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Project RULISON
ON-SITE RADIOLOGICAL PROGRAMS
DURING REENTRY DRILLING THROUGH PRODUCTION TESTING
FINAL REPORT

by

EBERLINE INSTRUMENT CORPORATION

Santa Fe, New Mexico

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TABLE OF CONTENTS

	Page
Abstract	5
Section I – Introduction and Objectives	6
1.1 Historical Description	6
1.2 Objectives	6
Section II – Reentry Drilling	7
2.1 Facilities	7
2.2 Personnel	7
2.3 Radiation Detection and Sampling Equipment	7
2.4 Decontamination and Rig Clearance	19
Figure 1	8
Figure 2	9
Figure 3	10
Figures 4 and 5	13
Figures 6 and 7	16
Figure 8	18

TABLE OF CONTENTS (Continued)

COPY

	Page
Figure 9	20
Figure 10	21
Figures 11 and 12	22
Section III – Flaring	23
3.1 General	23
3.2 Instrumentation	23
Figure 13	24
3.3 Contaminated Liquid Waste Management	25
3.4 Open File System	25
Figure 14	26
On-Site Radiological Safety Data	28
Figures 15 and 16	29
Section IV – Placement of Site in Standby Status	31
4.1 General	31

TABLE OF CONTENTS (Continued)

	Page
4.2 Preparation for Standby Status	31
4.3 Termination of EIC Coverage	33
Section V – Conclusion and Recommendations	34
5.1 Conclusions	34
5.2 Recommendations	34
Figure 17	36
Figure 18	37



ABSTRACT

Eberline Instrument Corporation provided radiological safety support for Project RULISON, the second experiment in which a nuclear explosive was used to stimulate the production of natural gas. This support included installation, calibration and operation of effluent monitoring systems, personnel dosimetry, contaminated waste handling and disposal, environmental sampling, survey and monitoring and exclusion area control. Pertinent data required by U. S. District Court action was evaluated, documented and published daily in an Open File Report. All of the above activities indicated that radioactive materials were controlled and disposed of in accordance with AEC guidance.



SECTION I

INTRODUCTION AND OBJECTIVES

1.1 Historical Description

Project RULISON was a joint experiment sponsored by Austral Oil Company, Inc., the U. S. Atomic Energy Commission and the Department of the Interior. Its purpose was to study the economic and technical feasibility of using *underground nuclear explosions to stimulate production of natural gas from the low productivity formation in the Rulison Field.*

The nuclear device for Project RULISON was detonated successfully on September 10, 1969, at a depth of 8,425 feet. The yield of device was estimated at 43 ± 8 KT. and was completely contained.

The Nevada Operations Office of the U. S. Atomic Energy Commission (AEC/NVCO) was responsible for the safety of personnel at Project RULISON. During reentry drilling and initial flaring, responsibility for safety was delegated by AEC/NVCO to the Los Alamos Scientific Laboratory (LASL). Eberline Instrument Corporation (EIC) provided effluent documentation and on-site radiological support to AEC/NVCO and LASL under the provisions of contract AT(26-1)-294 during reentry drilling, calibration flaring, production test flaring, and site preparation work for placing the site in standby status.

1.2 Objectives

A. The effluent documentation program was established to detect and measure radionuclides in any form that could have been released to the environment in significant concentrations. Tritium and Krypton-85 were the radionuclides of primary concern.

B. The on-site radiological safety program was designed to:

1. Limit personnel exposure to the lowest possible level. Basic guidance was set forth in AEC Manual, Chapter 0524.
2. Control any radioactive materials that might be brought to the surface to avoid the spread of radioactive contamination.
3. Operate an explosive mixture detection and alarm system.

C. The cleanup program was designed to restore the project site to a standby condition in which all radioactive contamination requiring control was identified and contained in a sealed or protected condition pursuant to established AEC guidance.



SECTION II

REENTRY DRILLING

2.1 Facilities

Mobile on-site facilities were prepared in Albuquerque, New Mexico, and shipped to Project RULISON in April, 1970. Included in these mobile facilities were a sample preparation laboratory, a radiation measurements laboratory and an access control trailer. An office trailer was later added. A large variety of portable instruments was provided for air sampling and radiation survey. The location of EIC facilities during reentry drilling is shown on Figure 1.

2.2 Personnel

Experienced radiation monitors and technicians were phased on-site in accordance with requirements for the operations. Technicians were programmed to arrive early to install and calibrate the instruments. During reentry drilling there were a maximum of 26 EIC personnel (including a field manager and engineers) on-site at peak activity periods.

2.3 Radiation Detection and Sampling Equipment

The EIC radiation and detection and effluent monitoring and control instrumentation is shown in Figure 2. These instruments will be discussed in sequence with the capital letters and numbers shown in Figure 2.

A. Rig Instrumentation

1. Rig Beta Detector. The detector was located at the driller's station near the center of the rig. This detector was an Anton-112 tube cabled through an Eberline RM-3C rate meter to a Moseley strip chart recorder. This recorder was connected to the central alarm console located in the Access Control Trailer. The background of the Anton-112 was approximately 30 cpm. The alarm was set to be activated at twice background reading, which was equivalent to 10^{-6} uCi/cc of ^{85}Kr .
2. Air Sampling. There were four (4) air sampling heads located on the rig floor, one at each corner. These head assemblies consisted of a 9.0 centimeter diameter Whatman 41 prefilter and a charcoal cartridge (Figure 3) protected by a plastic weather shield. The air was drawn through these heads at a measured flow rate of approximately 15 cubic meters per hour. The four samples were collected at the beginning of each eight-hour shift.

The Whatman 41 filters were analyzed during that shift for alpha, beta and gamma activity. The charcoal cartridges were analyzed for gamma. Initially, all positive filters (i.e., net counts greater



RULISON SITE - Figure 1

1. ACCESS CONTROL
2. COUNTING LABORATORY
3. SAMPLE PREPARATION
4. OFFICE
5. HYDROCARBON STORAGE TANKS
6. WATER HOLDING TANKS
7. FLARE STACK

