WSRC-MS-94-0642

The Inspection of a Radiologically Contaminated Pipeline Using a Teleoperated Pipe Crawler

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A document prepared for INTERNATIONAL JOURNAL OF ROBOTICS AND AUTOMATION

DOE Contract No. DE-AC09-89SR18035

DISCLAIMER

THE INSPECTION OF A RADIOLOGICALLY CONTAMINATED PIPELINE USING A TELEOPERATED PIPE CRAWLER

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ABSTRACT

In the 1950s, the Savannah River Site built an open, unlined retention basin to temporarily store potentially radionuclide contaminated cooling water from a chemical separations process and storm water drainage from a nearby waste management facility that stored large quantities of nuclear fission byproducts in carbon steel tanks. The retention basin was retired from service in 1972 when a new, lined basin was completed. In 1978, the old retention basin was excavated, backfilled with uncontaminated dirt, and covered with grass. At the same time, much of the underground process pipeline leading to the basin was abandoned. Since the closure of the retention basin, new environmental regulations require that the basin undergo further assessment to determine whether additional remediation is required. A visual and radiological inspection of the pipeline was necessary to aid in the remediation decision making process for the retention basin system. A teleoperated pipe crawler inspection system was developed to survey the abandoned sections of underground pipelines leading to the retired retention basin. This paper will describe the background to this project, the scope of the investigation, the equipment requirements, and the results of the pipeline inspection.

BACKGROUND

In 1989, the Savannah River Site came under the jurisdiction of provisions in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Under the requirements of CERCLA, several formerly radionuclide contaminated sites that were closed prior to the enactment of CERCLA must undergo additional assessment. One of these sites is an unlined retention basin.

The retention basin was designed and constructed as an open, unlined, temporary container for the storage of potentially radionuclide contaminated water from a chemical separations process. Additionally, it was to hold the storm water drainage from a facility that stored high level nuclear waste in carbon steel tanks. Under normal operating conditions, waste water was directly discharged into area surface streams. However, when radioactivity in the process or storm water runoff was detected, the water was diverted into the retention basin via an underground pipeline system. The basin was put into operation in 1955 and was used until 1972 when it was replaced by a lined retention basin. The exact volume of process and runoff water stored by the basin during its operation is unknown.

In 1978, soil samples were taken from the bottom of the closed retention basin. The major radionuclides present in the excavated soil were cesium 137 (Cs-137), strontium 89 (Sr-89), and strontium 90 (Sr-90). Other elements present include carbon 14, technetium 99, and tritium. The maximum soil concentrations were 80,600 pCi/g of CS-137 from a soil depth of 15-30 cm (6-12 in) and 15,400 pCi/g of Sr-89,90 from a soil depth of 0 to 15 cm (0-6 in).

By 1979, a total of nearly 1000 cubic meters (1308 cubic yards) of soil were removed from the retention basin. The calculated excavated inventory of radionuclides was 11.5 Ci of Cs-137 and 0.5 Ci of Sr-89 and 90. After excavation, additional soil samples were taken from the basin floor in an attempt to estimate the remaining radionuclide inventory in the soil. It was estimated that 54 mCi of Cs-137 and 530 mCi of Sr-89 and 90 were present. The basin was then filled with uncontaminated soil and seeded with grass. Unlike the retention basin, the process pipeline leading to the basin was not disturbed and was abandoned intact.

According to provisions in CERCLA, and agreements between the Environmental Protection Agency (EPA), the Department of Energy (DOE), and the South Carolina

Department of Health and Environmental Control (SCDHEC), a remediation investigation of the closed retention basin had to include data on the abandoned process pipeline. It was assumed that the contamination found in the retention basin would also be present in the pipelines leading to the basin. To verify this assumption, over 300 random soil samples were proposed to be taken from 366 m (1200 ft) of the abandoned pipeline system. This would be a very costly endeavor and there would always be concern if enough soil samples were taken to adequately represent the soil condition along the pipeline. Also, there would always be uncertainty about the structural condition of the pipelines. An internal inspection of the pipeline would help to remove concerns about the integrity of the pipeline and would be useful in identifying high radiation areas along the pipeline which might have the greatest potential for impact to the surrounding soil. As a result, the uncertainties associated with the soil sampling method would be reduced as well as the costs and time delays caused by taking numerous, unwarranted, soil samples.

RETENTION BASIN AND PIPELINE SYSTEM

The retention basin was excavated in a low lying area of the chemical separations and waste management facility. It measures approximately 61 m (200 ft) long, 36 m (120 ft) wide, and 2.1 m (7 ft) deep with a total volume capacity of 4611 cubic meters (6031 cubic yards). The pipeline system leading to the retention basin is constructed of several thousand feet of 61 cm and 91 cm (24 and 36 in) diameter reinforced concrete pipe. The depth of the pipeline ranges from less than 1 m (3 ft) below grade near the retention basin to 5 m (15 ft) below grade in other sections of the pipeline. Sections of the original pipeline system are still being used to divert water to the new basin. Approximately 366 m (1200 ft) of pipeline is abandoned. The diagram in Figure 1 shows the location of the retention basin and the abandoned process pipeline.

The abandoned pipeline can be divided into four sections that contain a number of valve boxes, a diversion box, and a manhole. The purpose of the valve boxes was to regulate the amount of water released to the retention basin. The pipeline sections include a segment of pipeline from diversion box A to valve box B, from diversion box A to manhole C, from manhole C to valve box D, from manhole C to valve box E, and from valve box E to the retention basin. The pipeline sections from A to B and from A to C are 61 cm (24 in) in diameter. The pipeline sections from C to D, from C to E, and from E to the retention basin are 91 cm (36 in) in diameter. Manhole C serves as a junction point for the 61 cm (24 in) and 91 cm (36 in) pipe sections. The valve boxes are approximately 2 m (6 ft) square and are 2.4 m (8 ft) to 6 m (20 ft) deep. They are constructed of concrete walls extending 0.3 m (1 ft) above grade. The concrete walls support several sections of metal grating which cover the top of the valve boxes. Diversion box A is also approximately 2 m (6 ft) square and made of concrete. However, it stands nearly 2 m (6 ft) high above grade.

Figure 1. Retention basin and pipeline system

INVESTIGATION PURPOSE, GOALS AND SCOPE

An internal pipeline inspection would provide quantitative data from which an informed, reasonable decision could be made about the level of remediation required, if any, for the abandoned sections of the pipeline system. The purpose of the inspection was to determine if conditions exist in the pipeline that might have led to or may lead to the contamination of surrounding soil. Unless somehow breached, the intact portions of the pipeline were assumed to prevent contaminant migration into the surrounding soil. If breaches are found, the next phase of the remediation investigation would be to obtain samples of the soil surrounding the pipeline breach and other areas identified as having higher than normal levels of radioactivity. If radiation levels did not exceed a predetermined threshold, then the pipeline as a whole would be considered to pose negligible risk to the environment. However, if radiation levels did exceed the threshold, environmental remediation actions might be necessary.

The goals of the investigation were to identify faults or defective areas and map the levels of radioactivity within the pipeline. A visual and radiological investigation would help answer 4 pertinent questions about the conditions inside the abandoned sections of pipeline.

1) Have any structural failures occurred in the pipeline?
2) Are there any excessive accumulations of contaminated sediments in the pipeline?
3) Is the radioactive contamination fixed or transferable?

