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Report On Plutonium Mining Activities At 216-Z-9 Enclosed Trench

J. D. Ludowise
Process Engineering Department

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Prepared for the United States
Department of Energy
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REPQRT ON PLUTONIUM MINING ACTIVITIES AT 216-Z-9 ENCLOSED TRENCH

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ABSTRACT

This report is divided into three major sections. The first section describes the 216-Z-9 enclosed trench prior to the mining operation. An overall history of the enclosed trench is presented with nuclear reactivity evaluations of the soil.

The second section discusses the mining phase of the enclosed trench. Descriptions of the mining equipment and mining operations are contained in this section as well as statistics and problems encountered in the operations. This section concludes with reports on post mining phase operations: the monitoring of radiolytically produced gases and the retrofit program to make Z-9 drums safe for 20-year retrievable storage. The final section summarizes what was learned in doing the program.

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DESCRIPTION OF THE 216-Z-9 ENCLOSED TRENCH

HISTORY

The 216-Z-9 enclosed trench, completed in 1955, was built for the disposal of both organic and aqueous plutonium waste solutions from the Recuplex Plutonium Scrap Recovery Facility in the 234-5 Z Plant. The Z-9 enclosed trench is an underground excavation with an active floor area of 9.1 x 18.3 m at a mean sea level elevation of 195 m and is located 152 m east of the Z Plant Exclusion Area in the 200 West Area. As shown in Figure 1, the trench was originally excavated to a depth of 6.1 m and was covered by a 23-cm-thick concrete slab, 2.7 x 3.7 m supported by six concrete columns. The walls of the enclosed trench slope inward to the floor of the trench. The enclosed trench was provided with two 3.8-cm stainless steel inlet pipes; one serves as a spare.

Initially, the slab contained five openings: a 77-cm manhole and four 10-cm vent risers. In later years, more penetrations of the slab were made to obtain trench soil samples and radiation measurements.

The Recuplex process was a solvent extraction system that recovered plutonium from many different types of scrap or wastes such as ingot and casting skulls (ingoting dross), slag and crucible, button line supernates, and fabrication oil (a mixture of lard oil and 75% carbon tetrachloride [CCl_4] used as a cutting oil during the machining of plutonium). The Recuplex waste solutions consisted of aluminum, magnesium, calcium, and other metal nitrate salt wastes, degraded solvents (15% tributyl phosphate [TBP] or dibutylbutyl phosphate [DBBP] in CCl_4), other organics such as solvent washings, fabrication oil, and other waste materials from hood and equipment flushes.

These waste solutions were collected in three tanks, each having 950ℓ capacity. After determining the plutonium content, the waste solution was drained by gravity through 3.8 cm underground stainless steel pipe to the Z-9 enclosed trench. A waste tank was drained about once every 8 hours.

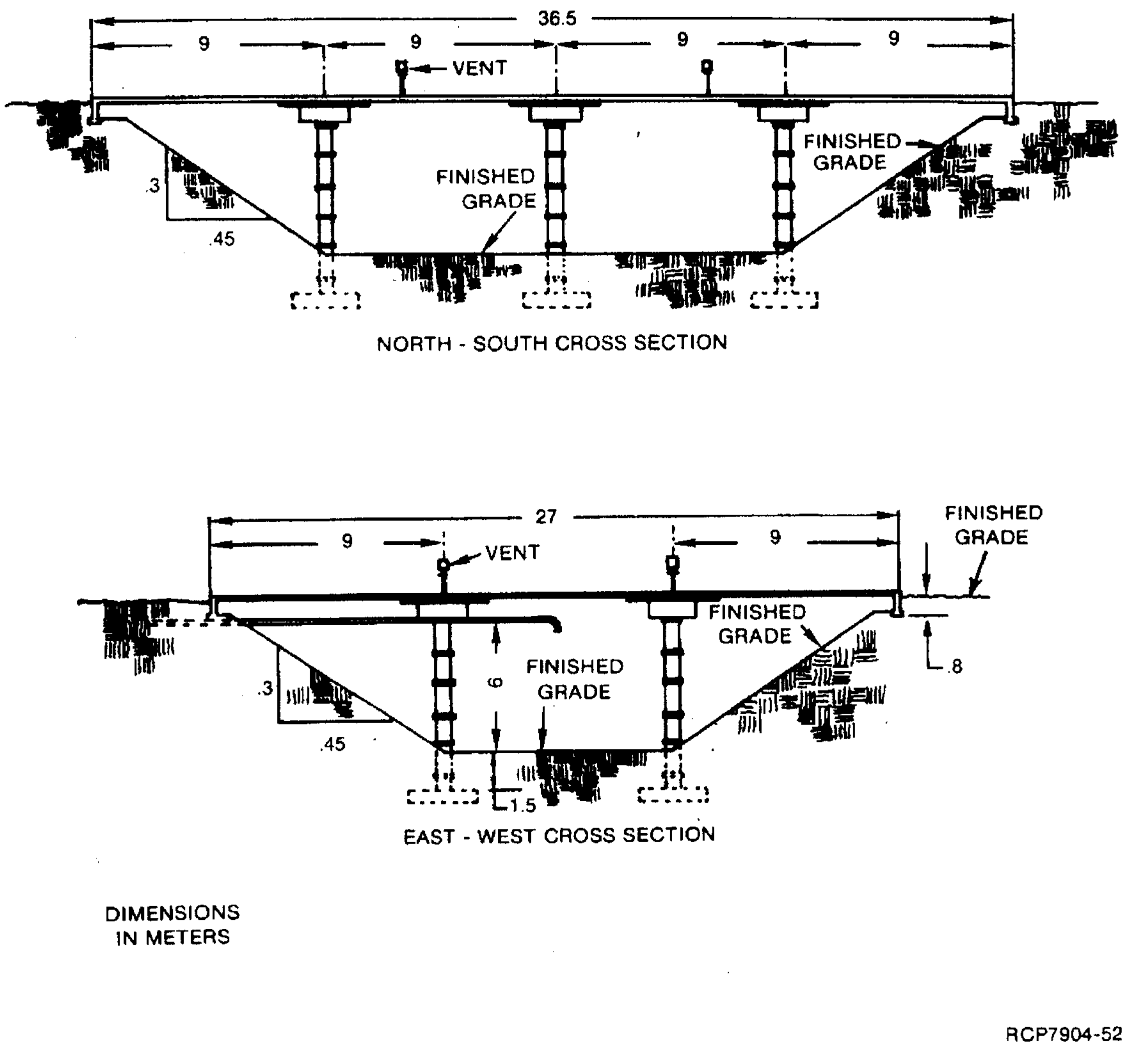

FIGURE 1. Z-9 Enclosed Trench Sections Prior to Mining Phase.