SCHEMATIC - PROJECT RULISON
RE-ENTRY DRILLING
EBERLINE INSTRUMENT CORP

FIGURE 2

ACCESS CONTROL TRAILER

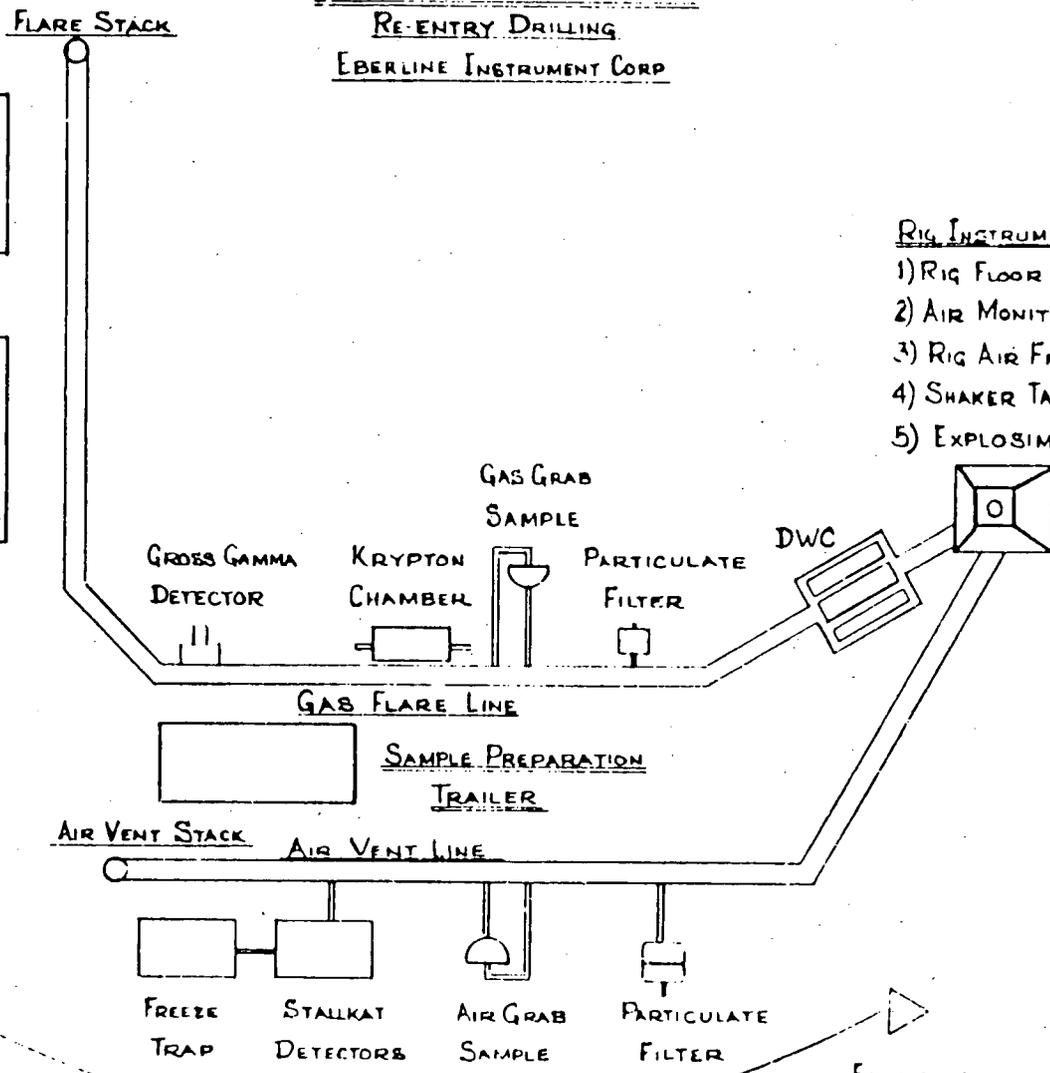
- 1) CENTRAL ALARM CONTROL
- 2) TLD ISSUE AND READOUT

RADIATION MEASUREMENTS TRAILER

- 1) TRI-CARB
- 2) STALLKAT SCALERS
- 3) PULBE HEIGHT ANALYZER
- 4) GROSS GAMMA DETECTOR
- 5) GROSS BETA DETECTOR (AC-4)
- 6) GROSS ALPHA DETECTOR (AC-4)
- 7) EXPLOSIMETER READOUT
- 8) REAL TIME RECORDERS

RIG INSTRUMENTATION

- 1) RIG FLOOR BETA DETECTOR
- 2) AIR MONITORING
- 3) RIG AIR FREEZE TRAP
- 4) SHAKER TABLE GROSS γ
- 5) EXPLOSIMETERS



ENVIRONMENTAL SOIL AND
 VEGETATION SAMPLES
 500' & 1000' FROM SGZ

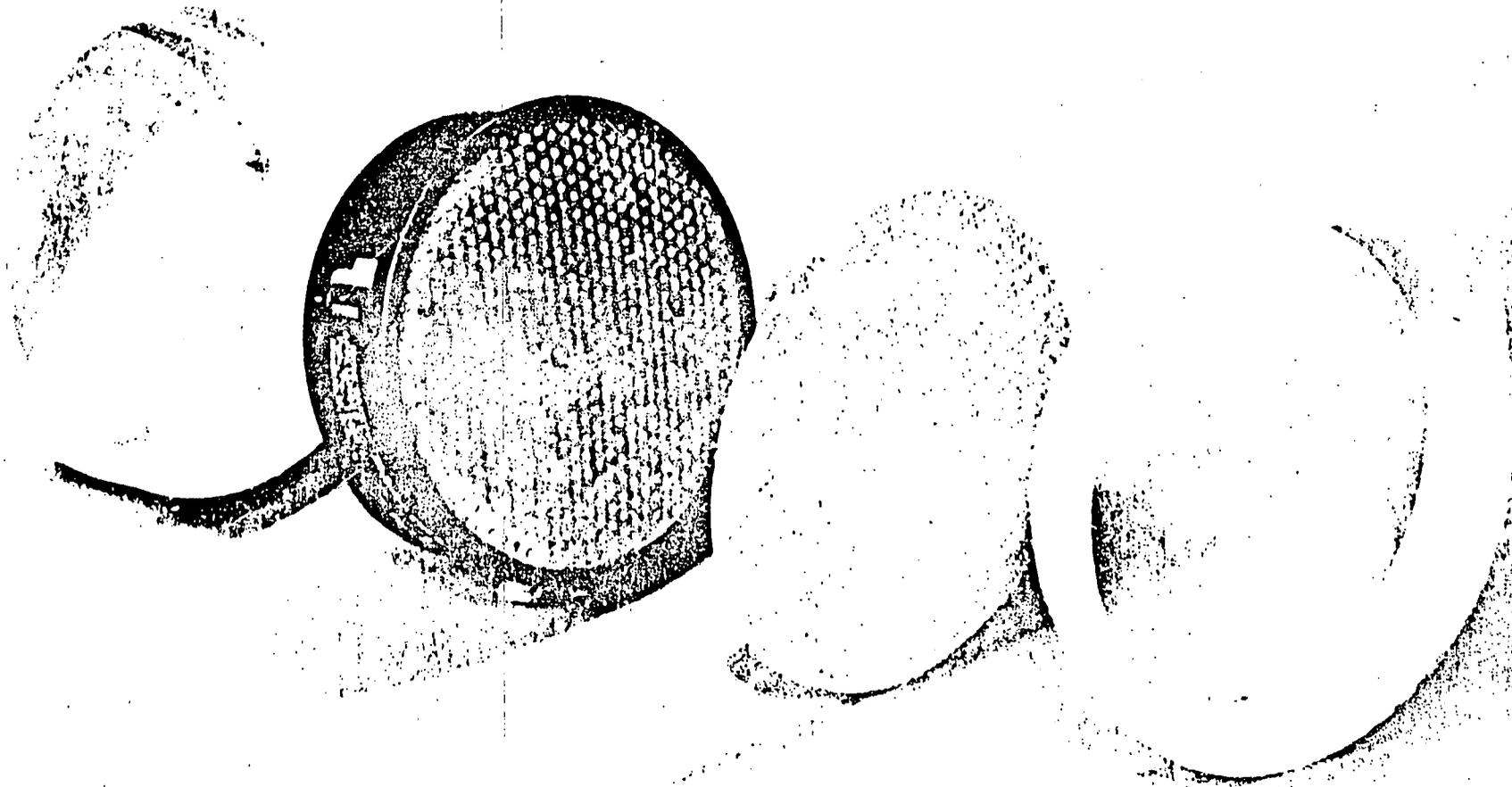


FIGURE 3 Air Sample Collection Assembly



than three times the standard deviation of background) were re-counted for alpha and beta after 5 days. If still positive, they were counted again after 12 days.

As the operation progressed, a pattern of counts for natural background was established and the 5- and 12-day recounts for beta were omitted when the initial count indicated insufficient beta activity to warrant additional analysis. The 5-day alpha recount was omitted when the initial alpha count warranted only a 12-day recount.

The Whatman 41 filter samples were counted for alpha and beta using an Eberline Model AC-4 gas flow proportional counter. The counter was calibrated for beta with a ^{90}Sr - ^{90}Y standard. It was calibrated for alpha with a ^{239}Pu standard. Under the sampling and counting conditions described above, the limit of detection for beta was 2.5×10^{-13} uCi/cc and for alpha was 2×10^{-14} uCi/cc.

3. Rig Air Freeze Trap. The rig air moisture sample was obtained by continuously pumping air from the rig at the rate of 2 CFM through the Tenny Environmental Chamber which was operated at -100°F . The frozen condensate was collected and analyzed for tritium on each eight-hour shift.

The frozen sample was melted and a 5 ml. aliquot was pipetted into a 20 ml. vial to which 15 ml. of scintillation fluid was added. This vial was then counted in the Packard Tri-Carb unit in the Radiation Measurements Trailer.

The limit of detection of tritium in water using this tri-carb was determined to be 10^{-5} uCi/ml.

4. Shaker Table Gross Gamma Alarm. A 2" x 2" NaI (TI) scintillation gamma detector was mounted above the rig shaker table. The amplifier for this detector drove a count rate meter and a recorder with an alarm set at three times background. The purpose of this detector was to provide immediate warning in the event that low level particulate gamma radioactivity should be inadvertently carried out of the well through the drilling mud stream. The sensitivity of Eberline Model SPA-3 detector used for this system is 500,000 CPM per mR/hr with ^{60}Co . A daily source check confirmed the operational effectiveness of the detector.
5. Explosimeter Alarm System. The MSA Model I-500 Combustible Gas Detection System was operated by EIC for Austral Oil. The containment system which was used to control and document the release of radioactive effluents during reentry drilling restricted the prompt dilution and dispersal of gas. This arrangement created a potentially hazardous situation which required the installation of MSA Diffusion Head Assemblies on the rig floor, in the covered drilling mud tanks,



in the air vent lines and in the pagoda beneath the rig floor. These head assemblies were cabled to the Control Module Housings and console located in the Radiation Measurement Trailer. These read-outs were connected to strip chart recorders which were set to activate the Central Alarm Console in the Access Control Trailer. The alarm level was set at 50 per cent of the lower explosive limit (2.5 per cent by volume of methane). This system proved helpful in confirming effluent release calculations. The system was calibrated monthly during reentry drilling.