4) What is the level of radioactivity in the pipeline?

A visual inspection of the pipeline interior would reveal structural problems in the pipe. Structural problems include separated joints, cracks, cave-ins and material degradation of the concrete pipe. These conditions could be severe enough to have provided a breach in containment for the radioactive effluent. In addition, a visual inspection would reveal the presence of sediment accumulations within the pipeline system. The accumulation of contaminated sediment at pipeline joints may provide a migration path for the radioactive effluent. Finally, an inspection of valve box, diversion box, manhole and joint construction would provide insight as to how well the pipeline system may have contained the radionuclide contaminated effluent.

A radiological survey would help answer questions concerning the type of contamination and the level of radioactivity in the pipeline. Based on retention basin history and previous soil sample results, contamination within the pipeline is expected. The contamination can take 2 forms; fixed and transferable. Fixed contamination occurs when radioactive nuclides become imbedded in a material and cannot be easily removed. This kind of contamination can be expected in the pipeline as a result of the contact between contaminated effluent and the concrete walls of the pipe. The concrete may have absorbed radionuclides from the effluent during pipeline operation. This type of contamination represents the least risk of migration into the surrounding soil since nuclide mobility is greatly reduced by its incorporation into the concrete matrix. On the other hand, transferable contamination occurs when radioactive nuclides are attached to small particles of debris such as sand or silt. Since the carrier particle is mobile in solution, it can be easily transported from one end of the pipeline to the other or into the surrounding soils through cracks in the concrete pipe.

The pipeline investigation would cover 366 m (1200 ft) of abandoned process pipeline. Pipeline still in use would not be inspected. The inspection would be recorded on videotape. The videotape and radiological data would be reviewed and used by both on and off-site environmental organizations in determining the need to remediate the process pipeline system.

PIPELINE INSPECTION SYSTEM

A teleoperated pipe crawler system was developed to perform a visual and radiological investigation of the interior of the abandoned sections of pipeline leading to the closed retention basin. The data from the crawler is correlated with its distance into the pipeline. In this way, any subsequent soil samples could be taken from the exact pipeline location exhibiting structural failures, sediment accumulations, or higher than expected radiation levels. The pipeline inspection system is shown in Figure 2. It can be subdivided into 4 parts; 1) the pipe crawler, 2) the radiation detection system, 3) the display and control console, and 4) the crawler deployment tool.

The pipe crawler is a commercially available product called Mini-Tracs and is made by Inuktun Services of Canada. The Mini-Tracs pipe crawler can be configured to navigate in pipe ranging in diameter from 15 to 91 cm (6-36 in). Two powerful and heavy duty drive units with deep lug belts propel the Mini-Tracs crawler. Each unit is composed of a precision machined, brass chassis containing a sealed, oil-filled, gear-driven motor train. They are designed to support a 68 kg (150 lb) payload. Each drive unit can be independently operated at speeds ranging from 0 - 10.5 m/sec (0-35 ft/sec). They each weigh 13 kg (29 lb) and measure 10 cm (4 in) high by 9 cm (3.5 in) wide by 38 cm (15 in) long. The drive units can be configured for operation in different pipe diameters by using combinations of aluminum mounting brackets.

A low light level, color camera and an adjustable intensity light are mounted between the Mini-Tracs drive motor units. The camera has a 4.8 mm, f1.8 lens for wide-angle viewing. Both the camera and light assemblies are housed in water-proof, aluminum containers and are attached to the crawler's control cabling with water-proof connectors.

Figure 2. Pipe crawler inspection system

The installation of a radiation detection system on the Mini-Trac crawler was a challenge. To develop an effective crawler deployable radiation system, the following questions had to be answered:

1) What are the major isotopes of concern?
2) What are the maximum expected levels of radiation and contamination?
3) Can the detector and radiation survey instrument be calibrated to work with a 152 m (500 ft) length of cable?

It was assumed that the isotopes in the basin would also be present in the pipeline. Based on earlier basin soil sampling, this meant that the major isotopes of concern were Sr-89/90, Cs-137, and possibly some alpha emitting isotopes. A pancake type detector such as the Eberline Model 210 is well suited for this isotopic mixture. The Eberline model HP210 is a gas-filled Geiger-Mueller detector used to measure gross alpha, beta, and gamma radiation. Additionally, since the maximum radiation levels were unknown, the ability to measure dose rates was needed. An Eberline HP270 detector was chosen. The HP270 is a cylindrical, energy compensated Geiger-Mueller tube detector with a range from background to 200 mR/hr. The Mini-Trac was slightly modified to carry 3 radiation detectors; 2 HP210 detectors and 1 HP270 as shown in Figure 3.

Figure 3. Mini-Trac with radiation detectors

One of the HP210 detectors was mounted on a bracket beneath the crawler with sufficient clearance from the bottom of the pipeline to allow for sediment accumulations. The other detector was mounted in a spring-loaded carrier and attached to one of the pipe crawler's drive motor assemblies. The carrier held the detector at a constant distance of 1.2 cm (0.5 in) from the pipe wall.

The Eberline model HP270 Geiger-Mueller detector was mounted on the top side of the crawler and just to one side of the camera housing. It has a sliding shield that allows for gross discrimination of beta and gamma radiation. This detector was calibrated for use in the dose rate mode. The nominal energy response of the HP270 detector is > 200 keV for beta and > 6 keV gamma with the shield open and > 70 keV gamma with the shield closed. There is no response to beta radiation with the shield closed. The dose rate detector was to be used if radiation levels in the pipeline exceeded the range of the HP210 detectors.

The HP210 and HP270 detectors were used in conjunction with the Eberline Smart Portable (ESP-2) microcomputer-based radiation survey instrument. The ESP-2 is a lightweight, compact, survey instrument with a digital display readout. It has the ability to store and print several hundred date and time stamped data points, and can be calibrated with a variety of detectors. The ESP-2 can be operated as a scalar or as a rate meter. In the rate meter mode, the instrument is useful as a gross beta and gamma count rate instrument. The ESP-2 can also produce an audible click when detecting radiation. As the radiation levels increase, so does the rate of the audible clicking.

The vendor recommended calibration procedure was used for the ESP-2 and the detectors. The ESP-2 and the detector were connected using a 1.5 m (5 ft) cable. The initial settings of the ESP-2 instrument were: 10 millivolt input sensitivity, maximum gain, a high voltage of 900 volts, response to pulser +- 10% of input across the ESP-2's full range, dead time and calibration constant per vendor recommendations for the detector, and a detector efficiency of approximately 30 % using a Sr/Y-90 source. After calibration with the 1.5 m (5 ft) cable, the 152 m (500 ft) cable was used. The measured high voltage and instrument response to the pulser and the source were unchanged. However, the instrument input sensitivity had increased to 90 millivolts. When the instrument's input sensitivity was adjusted back to 10 millivolts, pulse rollover was experienced. Pulse rollover is an increase in instrument response caused by the generation of low end signal noise over long cable distances. Several tests were performed and it was found that pulse rollover occurred with input sensitivities below 90 millivolts. To prevent pulse rollover, the input sensitivity of the ESP-2 was set at 100 millivolts.