The Z-9 enclosed trench received these wastes from July 1955 until April 1962, when the Recuplex process was deactivated. During its 7-year life, the enclosed trench received approximately $4 \times 10^6 \ell$ of waste.

Due to the high salt content and acidic nature of the Recuplex wastes, considerable gassing and soil plugging was expected when the wastes contacted the soil. As a result, the enclosed trench volume and active floor area were designed to handle the slow percolation rates of the wastes.

According to accountability records, the Z-9 enclosed trench was estimated to contain 13 kg of plutonium by September 1959, nearing the limit of 15 kg then permitted by criticality prevention specifications. After a study, based on trench soil samples and the estimated plutonium concentration in the soils, the plutonium limit of the crib was adjusted upward to 25 kg. In early 1961, the crib was estimated to contain 20 g of plutonium and in early 1962, the enclosed trench specification was increased to a limit of 50 kg based upon nuclear criticality computations. When the enclosed trench was deactivated in April 1962, records indicated it contained 27.4 kg of plutonium.

Another series of soil samples obtained in 1963 determined the plutonium distribution beneath the trench and further evaluated the need of a replacement enclosed trench for the new Plutonium Reclamation Facility. Shortly after the sampling program in 1963, the nuclear reactivity of the soil was determined by the pulsed neutron technique[(1)] and again in 1969, the soil reactivity was measured by the same method, but utilizing an improved neutron pulser. The 1963 pulsed neutron study determined the K_{eff} of the soil to be 0.86 ± 0.04,[(2)] while the 1969 study determined K_{eff} as 0.91 ± 0.01. The two studies did not vary significantly.

Based on size estimates the enclosed trench, depth of the soil layer containing plutonium, and plutonium concentrations from the sampling program, the plutonium content of the enclosed trench was estimated to be between 50 and 150 kg in 1971. The most probable value was 100 kg while

150 kg was carried on official records.[3] According to accountability records, the enclosed trench contained 27.4 kg of plutonium with the additional material coming from the 89 kg of material unaccounted for (MUF) in the Recuplex solvent extraction system.

Another nuclear and soil analysis of the Z-9 Crib was performed in 1973.[4] The plutonium content of the soil was estimated to be 25 to 70 kg with 40 kg in the top 30 cm of soil. Neutron pulse measurements using the same equipment at the same locations as the 1969 study showed that K_{eff} was 0.95 to 0.98. Because of the concern that K_{eff} may have been increasing, a 0.07 $\underline{M}$ solution of cadmium nitrate (a neutron absorber) was sprayed on the soil. A total of 11 kg of cadmium was used.

Analysis of the pulsed neutron data by the Savannah River Laboratory (SRL) and Los Alamos Scientific Laboratory (LASL) led to the conclusion that an equipment malfunction produced high original values of K_{eff}. Replacement of the defective equipment gave a K_{eff} of 0.3. Before the cadmium nitrate was added, K_{eff} was estimated to have been <0.8 and probably <0.5.

Although the enclosed trench no longer presented a criticality potential, removal of the top 30 cm of contaminated soil was viewed as a means of reducing the risk of environmental contamination and would be in accordance with the criterion requiring solid wastes to be packaged and stored in 20-year retrievable storage. The design criteria for the Z-9 mining operation were completed in 1973 and fabrication of the mining equipment was finished in 1976. The Z-9 mining facility was constructed under Project HCP-687 in 1976 and provided the structures required to house the mining apparatus.

Most of the problems encountered during the mining operation were associated with packaging of the soil. Three major problems were dealt with: (1) a discrepancy between the two different methods used for the non-destructive assay (NDA) of the soil; (2) radiolytic production of hydrogen gas; and (3) chemical decomposition of carbonate bearing soil producing carbon dioxide gas. Each of these problems is discussed later in the section entitled Problems Encountered During Plutonium Mining.

Mining of the Z-9 enclosed trench to a depth of 30 cm was completed on July 14, 1978 with the removal of a total of 58 kg of plutonium. The mine is currently being placed in the standby mode and is tentatively scheduled for decontamination and decommissioning in FY 1982.

NUCLEAR REACTIVITY EVALUATIONS OF THE 216-Z-9 ENCLOSED TRENCH

Neutron pulsing measurements taken in 1963 and 1969 indicated that the K_{eff} of the soil was 0.86 and 0.9, respectively. These values were not considered to be significantly different. However, in March 1973, a pulsed neutron measurement showed K_{eff} to be in the range of between 0.95 and 0.98 and there was concern that the K_{eff} of the trench soil was slowly increasing. The K_{eff} values could not be supported by reliable K_{eff} techniques and a more comprehensive analysis of the plutonium distribution was needed. In 1973, such a detailed investigation of the plutonium distribution in the Z-9 trench was undertaken.[4] This section summarizes the findings of that study.

The 1973 study was a two-phase investigation to define the plutonium distribution in the Z-9 trench (and consequently the reactivity) and to improve the understanding of neutron pulsing techniques.

Six methods were used to define the plutonium distribution: (1) infrared survey; (2) gamma survey; (3) neutron survey; (4) sampling and chemical analysis of the plutonium-rich areas identified by the surveys; (5) modeling of the systems based on information generated by the surveys and analyses; and (6) computation of the system reactivity based on the models developed.

The results of the infrared, gamma, and neutron survey were in qualitative agreement with each other, showing the same general distribution of plutonium at the surface with the highest plutonium concentrations being in the low elevation regions of the trench floor (Figures 2, 3 and 4). Core samples taken from the trench floor confirmed these surveys.