B. STALLKAT

The System to Analyze Low Levels of Krypton And Tritium (STALLKAT) was used to monitor the vent line for gaseous radionuclides during reentry drilling. This system was designed so that the gas flows through two chambers at a flow rate of approximately 1.8 liters per minute. The tritium chamber had a volume of 15.9 cm³ and contained a Ca F₂ (Eu) scintillation detector 0.010" thick and 1.75" diameter. The krypton chamber had a volume of 3665 cm³ and contained a Ca F₂ (Eu) scintillation detector 0.030" thick x 1.75" diameter (Figure 4). The signals from the detectors were amplified and pulse height selected by single channel analyzers. The tritium detector was kept at a temperature of -10°C by a refrigeration system. A scaler and count rate meter were driven by the analyzer output (Figure 5). The scaler drove a printer. The count rate meter drove a recorder and an alarm that was set at three times background (150 CPM - ³H + ⁸⁵Kr). The system was calibrated with a ⁸⁵Kr and a tritium labeled methane standard. Both standards were traceable to the National Bureau of Standards. A complete calibration was performed immediately before the start of reentry drilling. A calibration check using ⁸⁵Kr and tritium was performed daily until confidence was established in the operation of the system. The frequency was then reduced to a weekly check. When the calibration check was not made, an external gamma source was used to provide a daily response check of both detectors. The STALLKAT limits of detection were 2 x 10⁻⁵ uCi/cc for tritium and 1.3 x 10⁻⁷ uCi/cc for ⁸⁵Kr based on a 60 minute integration time.

The STALLKAT employs a bulk liquid trap, a particulate filter and a desiccant moisture trap before the detectors. Although the prefilter and traps have no effect upon the monitoring of krypton, these traps remove water vapor prior to the air from the vent line flowing to the detectors. In order to determine the tritium content of the vapor which is not seen by the on-line detectors, freeze-out samples are collected and analyzed for tritium by liquid scintillation counting as described in A3 above. Again, the limit of detection of this system for tritium was 5 x 10⁻⁵ uCi/ml with a 5 ml. aliquot and a 10 minute integration time.

C. Krypton Chamber

The Krypton Chamber was configured to monitor the gas flare line.

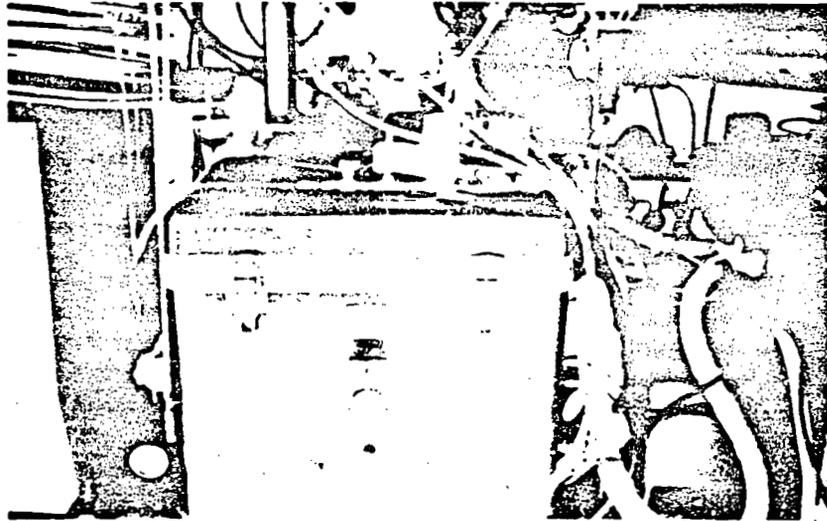


FIGURE 4 OPERATIONAL CONFIGURATION OF STALLKAT DETECTOR HOUSING



FIGURE 5 EIC ENGINEER MAINTAINING EQUIPMENT. STALLKAT SCALERS, ETC., (LEFT FOREGROUND)



The purpose of this line during reentry drilling was to provide a system to vent gas from the well without mixing gas with the air in the air vent line. Since any gas released from the well could contain radioactive material, the gas flare line was continuously monitored for ^{85}Kr . There were two detectors inside the 3 liter chamber. An Eberline Model PG-1 probe with a 1 mm thick Ca F_2 (Eu) scintillation crystal was inserted in one end of the cylindrical chamber; an Anton-112 detector was mounted in the other end as a back-up detector. The PG-1 amplifier output drove a scaler and a count rate meter. The count rate meter drove a recorder that was set to alarm at three times background.

The Krypton Chamber was calibrated with ^{85}Kr gas in methane. This gas was traceable to the National Bureau of Standards. Gas from the gas flare line flowed through the Krypton Chamber at approximately $20 \text{ m}^3/\text{hr}$. This high flow rate permitted the system to respond in a matter of seconds. The limit of detection for this chamber was determined to be $1.6 \times 10^{-7} \text{ uCi/cc}$ for ^{85}Kr during a 60 minute integration time.

D. Particulate Samples

Air from the vent line was passed through a Whatman 41 filter and then a charcoal cartridge at a measured flow rate of approximately 10 cubic meters per hour. These samples were normally changed once each eight hour shift and the filters were analyzed on the same shift for gross beta and gross gamma. The charcoal cartridges were analyzed for gross gamma. Filters that were positive, i.e., the net beta count was greater than three times the standard deviation of background, were recounted after 5 days. If they still were positive, they were counted again after 12 days. This procedure provided an immediate indication of any abnormally high beta activity and also allowed for decay of naturally occurring radon daughters. The beta measurements were made with an Eberline Model AC-4 gas flow proportional counter calibrated with a $^{90}\text{Sr} - ^{90}\text{Y}$ beta standard mounted on a filter paper in the same geometry as the samples. Under the sampling and counting conditions described above, the limit of detection for airborne particulate beta emitters is $5 \times 10^{-13} \text{ uCi/cc}$ with a 10 minute integration time.

Gas from the gas flare line was passed through a Whatman 41 filter and then a charcoal cartridge at a measured flow rate of approximately 20 cubic meters per hour (Figure 6). The procedure was the same as described for the air vent line except the limit of detection was $2.5 \times 10^{-13} \text{ uCi/cc}$ because of the higher flow rate.

E. Gross Gamma Radioactivity

A NaI (TI) scintillation gamma detector, 1" thick x 2" diameter was mounted on the outside of the air vent line. A similar detector 2"



thick x 2" diameter was mounted on the gas flare line. Both detectors were shielded with lead to reduce background. The amplifier for each detector was connected to a count rate meter and recorder with an alarm set at three times background. Gamma emitters were not expected to be present except ^{86}Kr which emits a 0.51 MeV gamma with only 0.41% abundance. Since it was not practical to try to calibrate the system for all gamma emitters that could possibly be present, a system for rapidly taking a special gas sample in an evacuated flask was devised (Figure 7). The intent was to use this sample to determine by gamma spectrometry what gamma emitters were present and the concentration of each.

F. Laboratory Instruments

1. Pulse Height Analyzer. The primary system for gamma spectroscopy and documentation was the Nuclear Data Series 2200 System Analyzer. This completely modular multichannel analyzer consists of an Analog to Digital Converter, Master Control, Read-In/Out Display and System Memory. This system had a 1024 channel memory. The printout was calibrated to display 10 KeV/channel. The detector for this system was the Canberra 802-4 scintillation detector which has a 3" x 3" NaI (TI) crystal, photomultiplier tube, radiation entrance window of 0.019" aluminum, and focus control.
2. Automatic Tri-Carb Liquid Scintillation Spectrometer. The primary system for tritium analysis was the Packard Model 2311 Tri-Carb which consists of three completely independent simultaneous channels. One channel was calibrated to tritium standards. The second channel was set to record energies of betas above tritium. A Carbon-14 source was used to calibrate this channel. A third channel was used as a standardization channel used to test for optical or chemical quenching.
3. Gross Alpha and Beta Counters. A number of samples required gross alpha and beta analysis. The instruments to perform the analysis were two Eberline Model AC-4, Large Area Flat Plate Gas Proportional Chambers. The alpha detector was readout on a Ludlum Model 22 Scaler. The efficiency of the alpha detector was 0.24 of 4π geometry using a ^{239}Pu calibration source. The beta detector was cabled to a single channel analyzer which was readout on a Canberra Scaler. The efficiency of the beta detector was 0.27 of 4π geometry using a ^{90}Sr calibration source.
4. Gross Gamma Counter. The detector used on this system was essentially the same as that described for the PHA, i.e., 3" x 3" NaI (TI). The detector was connected to a Packard Spectrometer Model 410A containing a high voltage power supply, scaler and time configured for gross gamma analysis.