The HP210 detectors were calibrated in the count rate mode. Their nominal energy response and efficiencies are as follows:

1) alpha > 3 MeV, approximately 50 % efficient for Th 230, 30 % for Pu 239.
2) beta > 40 keV, 20% efficient for Pm 147, 30% for Tc 99, and 45% for Sr 90.
3) gamma > 6 keV at 3600 cpm/mR/hr.

The efficiencies are based on the 2 pi emission rate of the radiation source, expressed in cpm, at less than or equal to 6.35 mm (0.25 in) from the source.

Before the crawler was deployed in the field, several radioactive sources were used to test the effectiveness of the inspection system. Plated sources of Sr/Y90 (2,200 dpm), Cs-137 (nominal 0.1 uCi) and Pu-239 (20,000 dpm) were placed in the path of the crawler. Using a very low speed, the crawler's detectors responded well to the sources. As the crawler's speed was increased, the ability to recognize an increase in response was reduced. By recorded. Concurrently, the radiation data was stored in the memory banks of both ESP-2 units. A printout of the data was generated when the pipeline section investigation was completed. After the crawler reached the end of the pipeline section, it was driven backwards out of the pipeline. Once the crawler returned to the pipeline entrance, it was driven onto the deployment tool's carriage, slid out of the pipeline, and raised to the surface by the remotely operated winch.

PIPELINE INSPECTION RESULTS

Over 240 m (800 ft) of pipeline were surveyed during the investigation. This included the pipeline sections A to B, A to C, E to D, and E to the basin. The visual inspection of the pipeline sections revealed that they are generally in very good condition. The pipe joints, with one exception, were shown to be intact and in excellent condition. A black, tar like, sealant applied to the joints during installation of the pipeline was quite evident from the videotape footage. The visual inspection also revealed 5 minor cracks of which 4 were located at the top of the pipeline. One crack was observed located in a section of pipeline that passes under a site road. The crack was located at a level on the pipe that may have been reached by the effluent. The cracks generally ran lengthwise along the pipeline. None of the cracks appeared to follow the circumference of the pipe and thereby produce a contaminate pathway out of the pipeline. Sediment was observed along most sections of pipeline. The sediment depth could not be quantitatively measured, but appeared to decrease as the crawler traveled up positive gradients and increase as the vehicle went down negative gradients. The deepest sediment accumulations were located near manhole C as shown in Figure 5.

Figure 5. Sediment accumulation near point C

The radiation levels in the pipeline were taken every 1.5 m (5 ft) or more frequently if a higher than usual reading was observed. The radiation data set from each pipeline section included 3 variables: 1) the distance traveled in the pipeline from the access point, 2) the beta-gamma measurements from the side-mounted detector, and 3) the beta-gamma measurements from the detector mounted on the underside of the crawler. Since the radiation data set was spatially correlated, classical statistical methods which assume random sampling and independence were not appropriate for analysis of the radiation data. Instead, an invariant, geostatistical technique known as kriging was used to characterize the pipeline data.

Kriging is a process of prediction. It relies on the spatial continuity of the collected data. Graphs plotted with kriged values represent spatially averaged estimates of radioactivity with upper and lower confidence bounds. The graphs are composed of 3 lines. The upper and lower lines represent a two-sided 95% prediction limit. The top line is a 97.5% upper prediction limit or confidence limit. It represents a reasonable upper bound on the average radioactivity level at any particular point within the pipeline. The top line can be compared to a pre-specified level of radioactivity that would trigger additional sampling. The middle line represents the estimated radioactivity as a function of pipeline location. Occasionally, a measurement appears that is much different than a neighboring measurement. It is referred to as an outlying measurement or outlier. Outliers are represented as dark circles on the graphs. If the upper confidence limit is less than a pre specified threshold of radioactivity and no outliers exceed the pre-specified level, then no locations are identified in the pipeline as having elevated levels of radioactivity. However, sections with large outliers should be investigated. In this investigation, no pre-specified radiation values were given before the inspection began.

The data from diversion box A to valve box B contains 57 measurements. The measurements were taken from point A to point B and in the direction opposite to effluent flow. The plot of the side detector readings is generally smooth, except at the four outliers noted on the graph. The highest side detector reading is 17,600 cpm and the highest level of radioactivity occurs in the region of 77.7 - 86.9 m (255-285 ft) from point A. The upper confidence limit for the side detector ranges from 13,000 to 14,500 cpm in this region. The local average of the bottom detector activity falls within a band between 2 and 6 thousand cpm. The highest level of radioactivity found by the bottom detector is located between 11 m and 14.3 m (36 and 47 ft) from point A. The upper confidence limit of the bottom detector reaches 6200 cpm. The outliers from the side detector's graph contain 3 points that exceed the upper confidence limit. The locations are at 0.3 m (1 ft) with a reading of 12,000 cpm, 7.6 m (25 ft) with a reading of 17,600 cpm, and 27.4 m (90 ft) with a reading of 10,500 cpm. The outliers on the bottom detector graph are all below the upper confidence limit. The plot of the kriged values is shown below in Figure 6.

Figure 6. Radiation data, point A to point B

The data from diversion box A to manhole C contains 54 measurements. The measurements were taken from point A to point C and in the direction of effluent flow. The plot of the kriged values is shown below in Figure 7.

Figure 7. Radiation data, point A to point C

The crawler's side detector registered a mean radioactivity of 34,600 cpm which is much higher than any other mean value from the other sections of pipeline. The highest locally averaged radioactivity is 55,000 cpm at approximately 23.4 m (80 ft) into the pipeline. At this point, the upper confidence limit is 80,000 cpm. The bottom detector shows a maximum locally averaged radioactivity of 6000 cpm at approximately 9.1 m (30 ft) from point A. The maximum upper confidence limit is approximately 9400 cpm. The bottom radiation levels were greatest between 6 m (20 ft) and 18.3 m (60 ft) from point A and decreased as the level of sediment accumulated in the pipeline.

The data from valve box E to the retention basin contains 29 measurements. The measurements were taken from point E to the retention basin and in the direction of effluent flow. The graph of the side detector shows a locally averaged peak radiation reading of 4400 cpm around 21 m (70 ft) from point E and decreases in both directions from this location. The upper confidence limit for the side detector is 9400 cpm. The graph of the bottom detector contains a number of peaks and valleys. The radiation level is lowest near the ends of the pipeline. A maximum locally averaged radioactivity reading of 8900 cpm occurs 16.7 m (55 ft) past point E in the direction of the retention basin. The upper confidence limit for the bottom detector is 11,000 cpm. No outlier values were found for this set of data points. The plot of the kriged values is shown below in Figure 8.

Figure 8. Radiation data, point E to the basin

The data from point E to point D consists of 12 measurements. The measurements were taken from point E to point D and in the direction opposite to effluent flow. The entire section of pipeline from point E to point D could not be investigated due to the lack of a wall crawling surface in manhole C and the inability to use valve box D as an entry point. Only the side detector measurements were obtained. The small number of data points does not lend itself well to establishing any spatial relationships between the measurements. About all that can be said about these measurements is that they exhibit a lower radiation level as compared with the data measurements in other sections of pipeline. The plot of the kriged values is shown below in Figure 9.