Core samples removed from the areas of high plutonium concentration were used to develop a plutonium distribution model for the basis to calculate the K_{eff} of the system. The plutonium content of the Z-9 Crib soil was estimated to be between 25 and 70 kg and 40 kg was estimated to be contained in the top 30 cm. The values of K_{eff} calculated from the sampling program and from a system having twice as much plutonium were 0.5 and 0.8, respectively.

Knowledgeable criticality prevention and plutonium chemistry personnel from LASL and SRL were invited to comment on the program and the information available at the time. The recommendations included: (1) additional neutron pulsing measurements with the detector located at different levels with respect to the trench floor; (2) additional calculation of the effect of cadmium nitrate on top of a system with a K_{eff} of 0.98 should cadmium nitrate addition be necessary; (3) a modification of the neutron pulse equipment which consisted of the substitution of a 4096 channel analyzer for the 256 channel analyzer used originally; and (4) the addition of cadmium nitrate to render the trench soil further subcritical.

The Z-9 trench was rendered further subcritical prior to the pulsed neutron measurements using the 4096 channel analyzer. A total of 1100 ℓ of a 10 g cadmium/ℓ concentration cadmium nitrate solution was added to the system for a total of 11 kg of cadmium. After the cadmium was added, the neutron pulsing measurement with the 4096 channel analyzer yielded a value for K_{eff} of less than 0.3.

Neutron pulse data, using the 4096 channel analyzer, were analyzed by three different laboratories: Battelle Pacific Northwest Laboratories (PNL), LASL and SRL. The analyses of the three laboratories revealed, depending upon the assumptions made, a wide range of values of nuclear reactivity was possible. The three laboratories

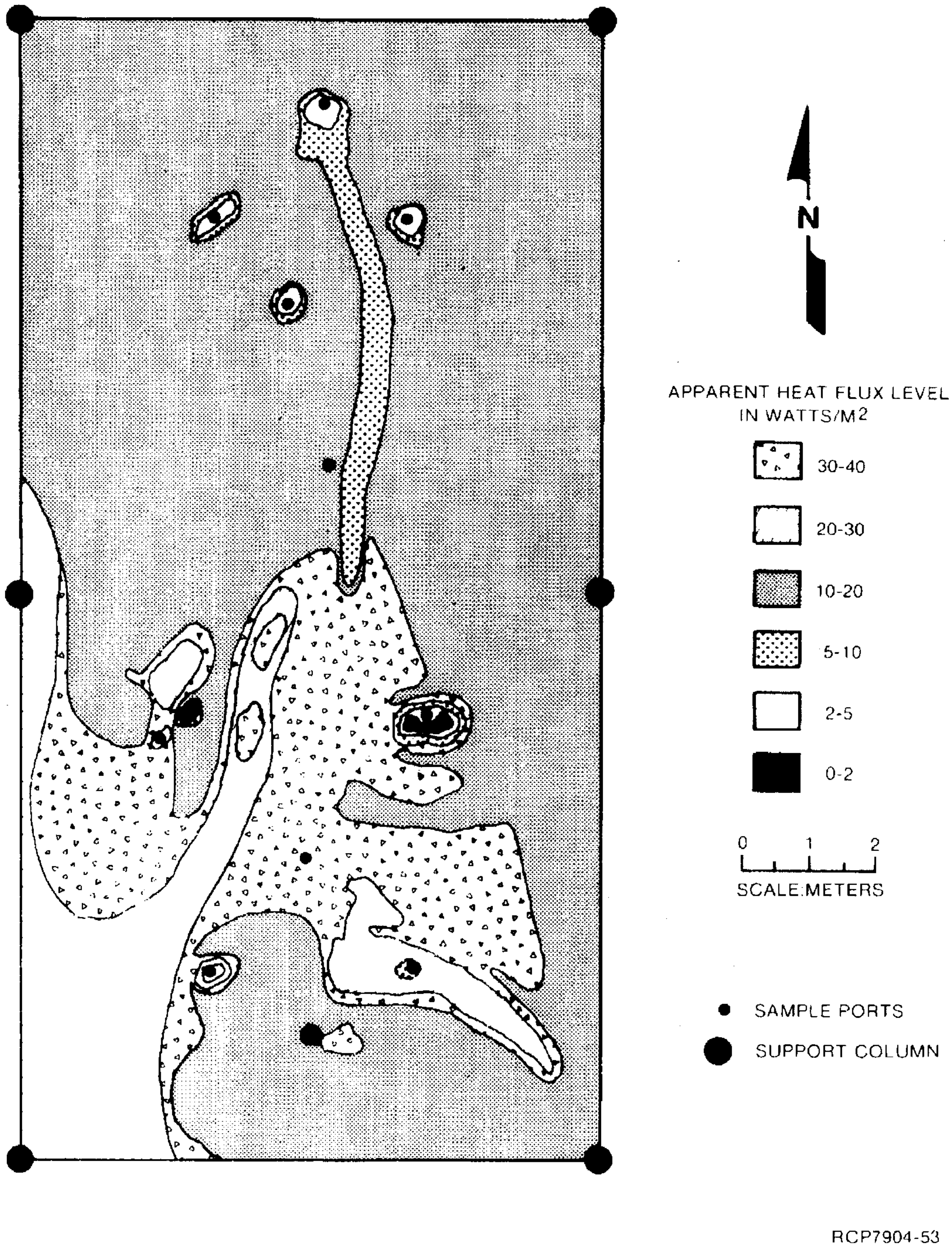

FIGURE 2. Z-9 Enclosed Trench Thermal Survey.

