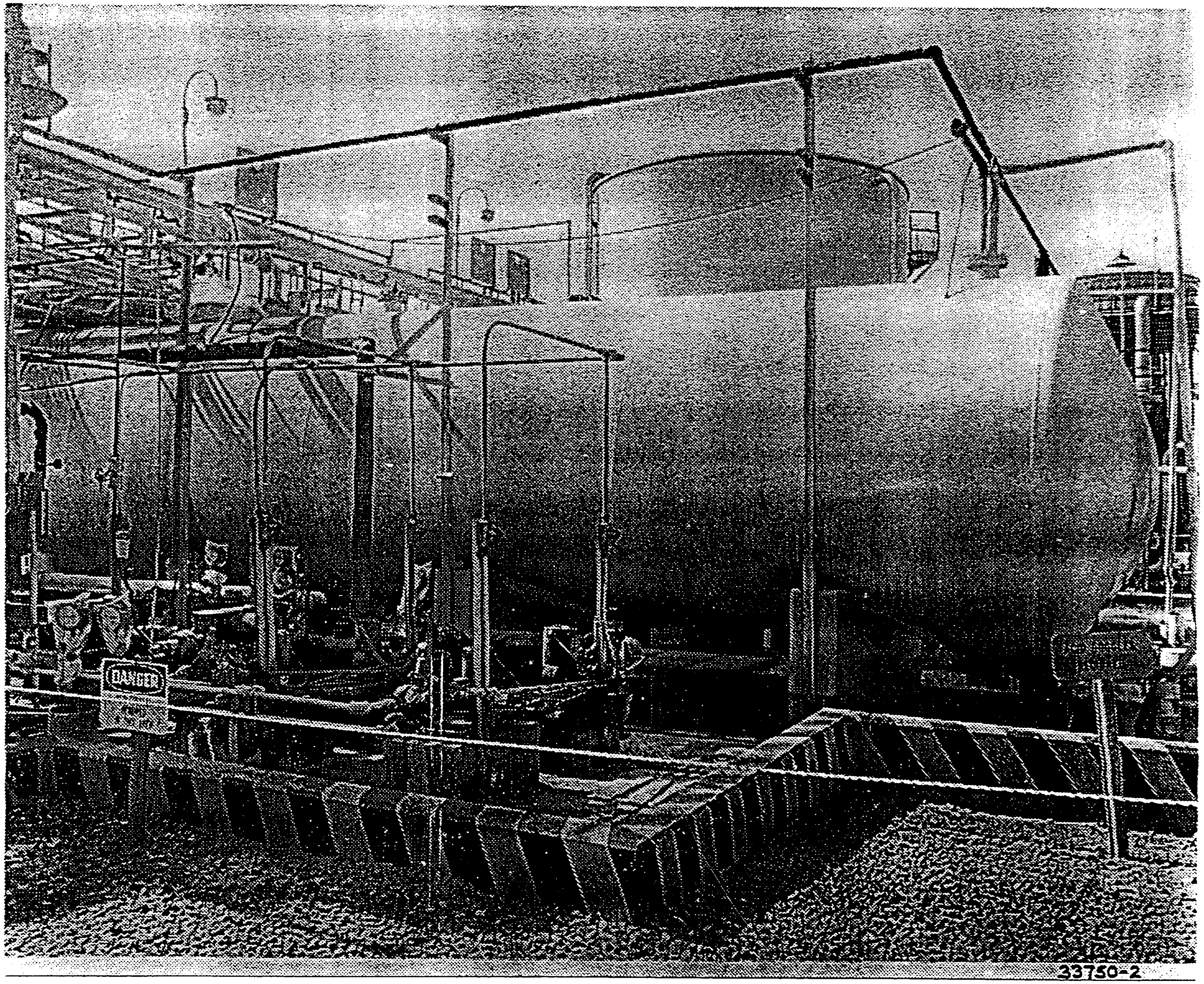


Figure 2. Buckled Sulfuric Acid Storage Tank

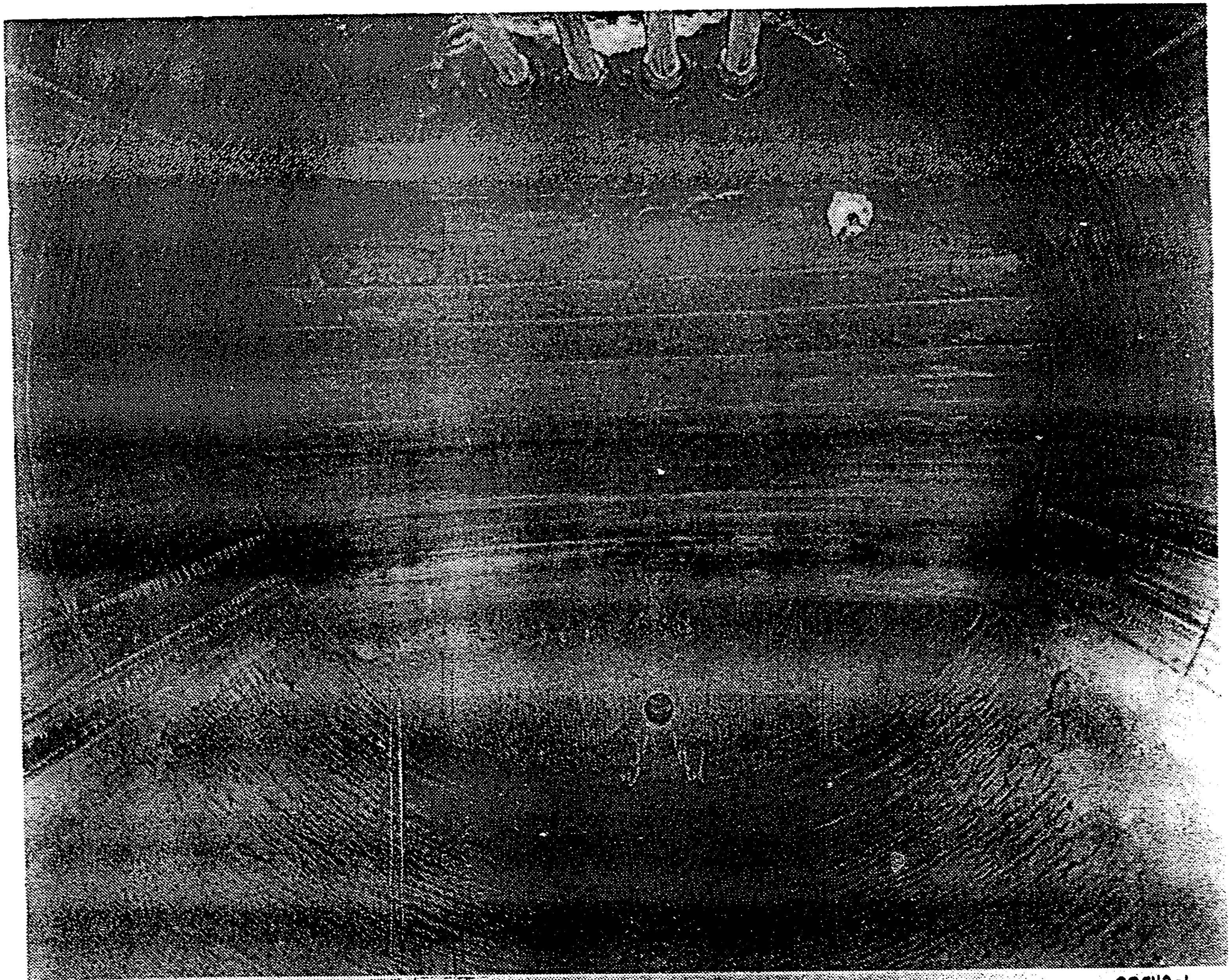


Figure 3. Overall View of the West End of Tank 43 (This view illustrates the location of the bayonet steam heater.)