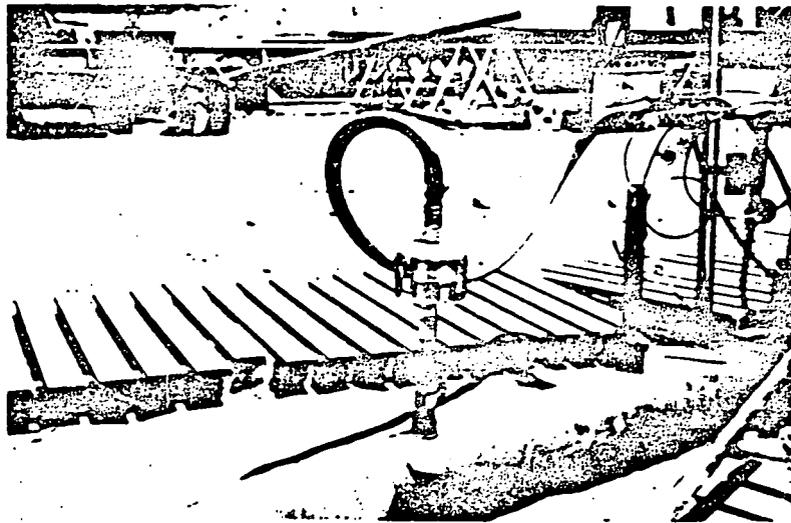


FIGURE 6 PARTICULATE FILTER HOUSING ON GAS FLARE LINE

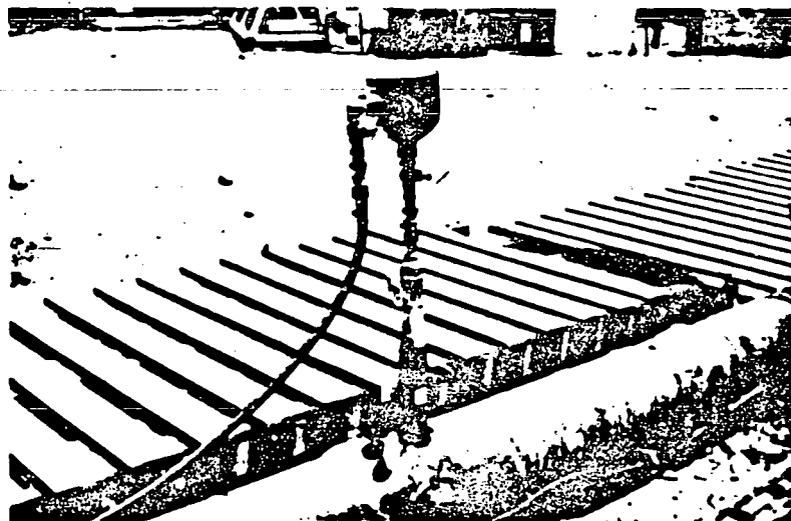


FIGURE 7 GRAB SAMPLE FLASK ON GAS FLARE LINE



G. Access Control

1. Thermoluminescent Dosimetry (TLD). All on-site personnel and visitors who entered the controlled area around the drill rig were issued TLD badges. The badges were designed to measure skin dose (i.e., beta from ^{85}Kr) and whole body dose from penetrating radiation (i.e., gamma). Each badge contained two LiF dosimeters $1/8'' \times 1/8'' \times 0.035''$ thick. The dosimeters store the energy absorbed from ionizing radiation in traps until the badge was returned for reading. Each dosimeter was read with an Eberline Model TLR-5 Thermoluminescent Reader which measured the light released as the dosimeter was heated from 150°C to 260°C . Light stored in traps lower than 150°C was rejected. Since the higher temperature traps are very stable, fading of the stored signal was less than 4 per cent in six months. The lower reporting limit using this technique was 0.01 REM per month with a monthly badge exchange.

During the Rulison Operation, 977 TLD badges were issued and read. No detectable radiation over established background was recorded.

2. Ansella Alarm Console. The Analog Selectable Low Level Alarm was connected to all systems which required monitoring for health and safety purposes. The Console was designed to receive and monitor up to eighteen separate channels of information. Each channel had two variable level settings. Panel lights of white, red and green indicate whether or not an instrument system was operating normally or was malfunctioning. A system which failed would not only indicate a red trouble light, but would trigger an audible "Sonalert" located in the chassis.

This system was monitored by Access Control Personnel on a 24-hour basis.

3. Portable Instruments. A variety of portable radiation detection instruments and gas detection devices were maintained in the Access Control by on-duty personnel. Instruments maintained in the inventory were:

Eberline Model E-400 (Beta-Gamma)

Eberline Model PAC-1S (Alpha)

Eberline Model PRM-5 (Gamma)

Radector Model 2035 (Gamma)

Eberline PIC-6 (Gamma)

MSA & J W Sniffer (Gas Detector)

Some of the instruments are shown in Figure 8.

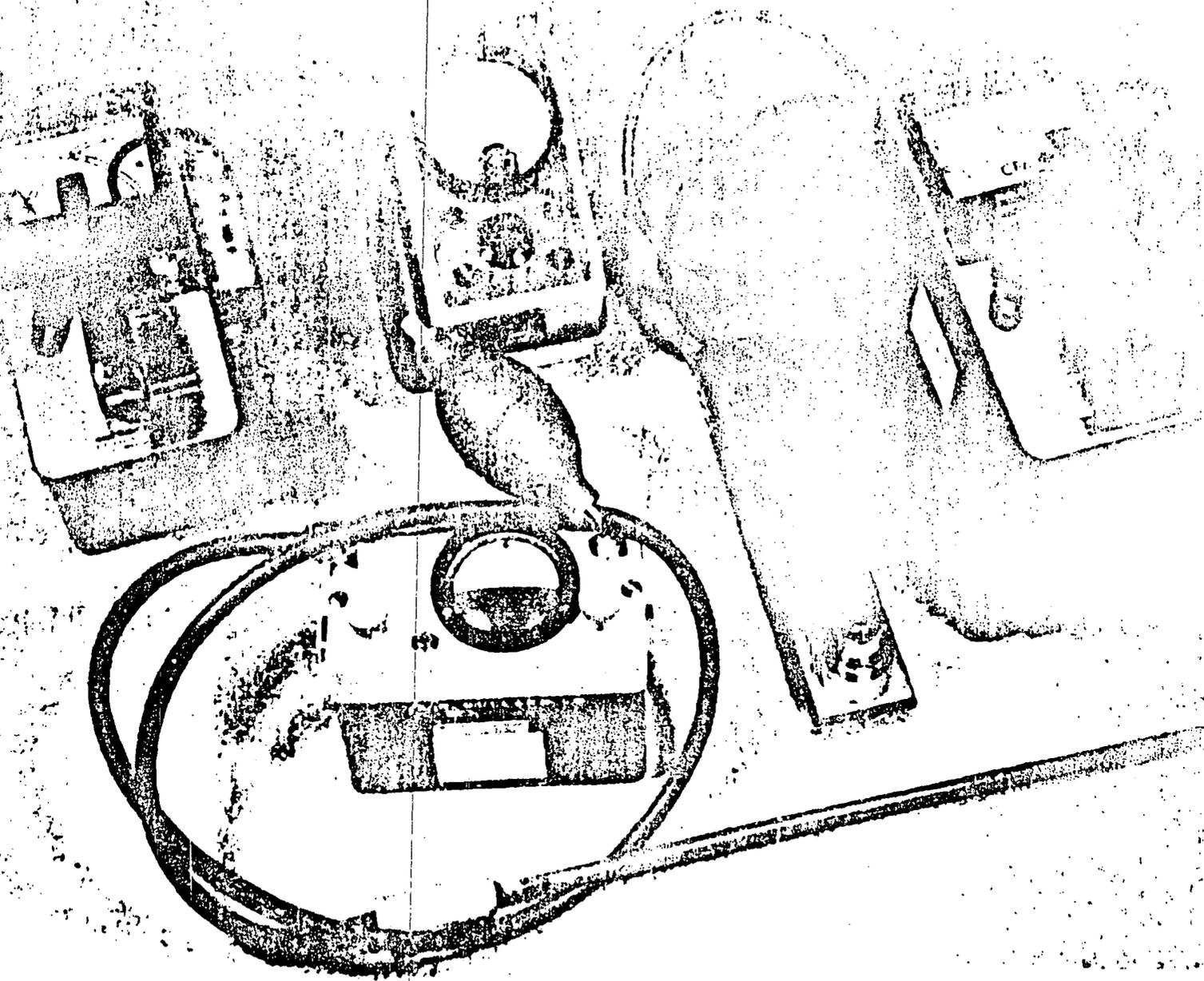


FIGURE 8 PORTABLE INSTRUMENTS USED AT PROJECT RULISON



4. Environmental Samples. Prior to detonation of the Rulison device, samples of soil and vegetation were collected around the site as shown in Figure 9. Another set of samples was collected prior to the start of reentry drilling. Sets of samples were collected thereafter at thirty-day intervals during that phase of the operation. All samples were analyzed for gamma emitters by gamma spectrometry. Representative samples were analyzed for tritium. For this latter purpose, water was distilled out of each sample for analysis.