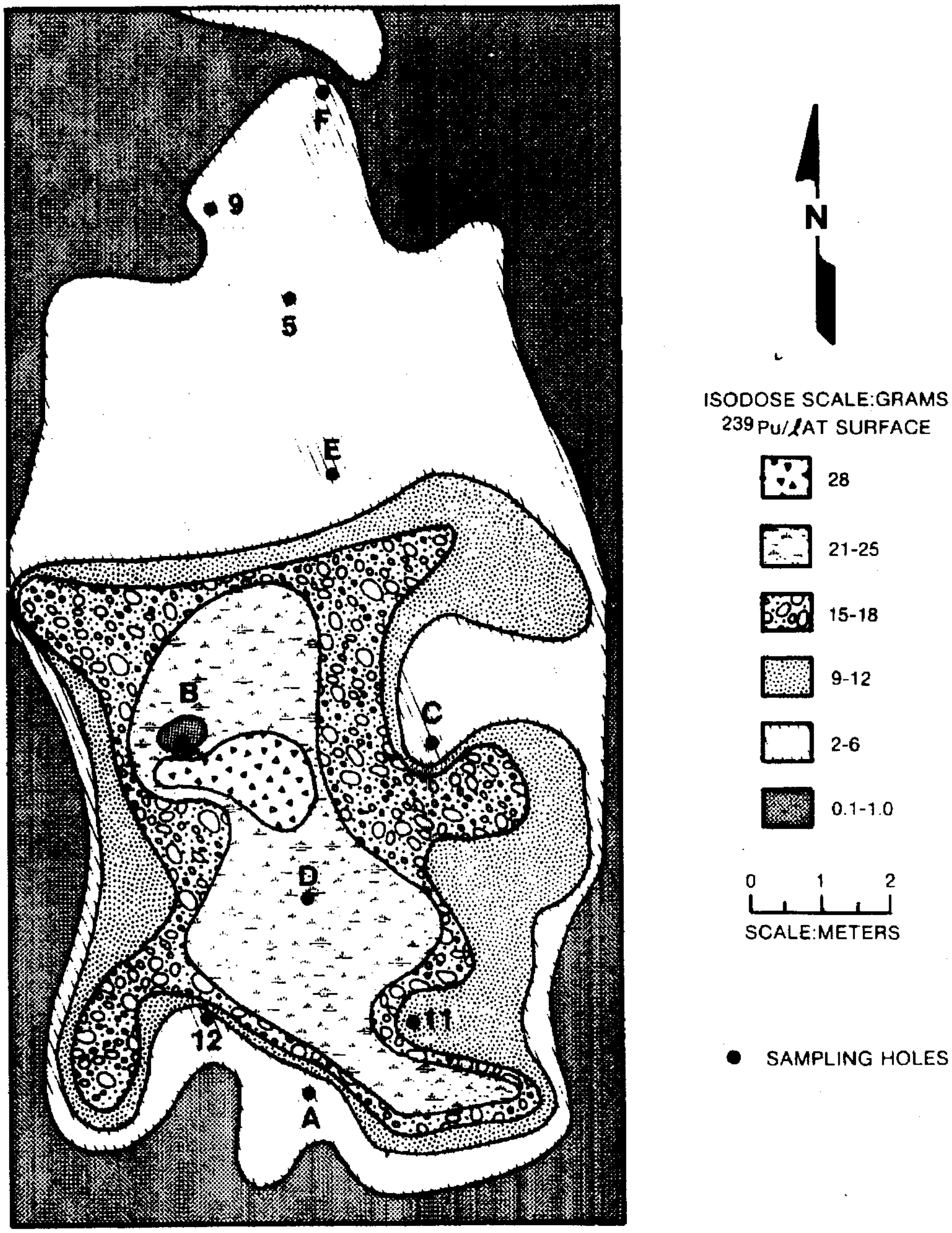

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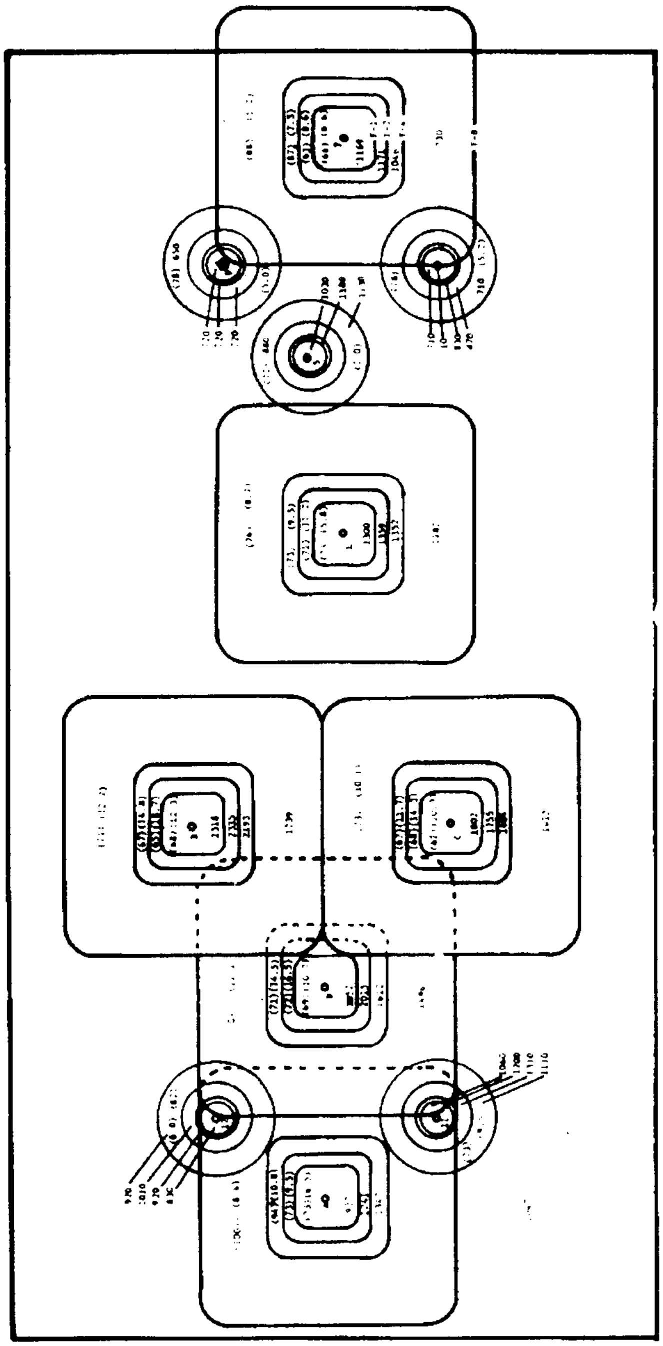
FIGURE 3. Z-9 Enclosed Trench Gamma Survey.