Figure 9. Radiation data, point E to point D

SUMMARY AND CONCLUSIONS

Current CERCLA regulations and agreements between federal and state environmental agencies required that an environmental characterization be performed on an abandoned pipeline system which once carried radioactive effluent. The characterization would require 300 soil samples. In an effort to reduce soil sampling costs and associated time delays, it was proposed that a pipe crawler system be developed to gather visual and radiological information about the condition of the interior of the pipeline.

A pipe crawler system was deployed and functioned very well. The visual inspection revealed that the pipeline was generally in good condition. However, the crawler did find a few cracks, some possible joint failures, and some large sediment accumulations. Radiological data was also obtained. A statistical analysis of the radiation data was performed and it revealed several areas along the pipeline that exhibited elevated radiation levels. A diagram of the retention basin and the abandoned pipeline system is shown in Figure 10. The diagram shows the areas where soil samples will be taken to determine if contamination migrated out of the pipeline and into the surrounding soil.

The internal pipeline inspection provided quantitative data from which an informed, reasonable decision could be made about the number of soil samples required for further characterization of the abandoned pipeline system. The pipe crawler investigation reduced the number of soil samples from 300 to 8.

Figure 10. Soil sample locations

REFERENCES

Report on the Robotics Investigation of the F-Area Retention Basin (281-3F) Process Sewer Pipeline, September 1994, Document No. WSRC-RP-94-1105.

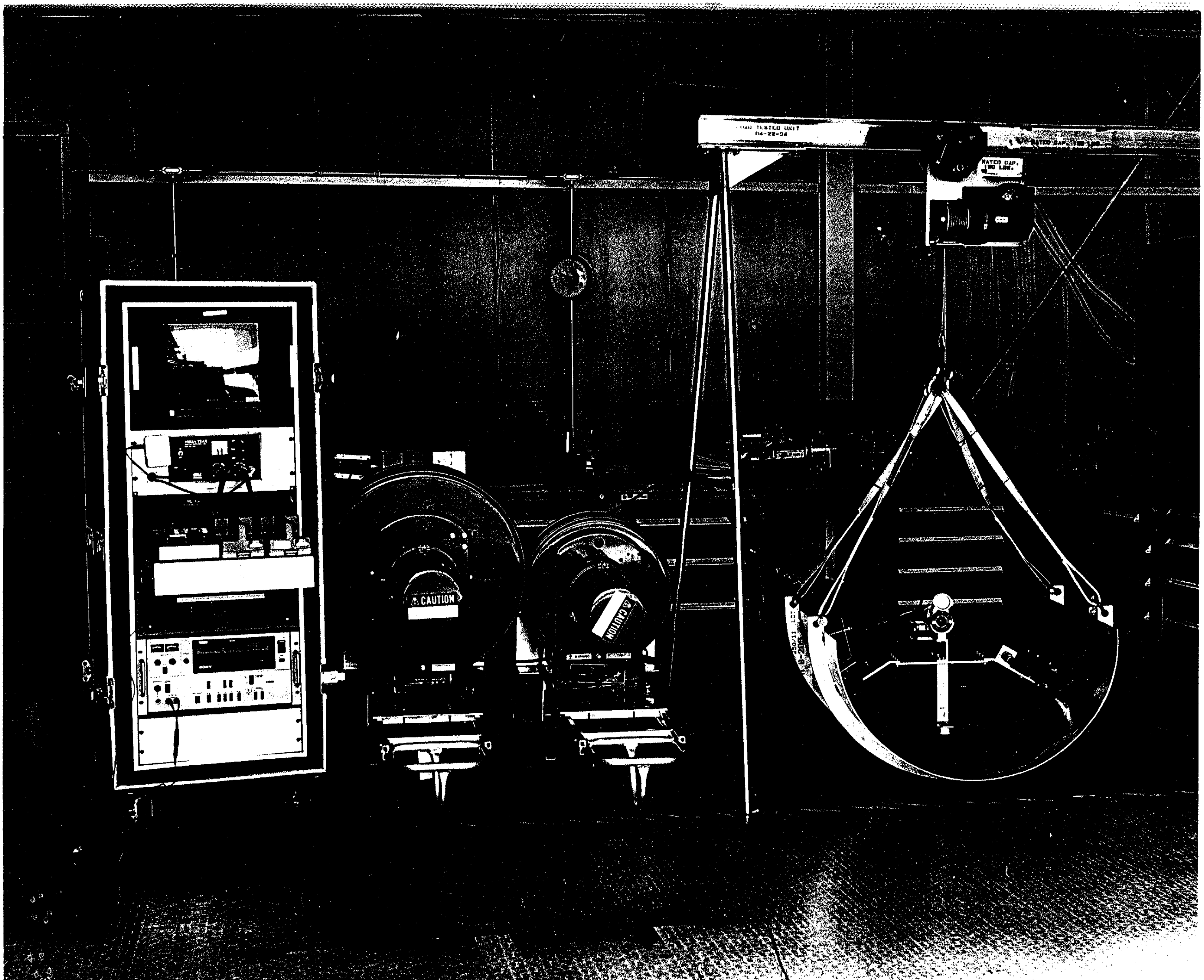
Remedial Technology and Characterization Development at the SRS F/H Retention Basins using the DOE SAFER Methodology, Document No. WSRC-TR-94-0257.

Exploratory Analysis of F-Area Process Sewer Line Data, Inter-Office Memorandum No. SRT-ASG-940055, To: K.J. Kuelske From: E.P. Shine.

ACKNOWLEDGMENTS

The author would like to thank Montenious Collins, Robert Witherspoon, Gary Henning and Ervin Proctor of the Robotics Development Group for their ideas and contributions that made this investigation a success.