5. Reentry Drilling Samples. The primary systems for radiation detection and effluent monitoring have been discussed in the foregoing paragraphs. In addition, it was essential to establish procedures and guidelines for the control and disposal of solid and liquid waste generated during reentry drilling. This material was generated from two sources:

- 1) Separation of the drilling chips from the recirculating drilling mud stream at the shaker table;
- 2) Water accumulated in the holding tanks from a variety of sources, but primarily from rig wash down.

In the interest of consolidating information, Figure 10 outlines the total sampling program which was conducted on-site by EIC personnel during reentry drilling.

2.4 Decontamination and Rig Clearance

No decontamination facilities or equipment had been authorized for this operation. It was necessary to hastily prepare a make-shift arrangement that was not completely satisfactory (Figures 11 and 12). The previous installation of a metal drip pan under the rig did assist considerably in controlling contaminated water.

Verbal guidance received for acceptable levels to which decontamination was to be performed was that items swipe tested for tritium should be determined to be less than 1000 DPM/100 cm², and that they be "cosmetically clean".

The rig and equipment was decontaminated and removed from the site in accordance with this guidance.

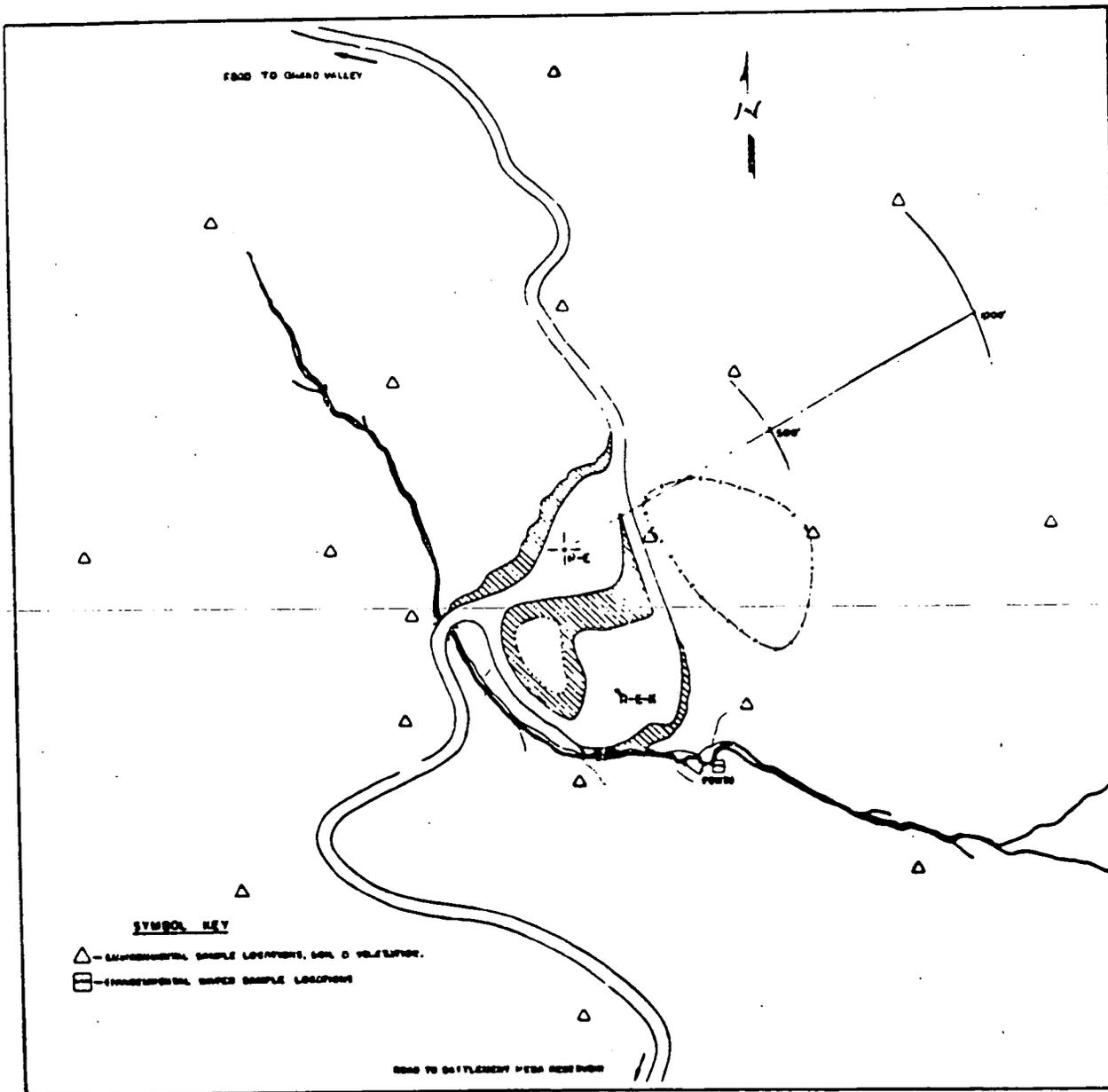


FIGURE 9 ENVIRONMENTAL SAMPLING

RE-ENTRY DRILLING SAMPLES

Type Sample	Analyzed for	Radio Nuclide of Interest	Frequency of Collection	Frequency of Analysis	System used for Analysis
<u>Rig</u>					
Air-Filter (4)	Alpha, Beta, Gamma		1/shift	1, 5, 10 days	Prop. Ctr/Gross Alpha
Air-Charcoal Cart (4)	Gamma	^{131}I	1/shift	-	Gross Gamma
Air-Freeze Trap	Beta	^3H	1/shift	-	Liq. Scint.
Drill Mud Stream	Beta, Gamma	^3H , ^{137}C	Every 2 hours	-	Liq. Scint.
Rig Wash. Water	Beta, Gamma	^3H , ^{137}C	Before Dump Tanks	-	Liq. Scint.
Drill Chips	Gamma	^{137}Cs	When Bucket Full	-	Gamma Spec.
Organic Distillate	Beta	^3H , ^{14}C	When Required	-	Liq. Scint.
<u>Air Vent Line</u>					
Part. Filter	Beta, Gamma	^{90}Sr , ^{137}Cs	1/shift	1, 5, 10 days	Prop. Ctr/Gross Alpha
Part. Charcoal Cart.	Gamma	^{131}I	1/shift	-	Gross Gamma
<u>Gas Flare Line</u>					
Part Filter	Beta, Gamma	^{90}Sr , ^{137}Cs	1/shift	-	Prop. Ctr/Gross Gamma
Part. Charcoal Cart.	Gamma	^{131}I	1/shift	-	Gross Gamma
Freeze Trap	Beta	^3H	1/shift	-	Liq. Scint.
<u>Environmental</u>					
Veg.	Beta, Gamma	^3H , ^{137}Cs	Monthly	-	Gamma Spec/Liq. Scint.
Soil	Beta, Gamma	^3H , ^{137}Cs	Monthly	-	Gamma Spec/Liq. Scint.
<u>BioAssay</u>					
Urine	Beta	^3H	As Required*	-	Liq. Scint.

*Primarily for drill rig personnel on a monthly basis.