LEGEND

1047 - RELATIVE NEUTRON FLUX

(70) - % THERMAL NEUTRONS

(7.0) - g/1. 14CM DEEP

ALL VALUES REPRESENT THE ENTIRE AREA WITHIN THE GIVEN BOUNDARY

• APPEARS TO BE AN ERROR ON THESE TWO NUMBERS

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FIGURE 4. Z-9 Enclosed Trench Neutron Survey.

agreed, however, that before addition of the cadmium nitrate, the K_{eff} was less than 0.8 and probably less than 0.5. With the new pulsed neutron data, the plutonium content of the trench was reevaluated and it was concluded that the trench contained between 26 and 69 kg with 38 kg contained in the upper 30 cm of soil.

It is significant to note that 58 kg of plutonium were actually removed in the top 30 cm of soil. This was 54% higher than the estimated 38 kg. If this 54% correction factor is applied to the total plutonium content of the crib, then at most 106 kg of plutonium was originally present and 48 kg of plutonium still remains. The fact that the estimates of Reference 4 are 54% low in no way detracts from that study. The estimates of plutonium content were simply based on the best information available at the time. The present estimate of 48 kg remaining is also based on the best information available and should in no way be viewed as being exact.

MINING PHASE OF THE 216-Z-9 ENCLOSED TRENCH

DESCRIPTION OF THE PLUTONIUM MINING OPERATION

The equipment used to remove the upper 30 cm of plutonium bearing soil is described in this section. Z-9 soil was mined using a clamshell digger and conveyer bucket system shown in Appendix E-2.

An 11-ℓ hydraulically operated clamshell was suspended from a trolley assembly which traveled along a horizontal boom (Appendix E-3). The boom rotated about the bottom of a vertical shaft supported from a 107-cm diameter flanged, trench-roof riser. As shown in Appendix E-4 and E-5, two trench-roof risers were located at the centers of the two mining areas. The 6 m long boom was capable of rotating 360 degrees in either direction at a maximum rate of 6 deg/sec. The clamshell lifted soil from the trench floor then rotated to the proper position and deposited the soil into the soil bucket. The horizontal boom and clamshell suspension were hydraulically collapsible to a position nearly longitudinal with the vertical shaft so that the excavator could be installed, deployed or collapsed, and removed through the 107-cm risers. Manipulation of the clamshell was done remotely by an operator stationed in the shielded operator's cubicle.

Operation of the clamshell could be viewed either directly through a viewing window or indirectly by a television camera and monitor. The viewing window was made of tempered safety plate with 0.64 cm X-ray shielding as a laminate, allowing a dose rate of less than 1 mR/hr.

Mining of the trench floor was done in sections using degrees and radii as shown in Appendix E-5. Soil from the trench was removed in an 11-ℓ soil bucket which resided on an inclined elevator carriage, as shown in Appendix E-6. The inclined elevator, approximately 9 m long, extended from the trench floor, through the trench roof into the glovebox located within the trench roof enclosure. For maintenance purposes, the elevator drive mechanism was located within the glovebox. The elevator was raised by the mining operator from the operator's cubicle and lowered by the glovebox operator.

Filled soil buckets, after being elevated into the packaging glovebox, were removed from the elevator position by an electrically operated chain hoist and placed on a bag-filling support stand. An alternate empty soil container was then placed on the elevator and lowered to the trench floor.

Limit switches were provided on both the miner and the bucket elevator to prevent accidental movement of the equipment at various stages of operation (Appendix E-7). The location of these switches and the function of each is shown in Table 1.

Packaging of the soil for storage was performed inside a glovebox. No more than 9.1 ℓ of soil was poured into a metal 10-ℓ canister. The slip fit lid was sealed in place with tape and the canister was loaded out of the glovebox into a 0.3-mm polyethylene bag which was heat sealed. Each sealed canister was placed inside an outer metal canister slightly larger than the inner 10-ℓ container and its slip fit lid was sealed. The canisters were identified by painting a number on each can.

TABLE 1. Locations and Functions of Mining Apparatus Limit Switches

Apparatus	Switch No.	Location	Funtion
Clamshell Limit Switches	LS-1	Above flange on bearing housing assembly	Limits counterclockwise rotation of miner and stops clam shovel over bucket conveyor.
	LS-2	Front of trolley assembly	Stops trolley motor when trolley gets to end of boom.
	LS-3	Rear or trolley assembly	Stops trolley motor when trolley gets to end of boom.
	LS-4	Above flange on bearing housing assembly	Limits clockwise rotation of miner and stops clam shovel over bucket conveyor.
	LS-7	On guide fork mounting bracket of clam shovel assembly	Disables boom rotation and trolley movement when clam shovel jaws are in the dirt.
	LS-8	Rear underside of trolley assembly	Disables rotation of boom when trolley is at the end of the boom.
	LS-9	Above flange on bearing housing assembly	Disables bucket conveyor when boom is in interference zone.
	LS-15	On jointed part of stairway (in trench)	Disables boom rotation when stairway is not in the folded up position.
Bucket Conveyor Limit Switches	LS-5	Top of bucket conveyor beam (in trench)	Stops bucket conveyor at the bottom of its travel.
	LS-6	Bottom of bucket conveyor beam (in trench)	Stops bucket conveyor at the bottom of its travel, disables miner boom rotation, when bucket is off bottom.
	LS-16	Above flange on bearing housing assembly	In conjunction with LS-6, limits boom rotation to area outside of the interference zone when bucket conveyor is not at the bottom of its track.

An electrically operated monorail hoist was used to transfer the soil canister to the assay room. Here, plutonium content of each canister was measured with a Sodium Iodide Soil Assay Monitor System (SAMS) and canisters were weighed. Every tenth canister and all canisters found to contain 20 g or more of plutonium were verified by assay with the Segmented Gamma Scan Assay System (SGSAS) unit in 234-5 Building.

After the canisters were assayed, they were loaded inside DOT-17H 55-gal drums. It was possible to load a maximum of eight canisters in each drum, however, drums were administratively limited to 185 g of plutonium. Four canisters were loaded in and the void was filled with vermiculite. After laying a plywood spacer on top, four more cans were loaded in and packed with vermiculite. Drums may have been packed with less than eight soil canisters to keep the total plutonium content of the drum less than 185 g. The drum lid was sealed in place with a metal ring closure.