The information contained in this paper was developed during the course of work under Contract No. DE-AC0989SR18035 with the U.S. Department of Energy.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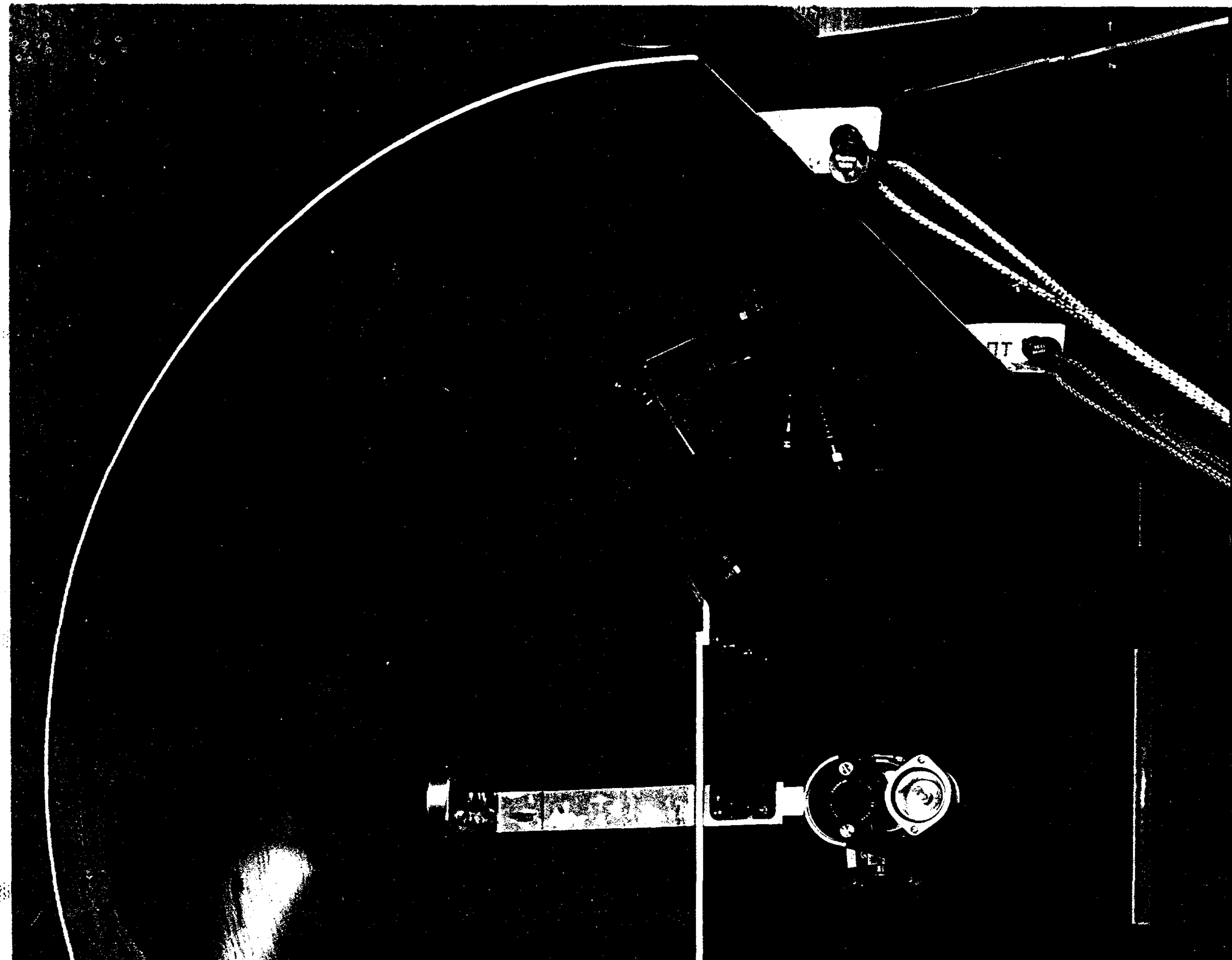