FIGURE 10

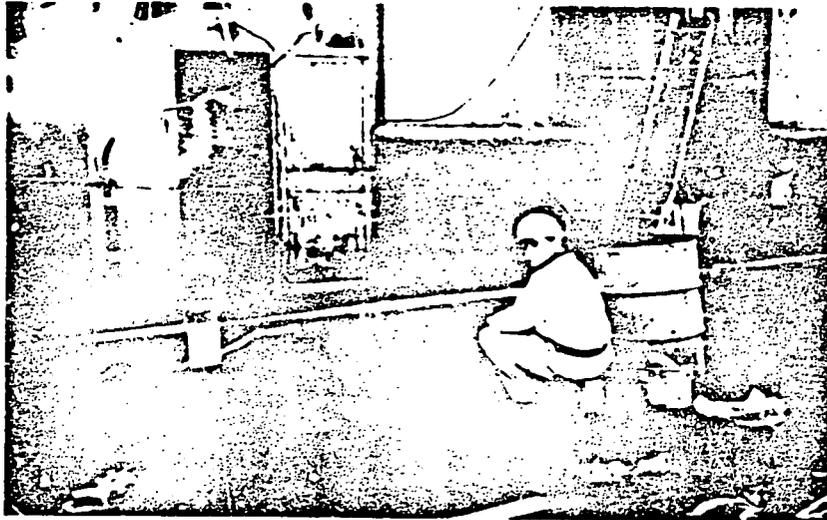


FIGURE 11 MAKE SHIFT DECON AREA FOR SMALL EQUIPMENT

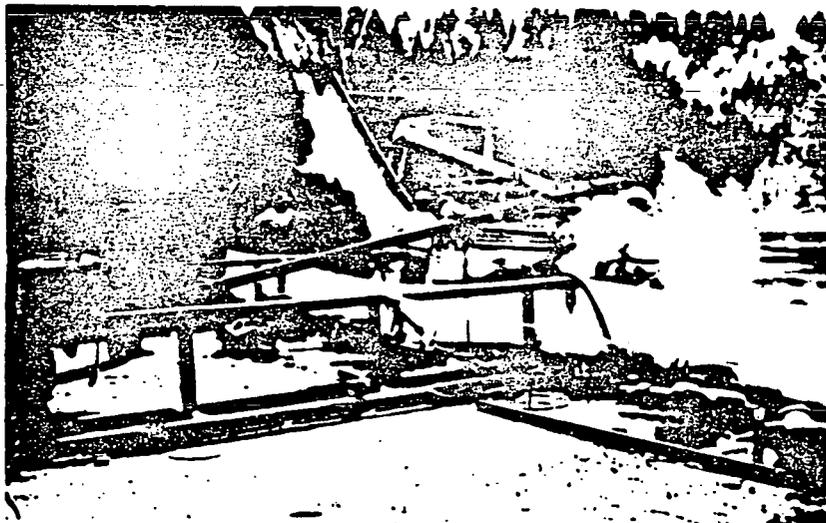


FIGURE 12 MAKE-SHIFT DECON AREA FOR LARGE EQUIPMENT



SECTION III

FLARING

3.1 General

There were four separate flaring phases during the course of the Rulison Operation:

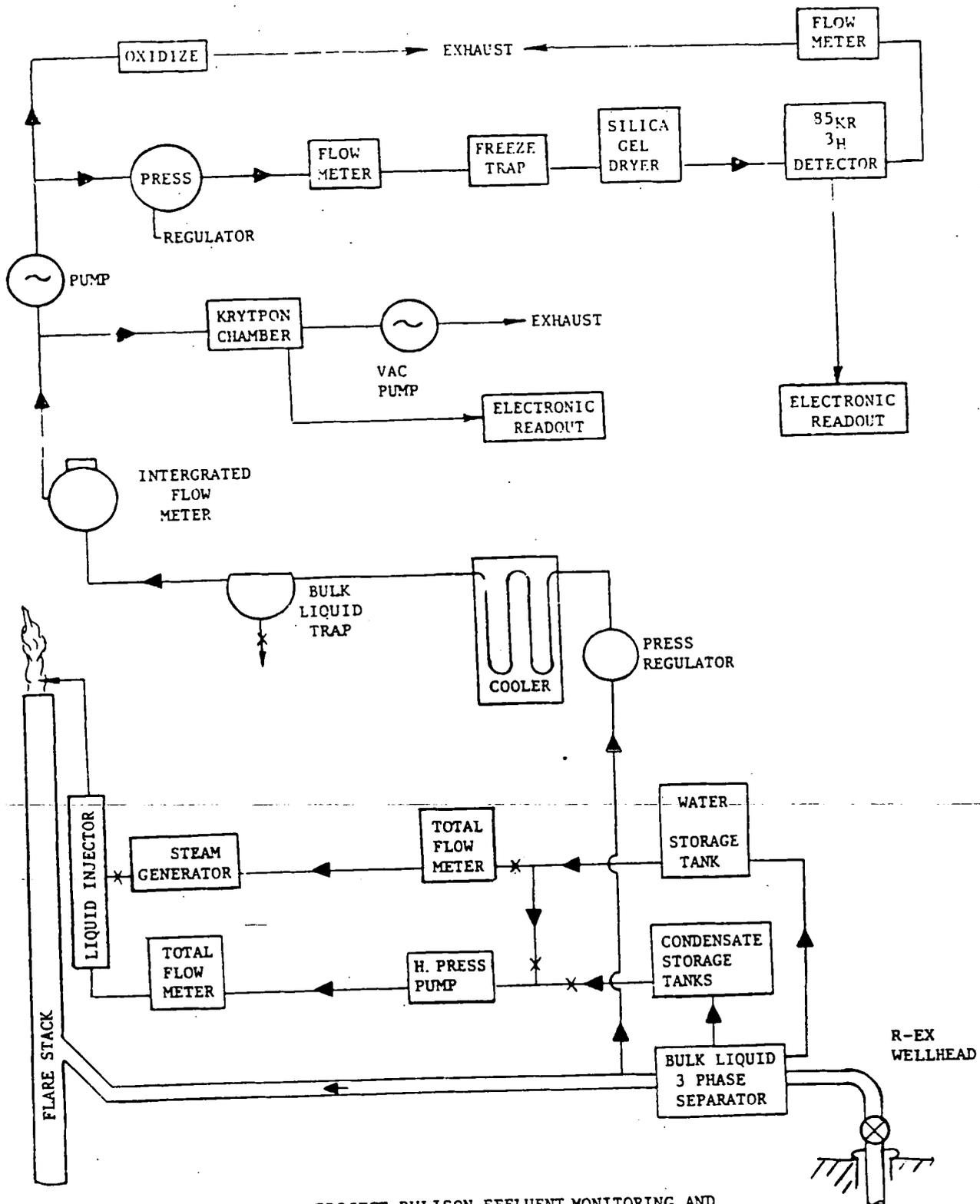
- Phase I Calibration Flaring (7-24 October 1970)
- Phase II. High-Rate Flaring (October 26 – November 3, 1970)
- Phase III. Intermediate Rate Flaring (1-20 December 1970)
- Phase IV. Long-Term Flaring (February 2 – April 23, 1971)

During this period a total of 452.5 M³CF (million standard cubic feet) of gas was flared from the Rulison Well. AEC delegated the responsibility to the Los Alamos -Scientific Laboratory (LASL) through EIC monitoring not only to insure the radiation protection of personnel operating on the site, but to document the on-site release of radioactive effluent. To accomplish this latter task, the instrumentation discussed in Section II was reconfigured as shown in Figure 13 to operation primarily on the Gas Flow Line.

3.2 Instrumentation

Function of the primary gas flare line monitoring systems, Figure 13, is discussed below.

- A. STALLKAT. The high temperature and the moisture content of the gas required that a heat exchanger and a series of bulk water traps be installed in front of the detector system. The separation process which occurred enabled the collected rain water and hydrocarbon components of the gas stream to be analyzed for ³H and ⁸⁵Kr as well as the dry gas. The liquid samples were analyzed by liquid scintillation counting. Toward the end of the long term flaring program, the sensitivity of the tritium detector was such that the very low levels of tritium in the gas could not be measured with any degree of confidence. This measurement was continued by using the Packard Oxidizer System discussed in the following paragraph. The STALLKAT freeze trap sample was taken and analyzed as previously described.
- B. Packard Oxidizer. The oxidizer was modified by EIC engineers to continuously burn a small quantity of gas. A one hour sample of the water condensed by the combustion process was taken on each 8-hour shift. A composite sample was then analyzed in the Packard Tri-Carb Liquid Scintillation Counter thereby providing an integrated 24-hour sample reading.
- C. Krypton Chamber. This system remained on the gas flare line as a



PROJECT RULISON EFFLUENT MONITORING AND CONTROL SYSTEM

FIGURE 13



back-up for the STALLKAT in the detection of radiation from ^{85}Kr in the gas.