Figure 4. View of Typical Pitting Corrosion Occurring in the Tank Wall at the Liquid Level Interface

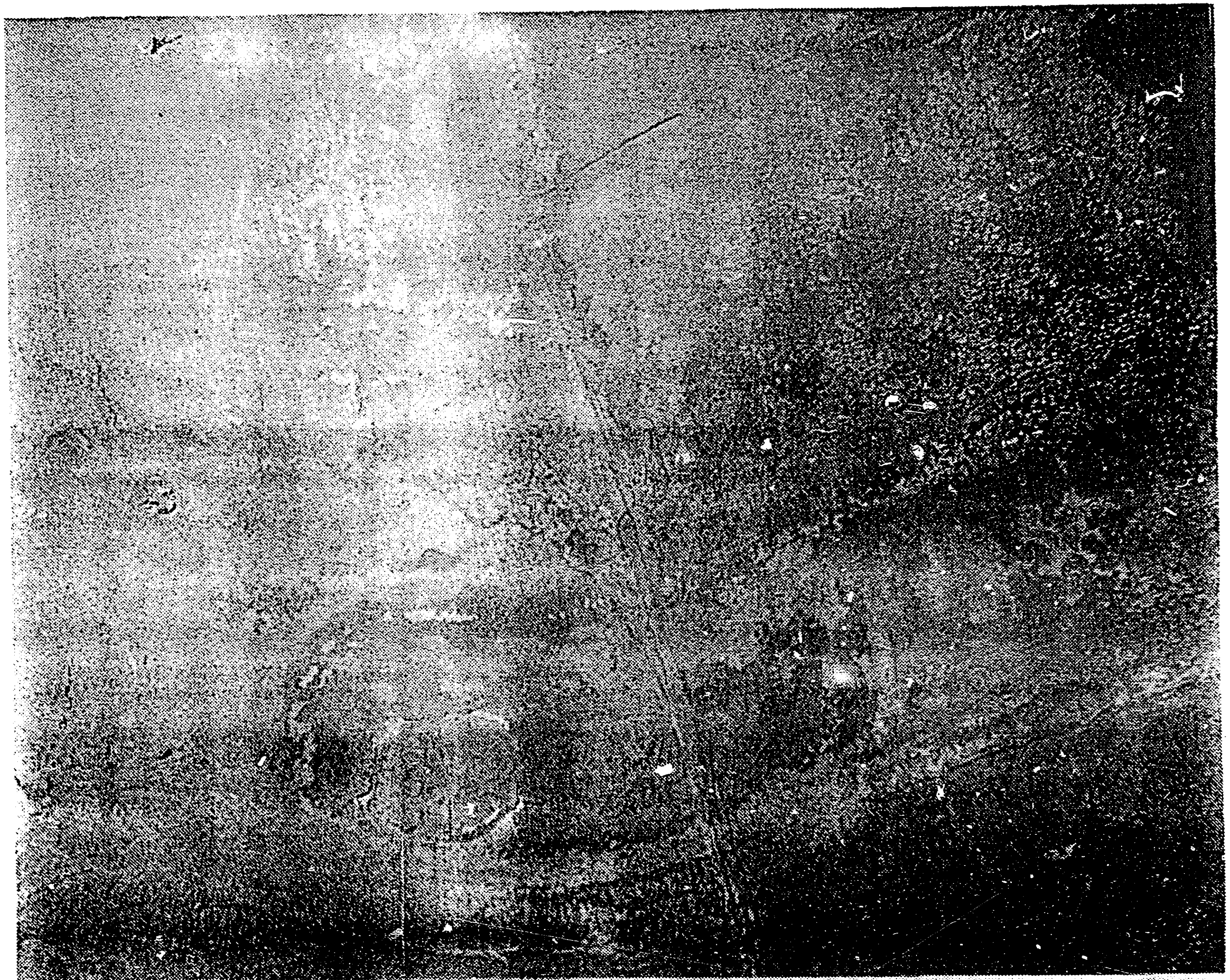

33542-15

Figure 5. View of Typical Pitting Occurring in the Tank Wall at the Liquid Level Interface

Figure 6. Close-up of the West End Tank Head (This view illustrates cracks that radiate approximately 1 1/2-2 in. from the thermowell.)