Shortly after mining began, it was discovered that the acid soil caused pitting of the inner canisters. To prevent corrosion, inner canisters were lined with a 0.05 mm polyethylene bag which was taped shut before the canister was sealed. Other measures adopted to combat the corrosion problem were the use of a 2.3-mm thick rigid wall drum liner with snap-on lid and heavier gauge steel DOT-17C drums instead of the DOT-17H drums.

Radiolytic decomposition of moisture and organics produced potentially dangerous gas pressures and hydrogen concentrations in the drums. To reduce the pressure inside each drum, a small vent was provided. The last modification of packaging was the placement of a packet of hydrogen-oxygen recombination catalyst on top of the vermiculite before closing the drum liner. All drums that were not originally fitted with catalyst and/or vents are being retrofitted to provide these devices. Figure 5 shows the final configuration of a loaded Z-9 soil drum.

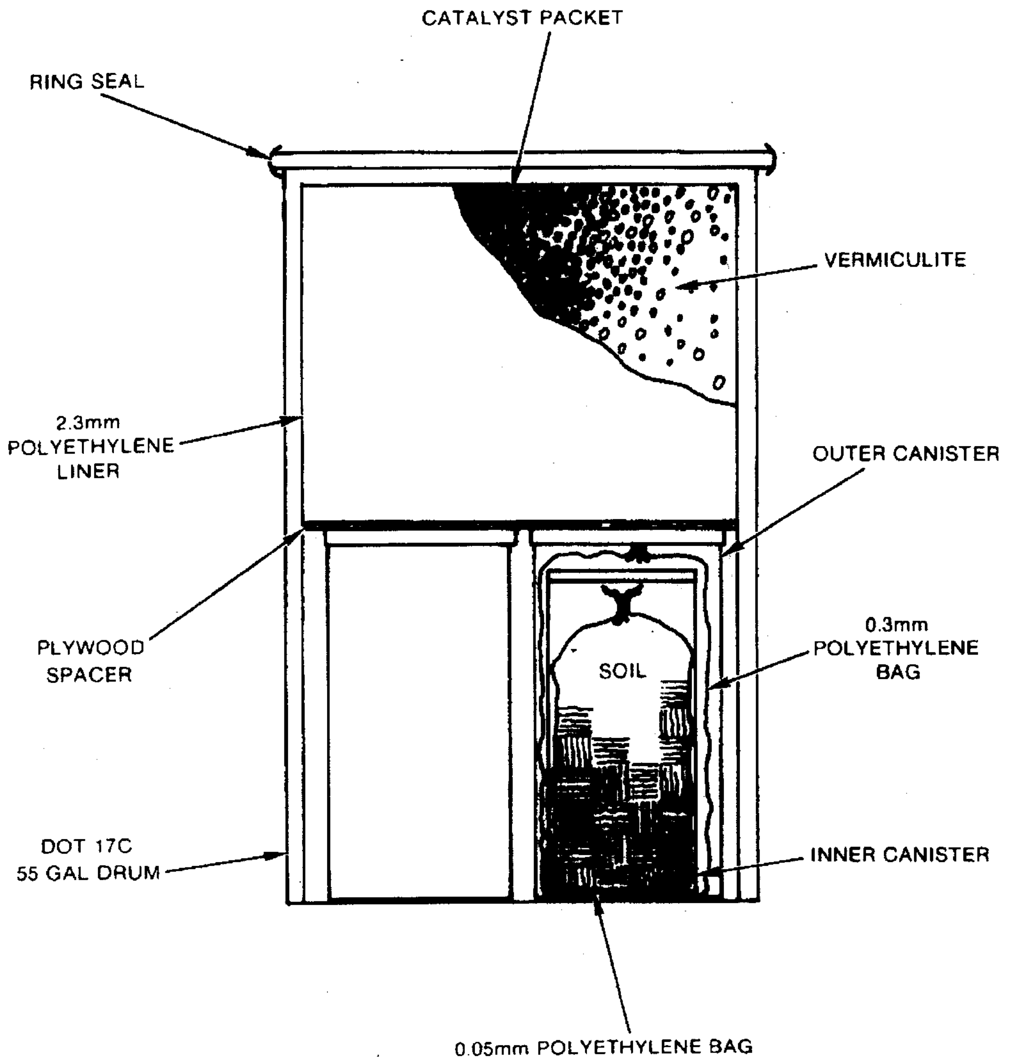

FIGURE 5. Packaging of 216-Z-9 Soil.

Canisters were classified according to the plutonium content of the container (Appendix A) and each drum contained material of only one classification. Drums containing canisters having less than 20 g of plutonium were classified as waste and there is no expectation of plutonium recovery. Plutonium in canisters containing greater than 50 g of the material was considered recoverable scrap while the remaining canisters contained plutonium which was considered potentially recoverable.

TESTING OF THE PROTOTYPE MINER

Before being inserted in the Z-9 trench, the mining equipment was extensively redesigned and tested in a nonradioactive environment located approximately 275 m west of 271-T Building. These tests allowed for the verification of the design and improvement of the operation of the equipment. It is because of this extensive testing program that the miner had very little down time due to mechanical or electrical failure and servicing of the equipment in a radioactive environment was minimal.

Items that were tested included the reliability of the hydraulic system, difficulty of picking up rocks and loose or compacted soil, and all components such as controls, interlocks, and limit switches of the miner that may have been defective in design or fabrication. Other checks on the miner were determining counterweight requirements, speed of operation, volume of soil in an average bucket load under various conditions, the ability of the conveyor to transfer soil without spillage, coverage and clarity of television monitoring system, and the ease with which the mining equipment could be lifted and moved with cranes.

Most of the modifications to the miner during the prototype test were of a minor nature. For example, the bucket assembly was shimmed so the clamshell would hang vertically and the coordinates of the miner location observed by the mining operator would agree with the actual location on the trench floor.