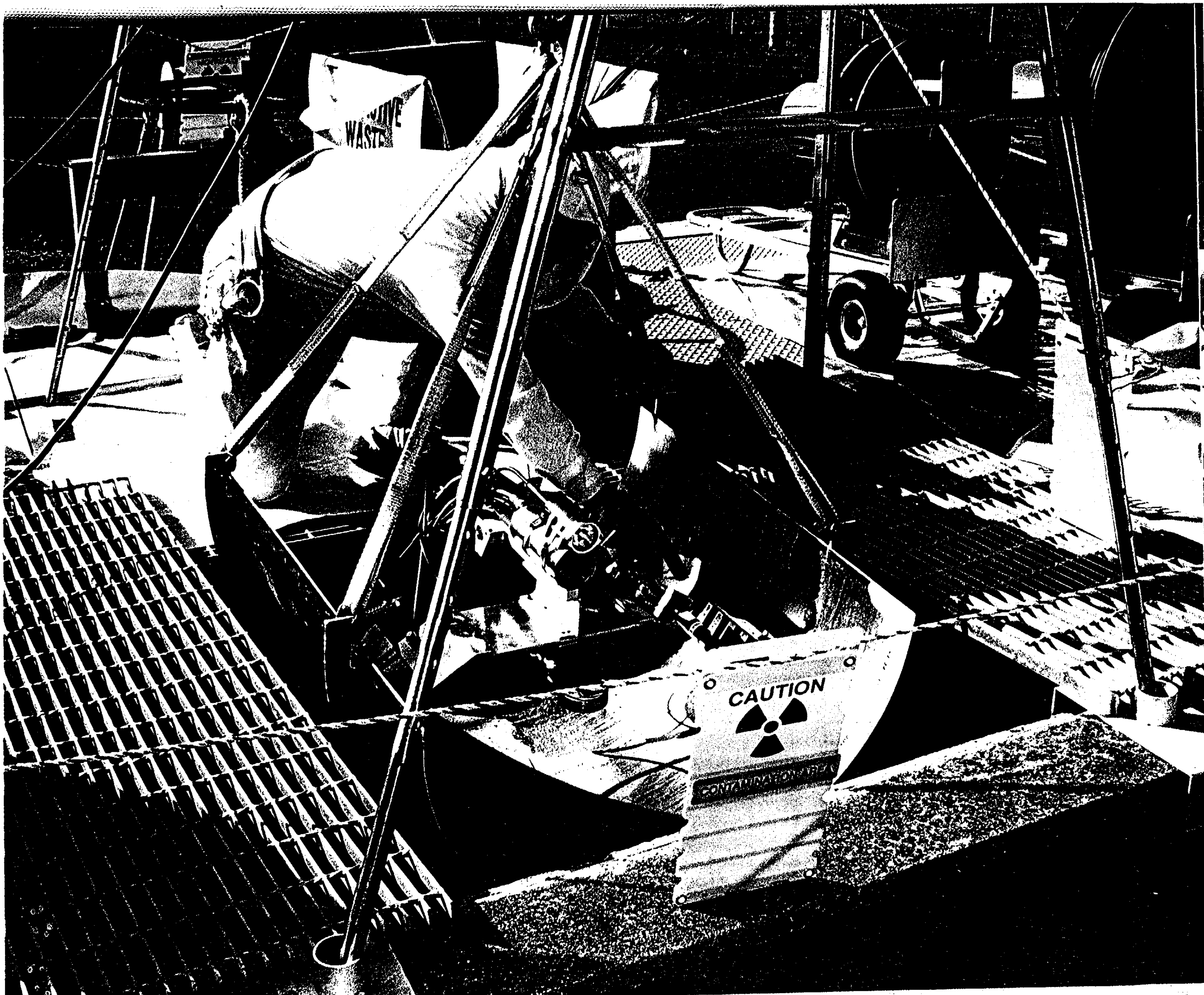
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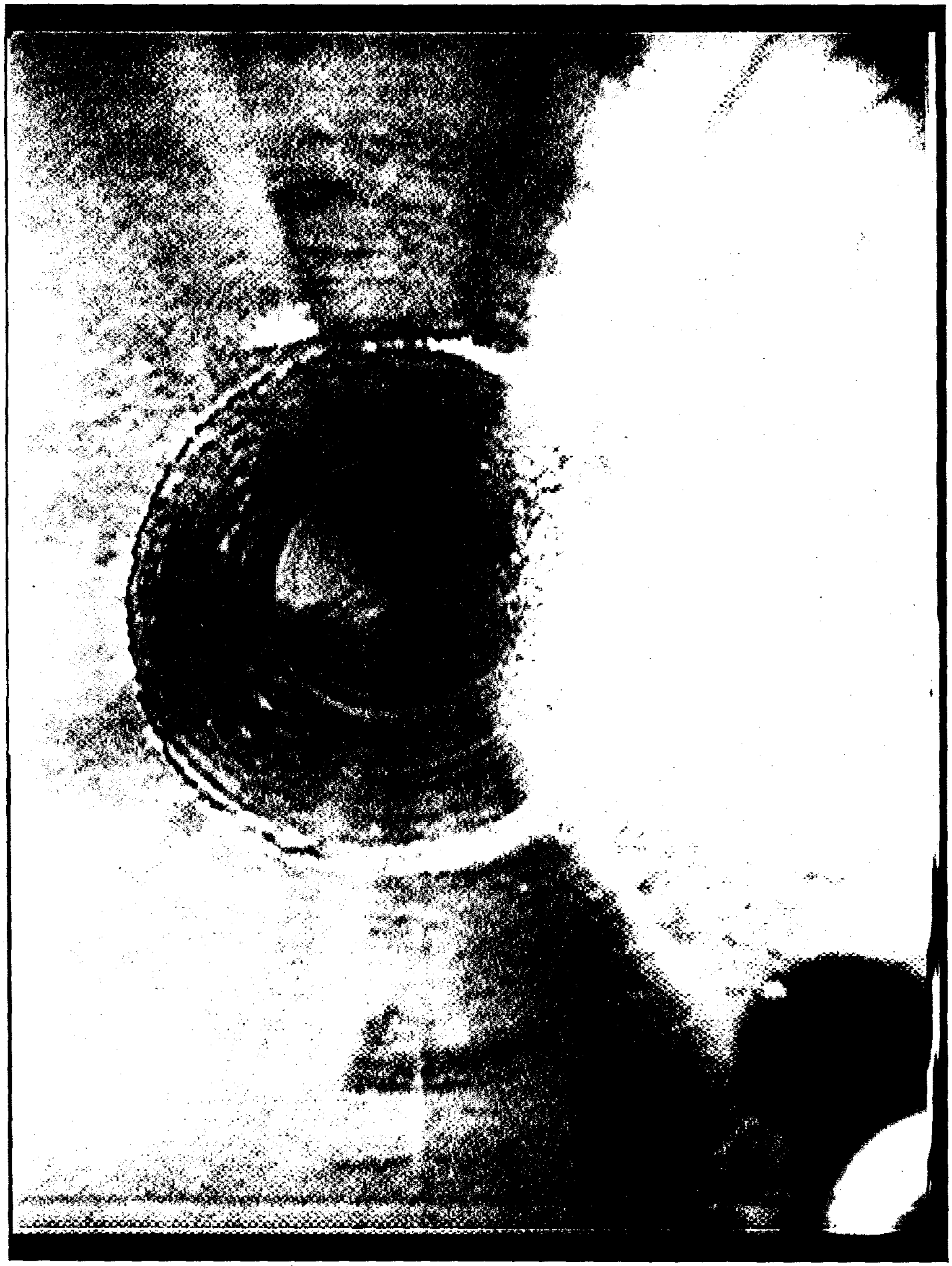
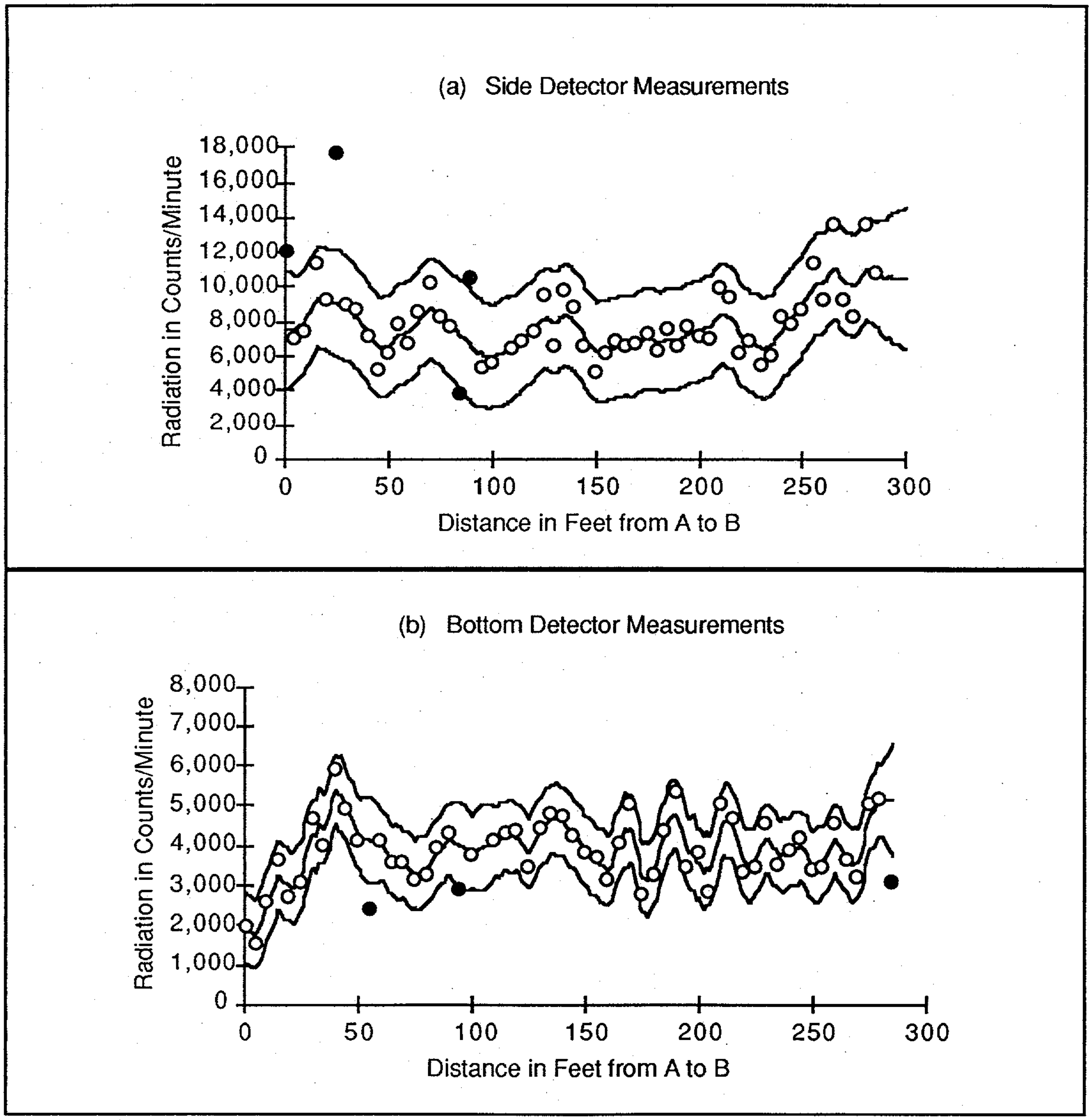
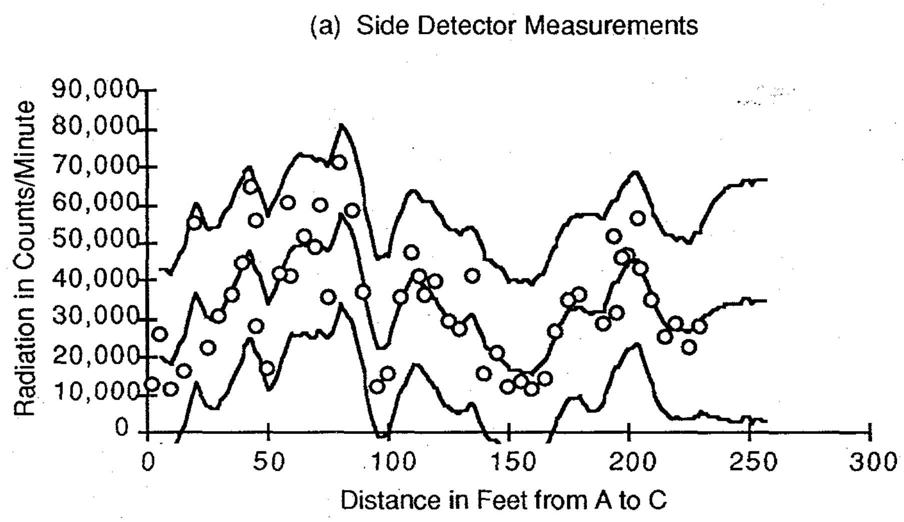