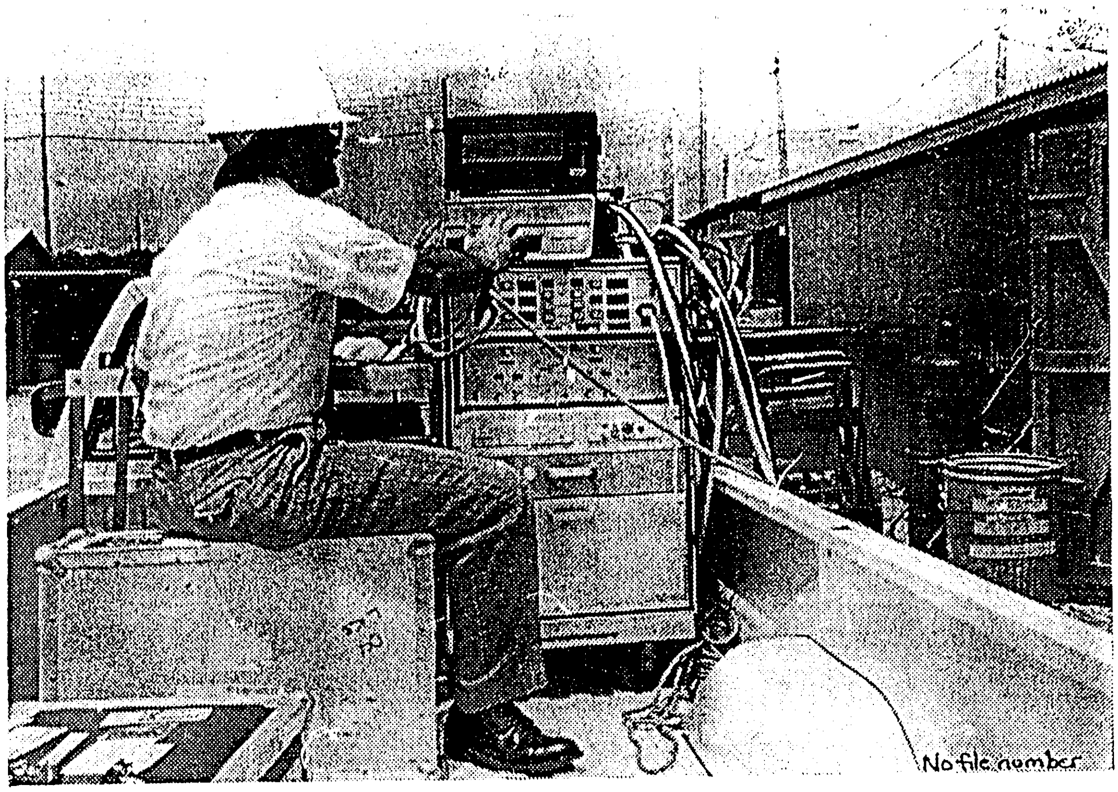


Figure 7a. Automated UT Scanning System with Actual UT Scanner

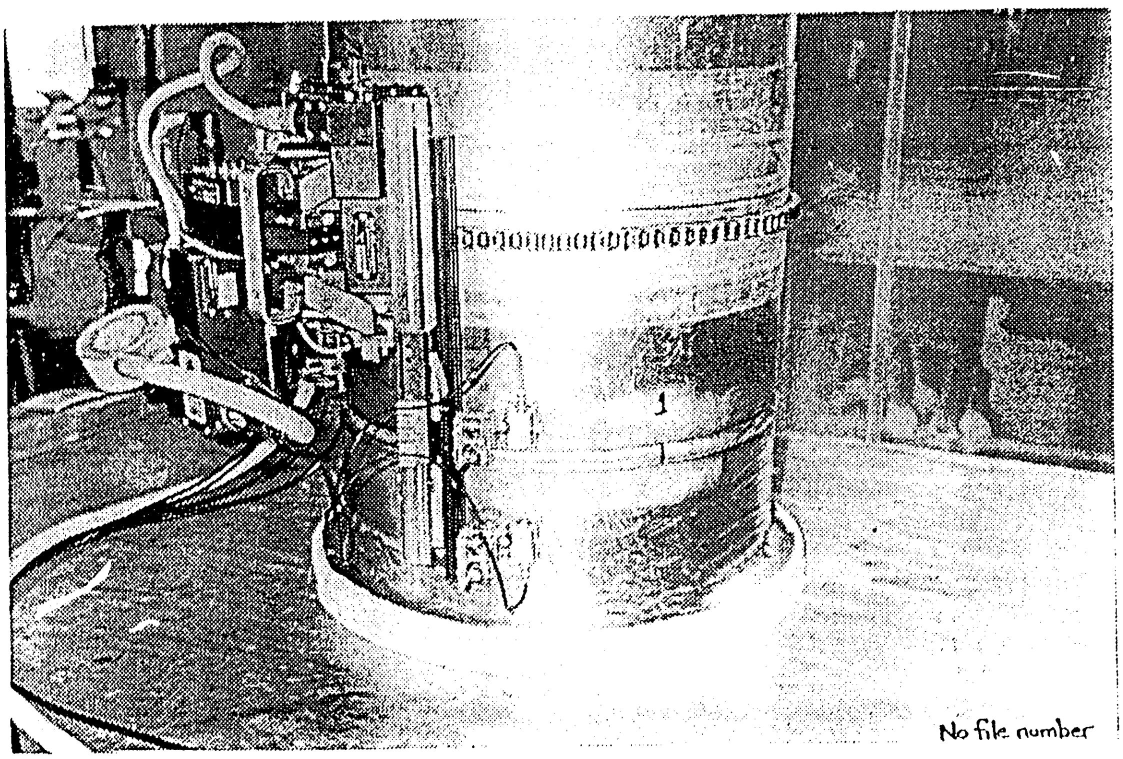
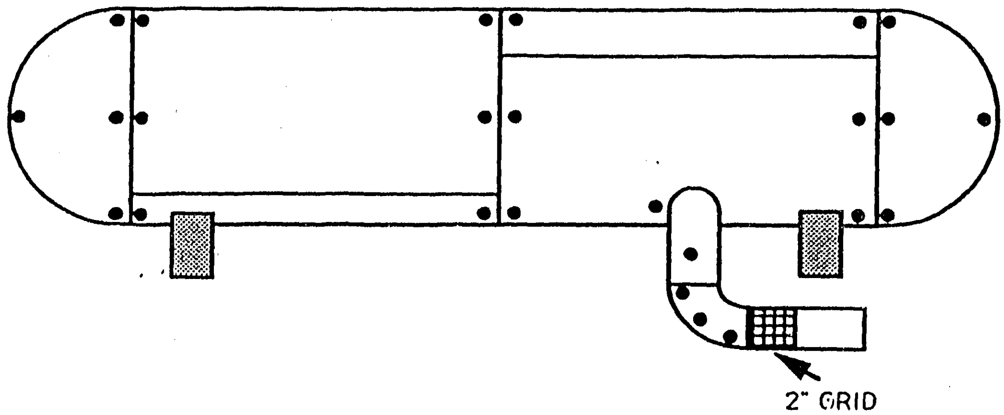


Figure 7b. Automated UT Scanning System

• = typical manual thickness reading locations for a horizontal storage tank