- D. Particulate Samples. The particulate sampling system was the same as previously used. However, during high-rate flaring the filters became ineffective because large quantities of water entrained in the gas stream saturated the filters and blocked the gas flow. As an interim measure, the bulk water trapped from the same line was filtered and analyzed for particulate. The filter system did prove adequate during subsequent flaring phases.

At the beginning of intermediate flaring, gamma spectrometry of the charcoal cartridges revealed the presence of ^{203}Hg , a neutron activation product. The activated charcoal cartridges did not provide for a complete entrapment of ^{203}Hg and were replaced with special "CK" charcoal cartridges designed with an enhanced affinity for mercury. With the new cartridges it was possible to provide a more accurate estimate of total ^{203}Hg released.

3.3 Contaminated Liquid Waste Management

A total of 824,627 gallons of radioactive liquid waste was disposed of during the flaring phases. Most of the liquid waste consisted of contaminated water and some liquid hydrocarbons processed out of the gas stream by a phase separator. The water and hydrocarbon condensate left the separator in two different liquid fractions. This was a gas drying process common to natural gas production operations. The water was stored in 9,000-gallon steel tanks and the liquid hydrocarbons in 1,000 gallon steel tanks. When a tank was full, it was isolated from the system and a representative sample of the liquid was gamma scanned and was analyzed for tritium by liquid scintillation counting. The quantity of liquid in the isolated tank was then identified with the resulting tritium concentration. The water was disposed of by steaming and/or direct spray injection into the flare where it was vaporized (Figure 14). The liquid hydrocarbons were disposed of by direct injection into the flare.

This system of disposal was adequate at high gas flow rates (the flare provided adequate heat for vaporization). Toward the end of long term flaring when the gas flow rate was 1-3 M³CF/D, careful surveillance had to be maintained to ensure that the liquid was being dissipated in the flame and not precipitated on the ground. Adverse weather conditions at times prevented injecting or steaming of the liquid waste. The concentrations of tritium in the water was normally in the range $3 - 5 \times 10^5$ pCi/ml. The concentration of tritium in the liquid hydrocarbon condensate was normally in the range $3 - 8 \times 10^4$ pCi/ml.

3.4 Open File System

In accordance with a United States District Court decision of March 16,

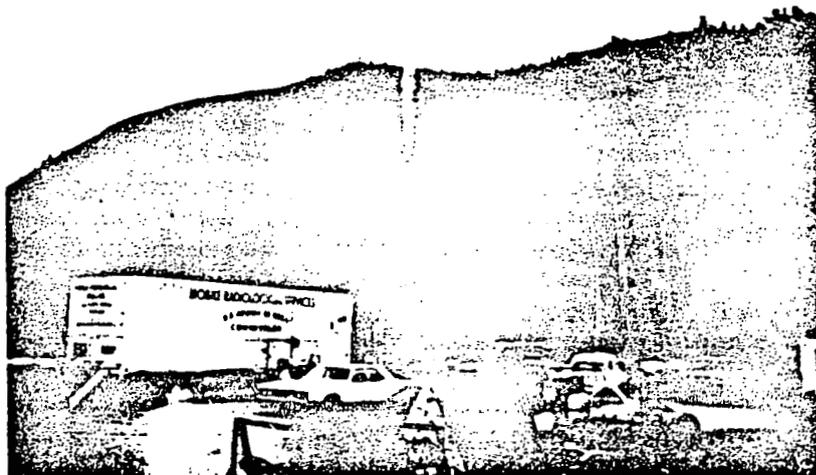


FIGURE 14 FLARE STACK, WATER & HYDROCARBON STORAGE TANKS



1970, EIC was directed to report data developed from on-site radiological monitoring programs to an Open File System. The reporting of this data was initially made to the Operations Director at the site and to the Nevada Operations Office of the AEC. The procedures followed were those contained in Appendix A of the Court decision as follows:

APPENDIX A

PROCEDURES FOR PUBLIC DISSEMINATION OF PROJECT RULISON RAW MONITORING AND RELATED DATA

In order that the public and the scientific and industrial communities might be kept informed on joint Industry-Government Plowshare projects, the Open-File System was established on October 23, 1968. Open Files were established in Denver, Colorado; Las Vegas, Nevada; and Bartlesville, Oklahoma. Open-File data on the first joint Industry-Government Plowshare project, Project Gasbuggy, included preliminary unevaluated data and data analyses. Final reports, published and disseminated through AEC and technical-journal channels, are also displayed at the Open Files.

Set forth below is a description of the raw monitoring and related data for the well reentry and testing phase of Project Rulison which are planned to be placed in the Open Files, and the procedures relating thereto. In addition to the data described below, the Project Rulison final reports, containing evaluations of the subject data and other project information will also be displayed at the Open Files after their publication. These reports entail extensive analysis and interpretation of project data which, in turn, dictates the time required for their preparation and publication.

The data described below and the final project reports will, in addition to Open-File placement, be provided to the Colorado State Public Health Department when they first become available.



ON-SITE RADIOLOGICAL SAFETY DATA*

All of the following data and samples will be collected by the Eberline Instrument Corporation (EIC) at the Rulison site on a daily basis. Direct data from samples will be derived by EIC at their Rulison site facilities. The subject data then will be mailed to the Open Files through the Nevada Operations Office. It is expected that these data will reach the Open Files about one week following collection. The extent of the sampling effort will be contingent upon the rate of flaring, relevant meteorological conditions, and the results of previous sampling and monitoring.

1. STALLKAT Data. These digital data, along with applicable conversion factors and measured gas flow rates, will permit calculation of Tritium and Krypton quantities flowing out of the flare stack.
2. Particulate Samples from Gas Stream. Derived data from these samples will permit identification of any particulate radionuclides.
3. Gross Gamma Radioactivity in Flare Stack. Continuous recordings allow detection of gamma emitting nuclides in the gas stream.
4. Water and Hydrocarbon Condensate Sampling. Sampling of water and other condensates from the gas stream separator will provide data on total radioactivity content prior to injection into the flare.
5. Special Gas Samples from Flare Stack Data from these samples will permit identification of gamma emitting nuclides whenever the gross gamma detector indicates their presence.
6. Air Samples. The purpose of these daily samples is to permit detection of alpha, beta and gross gamma radiation in the air of the work area. Filters will be recounted five and twelve days after collection of samples to allow for decay of naturally occurring radionuclides.
7. Thermoluminescent Dosimetry (TLD). Data from TLD's will show 30-day cumulative exposure of on-site personnel to beta and gamma radiation.
8. Vegetation and Soil Samples. This data will allow detection of radionuclides deposited in the soil and taken up by vegetation after 30 days accumulation.

The development and processing of this information initially required an engineer/analyst and an operator for the Digital PDP-8 Computer (Figures 15 and 16). At the peak of the reentry operations on a typical day (5/29/70), the Open

*As used herein, the term "on-site" refers to an area within a radius of approximately 1000 feet of the well.