(a) Side Detector Measurements
Radiation in Counts/Minute
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0
50
100
150
200
250
300
Distance in Feet from A to B
(b) Bottom Detector Measurements
Radiation in Counts/Minute
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
50
100
150
200
250
300
Distance in Feet from A to B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50,000
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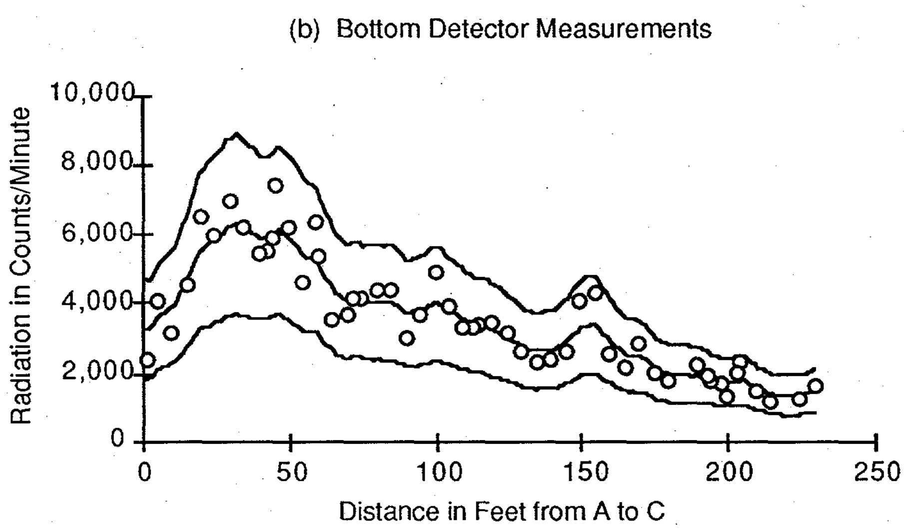
20,000
10,000
0
0
50
100
150
200
250
300
Distance in Feet from A to C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Radiation in Counts/Minute
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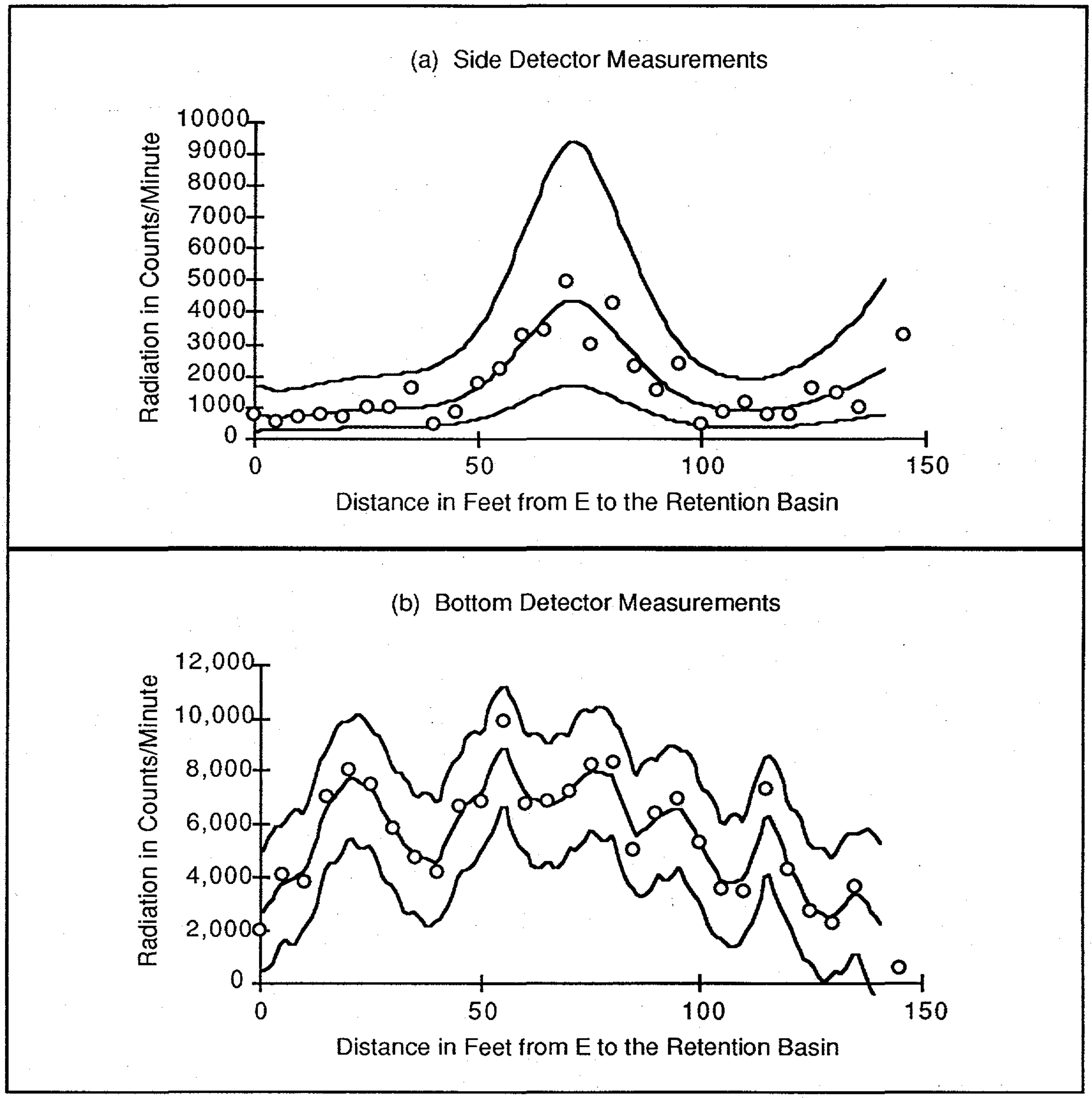
6,000
4,000
2,000
0
0
50
100
150
200
250