Some of the modifications eliminated the deficiencies of the original design. Major changes were the modification of the overhead hydraulic cylinder mount to provide for easier maintenance, installation of guide rollers on the boom winch cable line to prevent the cable from rubbing on hydraulic lines and electrical cables, and the remounting of hydraulic valves above riser level for easier maintenance. The mining apparatus was also scraped and painted with chemically resistant paint. The report detailing the problems encountered during the prototype test is contained in Appendix B.

STATISTICS OF THE PLUTONIUM MINING OPERATION

Z-9 mining operations lasted from August 17, 1976 through July 14, 1978, with no mining done between August 26, 1976 and January 11, 1977, to resolve the discrepancy in the results of the NDA methods. An average of approximately thirteen 10 ℓ canisters were mined per day, amounting to 5,222 canisters over the two years. The canisters were packaged into 653 55-gal drums. Approximately 86.8% of the canisters were classified as waste, 12.6% potentially recoverable, and 0.6% scrap (recoverable). Twenty-eight kg of plutonium was mined from the north half of the mine and 30 kg from the south half for a total of 58 kg. Table 2 summarizes the monthly production of soil and Figure 6 shows this production rate was rather constant. Except for the period in late 1976 when the mining operation was shut down to resolve the discrepancies in the NDA methods, the operation had little down time.

Soil from each day's mining was analyzed for moisture, organic, and cadmium content. The moisture content ranged between 0.2 and 24.4 wt%, averaging approximately 5 wt%. Organic content was slightly higher than moisture, averaging 7.1 wt% with a range of 0.2 to 46.4 wt%. Cadmium concentrations ranged between less than 0.8 wt% and 0.2 wt%.

Mining was begun in the north half of the trench. The major problems encountered were repeated failure of the LS-8 limit switch (see Appendix E-7) and the clamshell clogging with soil. The limit switch was finally shimmed so that it would be tripped by the striker.

TABLE 2. Monthly Production of 216-Z-9 Soil Canisters

Date		Canister Filled	Total Canisters Filled to Date
1976	Aug	23	23
	Sept	0	23
	Oct	0	23
	Nov	0	23
	Dec	0	23
1977	Jan	153	176
	Feb	83	259
	Mar	335	594
	Apr	305	899
	May	290	1189
	June	192	1381
	July	312	1693
	Aug	364	2057
	Sept	307	2364
	Oct	228	2592
	Nov	233	2825
	Dec	275	3100
1978	Jan	280	3380
	Feb	275	3655
	Mar	277	3932
	Apr	275	4202
	May	454	4661
	June	390	5051
	July	171	5222

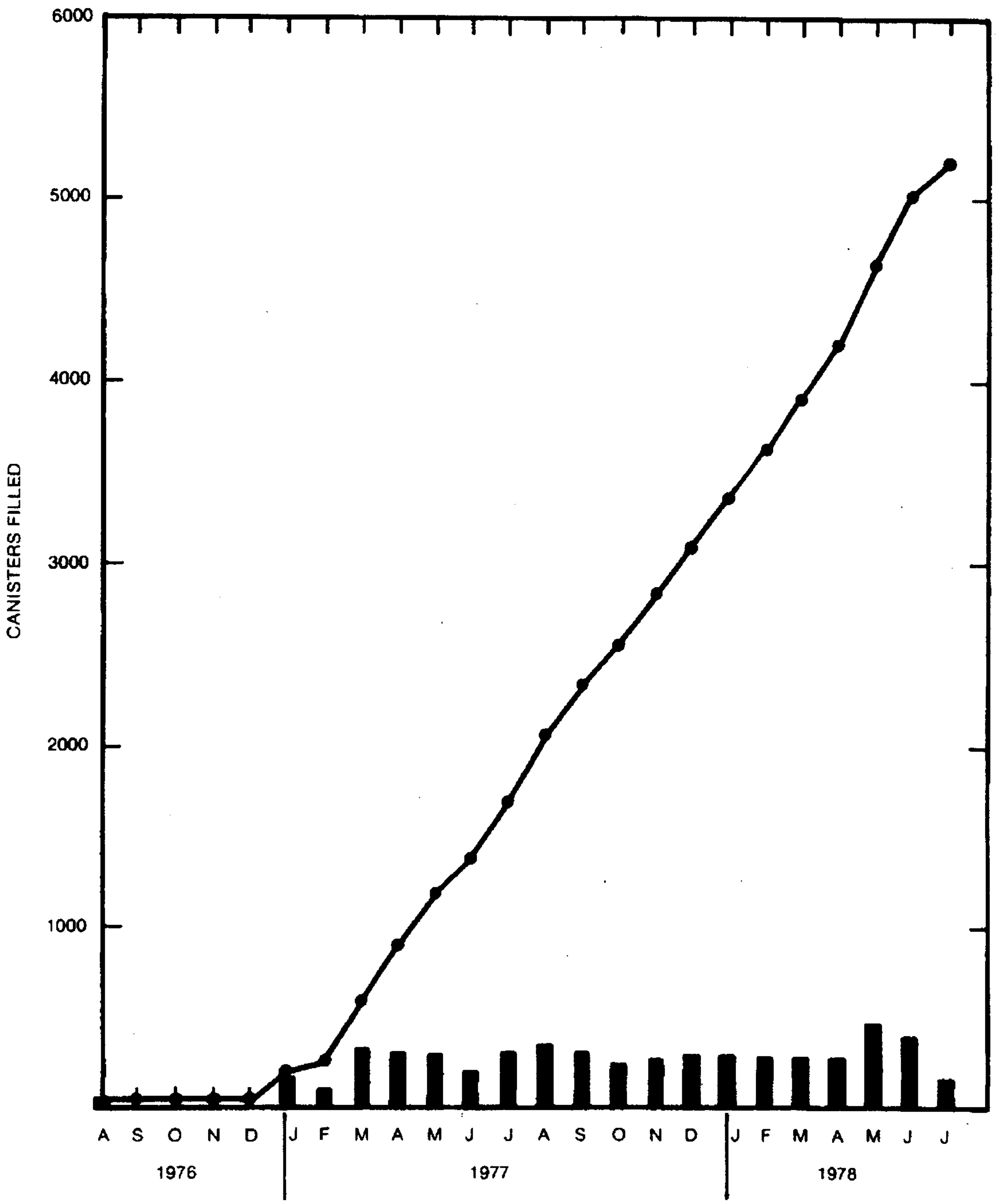

FIGURE 6. Monthly Production of 216-Z-9 Soil Canisters.