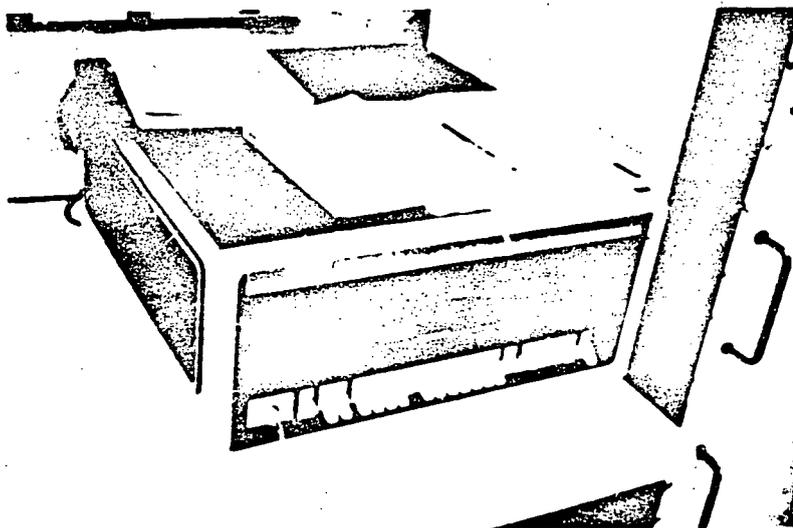


FIGURE 15 COMPUTER FOR OPEN FILE PREPARATION

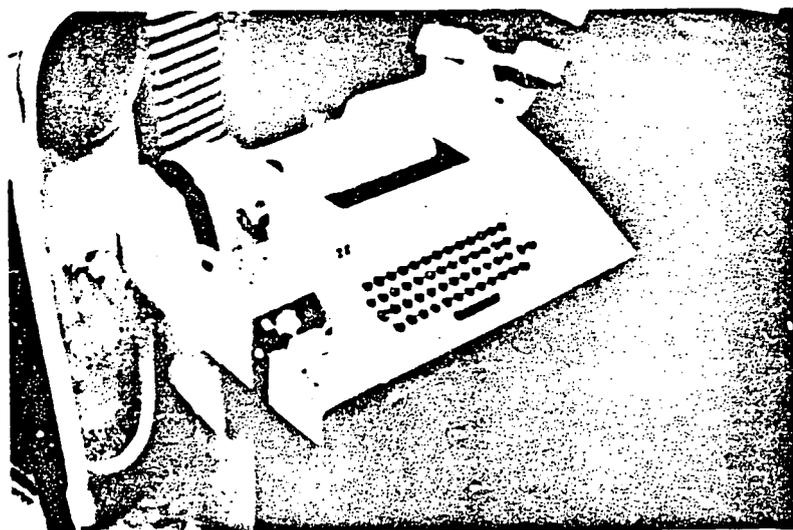


FIGURE 16 TELETYPE & TAPE INPUT FOR PDP-8 COMPUTER



File Report consisted of twenty-two pages of analyzed data requiring approximately 160 lines of calculated information. At the end of long-term flaring, analysis of the data had been streamlined to a part-time task for one individual. The preparation of a typical report (4/23/71), while still meeting the court's requirements, was reduced to a desk calculator operation producing 13 pages of analyzed data requiring 21 calculated entries.



SECTION IV

PLACEMENT OF SITE IN STANDBY STATUS

4.1 General

On April 23, 1971, the long-term production flaring operations at Rulison were terminated. At that time it became necessary to place the site in a standby status. The following guidance regarding the control and handling of site radiological problems was received from the USAEC.

- A. Any contamination areas, both inside and outside the proposed fence, were to be cleaned up so as not to exceed a radioactivity contamination level of 30,000 pCi/gm for tritium in soil, or lower if practical.
- B. All contaminated material or equipment planned to be removed from the site should be decontaminated to meet the criteria of 1000 DPM/100 cm² for beta and gamma emitters, removable from the surface by approved swipe techniques.
- C. Accessible surfaces of all contaminated equipment on-site should be decontaminated to as close as practicable to the criteria for removal from site.
- D. For liquids in the mud pits, the appropriate criteria was as stated in AEC Manual 0524 Appendix, Section II, and Annex A, Table II. Disposal methods should also be predicated on the other factors such as acidity, oil content and quantity.
- E. The solids in the mud pit and contaminated solid materials such as soil in barrels should be analyzed and, if the tritium concentration is less than 30,000 pCi/gm, they may be disposed of without further controls.
- F. Low level contaminated flammable material may be disposed of by incineration at the site provided the additional radioactivity plus the radioactivity from the flare gas will not produce a total dose in excess of the criteria described in AEC Manual Chapter 0524, Section II, Annex A.
- G. Site area should be fenced in such a manner as to preclude any inadvertent access to remaining equipment and materials. If all the above criteria are met in preparing the site to be placed in a standby status, there will be no requirements for radiation warning signs on the proposed fence.

4.2 To prepare the site for standby status in compliance with the above guidance, the following action was taken by EIC personnel.



- A. Swipes were taken of all items of equipment on-site. These swipes were the basis for the decontamination program. All equipment to be removed from the site was steamed off even though they were below the radiological criteria for removal. Those few items which could not be decontaminated were labeled with appropriate contamination stickers and stored in a locked building set aside exclusively for contaminated items. An inventory of these items is maintained by the USAEC/NVOO, Austral Oil Company and EIC.
- B. During the course of operations at the Rulison Site, a continuing radiation clean-up program had been in effect. All contaminated soil resulting from leaks or spills had been picked up, insofar as was possible, and placed in ninety-three 55 gallon drums. The contents for each barrel were analyzed for tritium and particulate radiation. Seven (7) drums were considered to contain radioactive debris which should be controlled. These drums were sealed and labeled with appropriate information and placed in the building set aside for this purpose. The material in the other 86 drums contained insignificant levels of radiation and were dumped into the vinyl-lined pit on the RE-X pad. This pit was later covered with approximately three feet of dirt. All empty barrels were steam-cleaned.
- C. A small quantity of low level tritium contaminated water (20 pCi/ml) was in the above-mentioned vinyl-lined pit. The contents of the pit were below criteria established in paragraph 3.1 above.
- D. The liquid in the holding water tanks in the tank farm area were steamed to the lowest possible level. The remaining contents were sampled and determined to be above acceptable limits for dumping. Since these tanks would be used in any future flaring program, EIC was advised to secure the tanks in a manner to prevent any inadvertent release of the material. Hoods, locks and seals were placed on tank valves. The observation ports on top were locked.
- E. The ground in the immediate vicinity of the flare stack had been contaminated with tritium as a result of the production test flaring. This area was gridded out to 1000 feet to locate sampling points. Soil samples were taken from the surface at each location. Certain locations were sampled at other depths to obtain additional information. All samples collected were analyzed for tritium in soil moisture and in soil by weight. Figures 17 and 18 show the sampling locations referenced to the flare stack, give the sampling depth(s) in inches at each location, and state the tritium concentrations in pCi/ml of soil moisture and in pCi/g of soil. A total of 133 samples were taken from 70 sampling points. Concentrations ranged from 6 pCi/ml to 7400 pCi/ml in soil mois-



ture, and from 1 pCi/g to 1600 pCi/g in soil by weight. Concentrations decreased as distance from the stack increased, and they seemed to be generally higher in a north direction from the stack.

- F. As a final effort to leave the site as clean as possible, over 100 plastic bags of trash and low level contaminated flammable material were disposed of by using a gas fired incinerator, locally constructed.
- G. All external surfaces of pipes, tanks, separator, wellhead christmas tree and building remaining on-site were steam cleaned.

4.3 At 1645 hours on 12 May 1971, EIC terminated coverage at the Rulison Site.



SECTION V

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

- A. Extreme difficulty was experienced with water separation in the gas flare line. The resulting accumulation of water caused freezing of the sampling systems during periods of high gas flow and/or low ambient temperature.
- B. Much effort was expended in attempting to comply with changing radiation control criteria relating to the decontamination of material, ground contamination and low level waste disposal. These criteria were related to satisfying the more stringent guidance relating to environmental considerations than to satisfying established health and safety criteria for on-site workers.
- C. An extensive radiological sampling and analysis program was conducted and documentation made of a variety of situations, many of which contributed little to radiological health and safety evaluations. It was not until the period of long-term production flaring occurred that a program, commensurate with the evaluated problems, was initiated.
- D. The radioactivity contaminated water handling and disposal system was improperly designed and inadequately controlled to meet the varying conditions encountered during production testing.
- E. The use of dosimetry devices on personnel was appropriate for reentry drilling, but is considered unnecessary after the reentry drilling has been completed and the radiological problems have been evaluated as being negligible.
- F. Industrial safety during reentry drilling was inadequately programmed and supervised, resulting in numerous minor injuries to EIC personnel. More serious injuries could easily have resulted from industrial safety hazards which prevailed on and around the drilling rig.

5.2 Recommendations

- A. That future projects of this nature have separate gas drying and sampling systems that are independent of the conventional gas processing systems.
- B. That an analysis be made of radiation protection criteria required for the health and safety of on-site workers vis-a-vis the radiation which is permissible for release to the environment and that controlling radiation criteria be established which will provide adequate guidance for the



timely development of instrumentation and techniques to meet anticipated problems (i.e., decontamination of material, low level waste disposal and allowable ground contamination).

- C. That an evaluation be made of each Plowshare Project to determine the probable hazards which require full instrumentation and evaluation and those improbable occurrences which should be instrumented with alarms only until they develop.
- D. That radiation safety personnel be included in the planning and engineering of any future contaminated water handling and disposal system. That the handling and disposal of contaminated water be totally under the control of the organization having the radiological protection responsibility.
- E. That dosimetry devices (TLD's) be used for all personnel within the controlled area during reentry drilling, but be discontinued after the radiological problems have been evaluated and determined to be negligible.
- F. That future Plowshare Projects have a more adequately defined and implemented industrial safety program.

1140 32

1210 60

200 1130-43

500 129 10
620 3

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612 3

MAGNETIC NORTH →

129 10

129 24

2

FIGURE 17

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