Distance in Feet from A to C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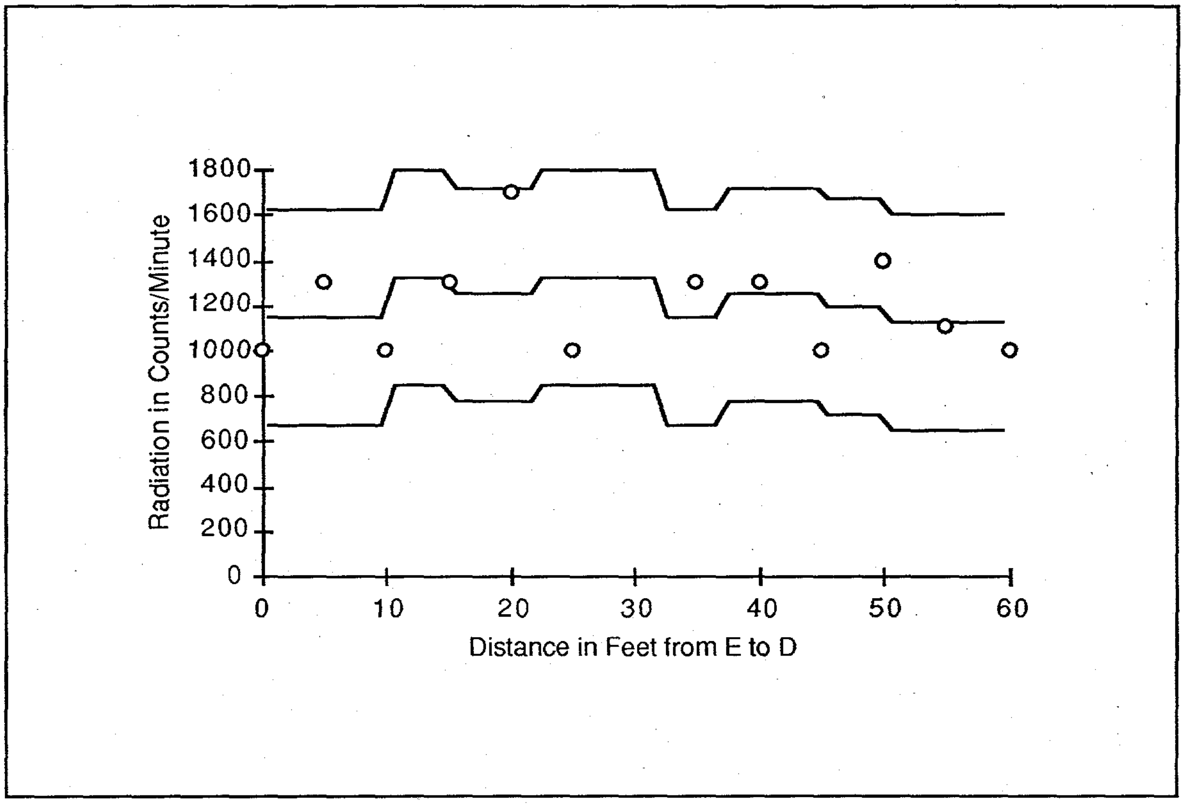
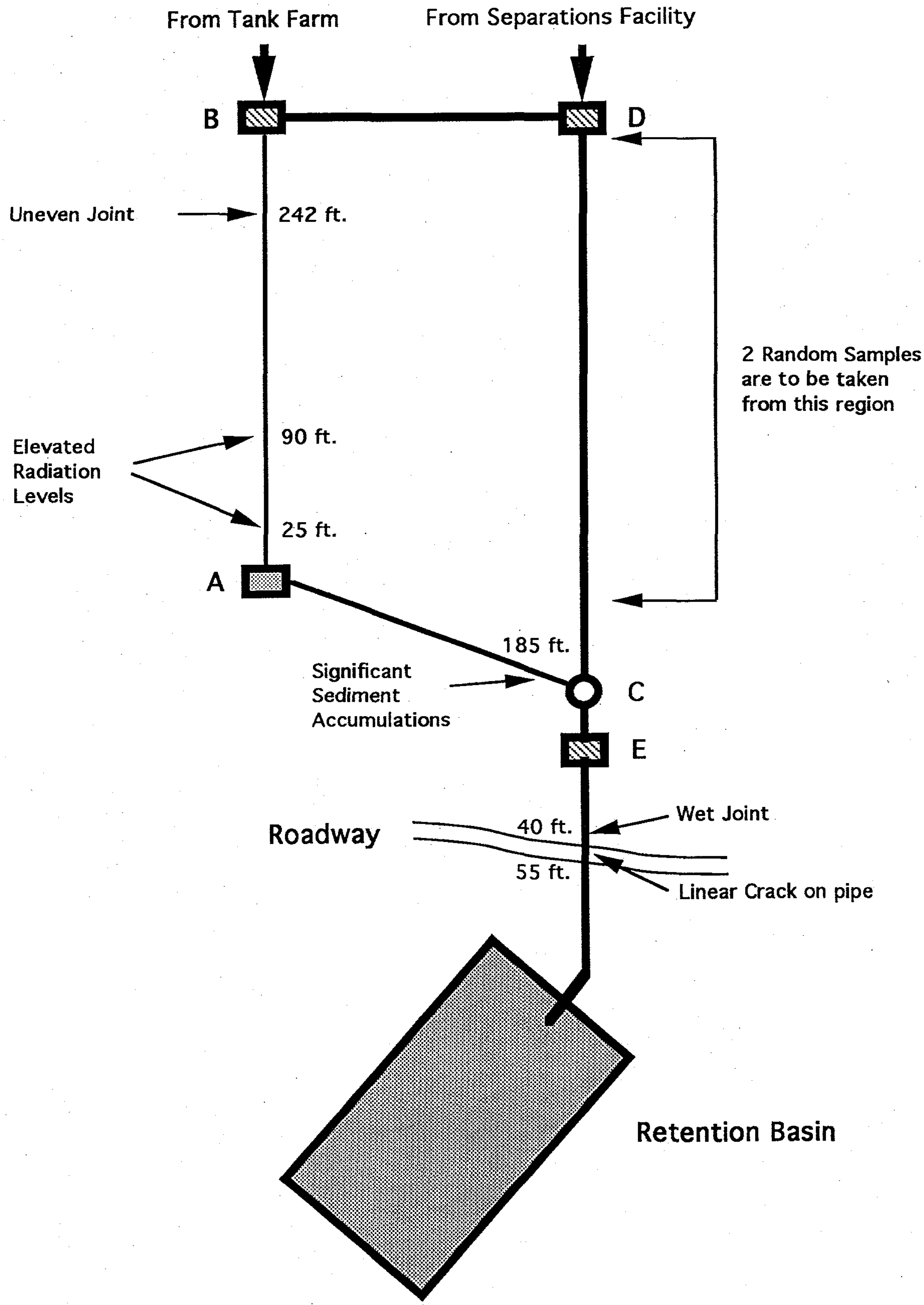
Radiation in Counts/Minute
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
50
100
150
Distance in Feet from E to the Retention Basin
(b) Bottom Detector Measurements
Radiation in Counts/Minute
12,000
10,000
8,000
6,000
4,000
2,000
0
0
50
100
150
Distance in Feet from E to the Retention Basin


1800
1600
1400
1200
1000
800
600
400
200
0
Radiation in Counts/Minute
0
10
20
30
40
50
60
Distance in Feet from E to D



From Tank Farm
From Separations Facility
B
D
Uneven Joint
242 ft.
2 Random Samples are to be taken from this region
Elevated Radiation Levels
90 ft.
25 ft.
A
185 ft.
Significant Sediment Accumulations
C
E
Roadway
40 ft.
Wet Joint
55 ft.
Linear Crack on pipe
Retention Basin