(spot readings every 90° at each weld and on the head)



= P-SCAN thickness mapping location
(complete coverage of entire scan area)

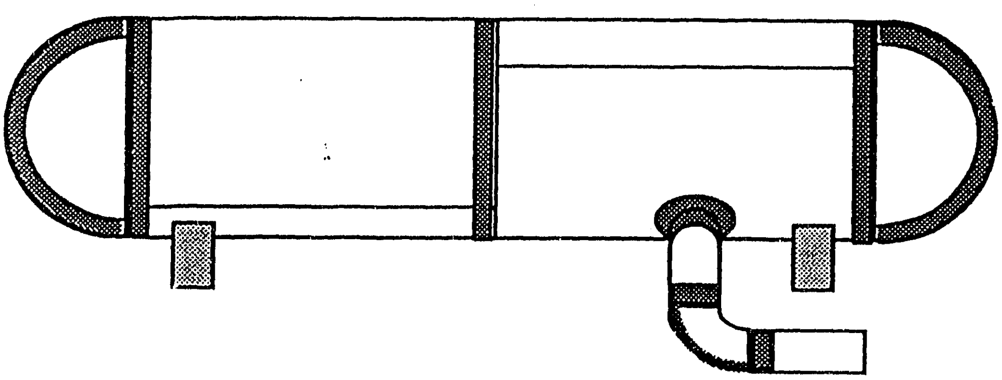


Figure 8. Comparison of Manual and Automated Thickness Reading Locations

END

DATE
FILMED
6 / 23 / 92