After the clamshell had been manually cleaned out, clogging was never a problem again. However, a new selfcleaning clamshell was fabricated, but never installed.

In November 1977, the miner was moved to the south riser and operations were resumed. A major mechanical problem resulted when the limit switch LS-6 failed to trip due to dirt accumulation around the bottom of the conveyor. This caused the conveyor motor to keep unwinding the cable which eventually snagged and caused the motor to burn out. After the limit switch failed again, it was bypassed, which permitted mining at the 0° boom angle (Appendix E-5).

After mining was completed in July 1978, the packaging and assay room of the facility were converted into the Drum Retrofit Facility and the miner was placed in standby.

PROBLEMS ENCOUNTERED DURING PLUTONIUM MINING

Nondestructive Assay

Shortly after mining began in August 1976, a discrepancy was noticed in the results of the two different methods of nondestructive assay (NDA) of Z-9 soil. Prior to packaging the 10-ℓ canisters of Z-9 soil into 55-gal drums, each canister was assayed for plutonium at the Z-9 facility using a Sodium Iodide (NaI) gamma detector and SAMS. To verify the SAMS assay during startup of the mining operation, a SGSAS, located in the 234-5 Z Building was also used, The SGSAS method is considered to be a very accurate gamma measurement system available for routine determination of plutonium contaminated waste and scrap in their shipping and storage containers.(5) The SGSAS results indicated the SAMS measurements were 25 to 55% high.(6) Errors in the SAMS measurements were due to differences in matrix density between the mined soil and calibration standards prepared by LASL using Hanford soil and known amounts of plutonium. The major reason for the differences was due to the high moisture and organic content of the crib soil compared to Hanford soils used in preparing the standards.

Correction factors were calculated to provide for adjustment of the SAMS analytical results, using canister net weight and volume to estimate the matrix density effect. As a result, measurement differences between SAMS and SGSAS results were held to less than 5 g plutonium for over 96% of subsequent measurements.

The validity of a matrix density correction for the SAMS was supported by various measurements of Z-9 soil using other NDA methods, all of which agreed with the SGSAS measurement.[7] Three approaches provided this support. The first was to recount a previously measured canister, divide the contents, and count the portions. A second approach was to compare the results of several NDA methods on the same soil samples. The third approach was to spike a canister with a known amount of plutonium and measure the recovery using both the SGSAS and SAMS units. Results of these tests showed there were some limitations to the measurement systems and both systems had a current low bias of approximately 10%. Recalibration of the systems removed the majority of the bias prior to resumption of mining in January 1977.

A quality control program, using three simulated soil standards, was initiated after resumption of mining operations to monitor performance of the SGSAS results. A referee measurement program was established at 216-Z-9 to measure SAMS variability. These two programs were instrumental in maintaining instrument control throughout the duration of the mining operation.

Radiolytic Hydrogen Production

Before mining began in 1976, radiolytic decomposition of organics and moisture was recognized as being the source of a potentially explosive mixture of hydrogen and oxygen. The time required for the gas in a drum to reach the combustible limit of 4% hydrogen was calculated to be approximately three months, although for drums containing the maximum allowable plutonium, the combustible limit could be reached in as little as two days (Appendix C). The evolution rate of gases was experimentally determined in 1977.[8] The greatest measured gas production rate was 1.3×10^{-6} g-mol/hr/g plutonium. The evolved gas composed of 49.5 M% nitrogen 23.3 M% hydrogen, 14.1 M% oxygen, and 13.1 M% carbon dioxide.

This composition was determined from gases evolved from moisture rich soil--soils rich in organics are expected to produce greater percentages of hydrogen.

Even though no ignition sources were present within the drums, it was considered possible that two of the inner canisters might strike each other during transport, creating a spark resulting in an explosive reaction of hydrogen and oxygen.

Hazards Research Corporation, Denville, New Jersey, was commissioned to study the effect of packing the spaces around soil canisters in Z-9 drums to improve the ability of the 55-gal drum to contain an internal explosion of hydrogen and air.(9)

The Hazards Research investigation, as summarized in Table 3, demonstrated that packing the spaces between inner canisters with vermiculite enabled the drums to contain an internal explosion. Even when a stoichiometric mixture of hydrogen and oxygen (H_2:O_2 equal to 2:1) was ignited, the packed drum was able to contain the explosion without rupture. The study concluded that packing the drum had three favorable effects: (1) the volume available for gas accumulation is reduced by the packing; (2) the packing serves as a flame arrester; and (3) the packing acts as a cushion reducing the pressure of the expanding gases.

TABLE 3. Explosion Resistance of 55-Gallon Drums Containing 2:1 Ratios of Hydrogen to Oxygen

Trial	55-Gallon Drum Packing	Ignition Point	Results
1	None	Inside Soil Canister	Lid of drum blown about 4.6 m.
2	Vermiculite	Inside Soil Canister	Lid bulged, but remained on drum.
3	Coarse glass foam beads	Inside 55-Gallon Drum	Lid bulged, but remained on drum.
4	Fine glass foam beads	Inside Soil Canister	Lid bulged, but remained on drum.

Although the drums were found able to contain an internal hydrogen-oxygen explosion, pressurization of the drums (at the rate of about 230 mm Hg/yr) due to the buildup of gases as well as the possibility of a hydrogen-oxygen explosion as the drums are opened, had the potential for endangering workers during the retrieval of drums in some 20 years. To prevent the buildup of gas pressure, a vent was devised.

To further reduce the potential for explosion, packets of Engelhard Type D hydrogen/oxygen recombining catalyst (Figure 7) were added to the drums on top of the vermiculite packing. Catalyst packets were made of 1 mm mesh stainless steel screen and contained 30 to 60 4-mm catalyst pellets. Although much more hydrogen than oxygen would be produced due to the large ratio of organic to water content (organics have a higher H_2 to O_2 ratio than does water), the catalyst will allow oxygen and hydrogen to combine until the oxygen is depleted. Hydrogen will still be produced, but the risk of an explosion is reduced due to the absence of oxygen (Appendix D).

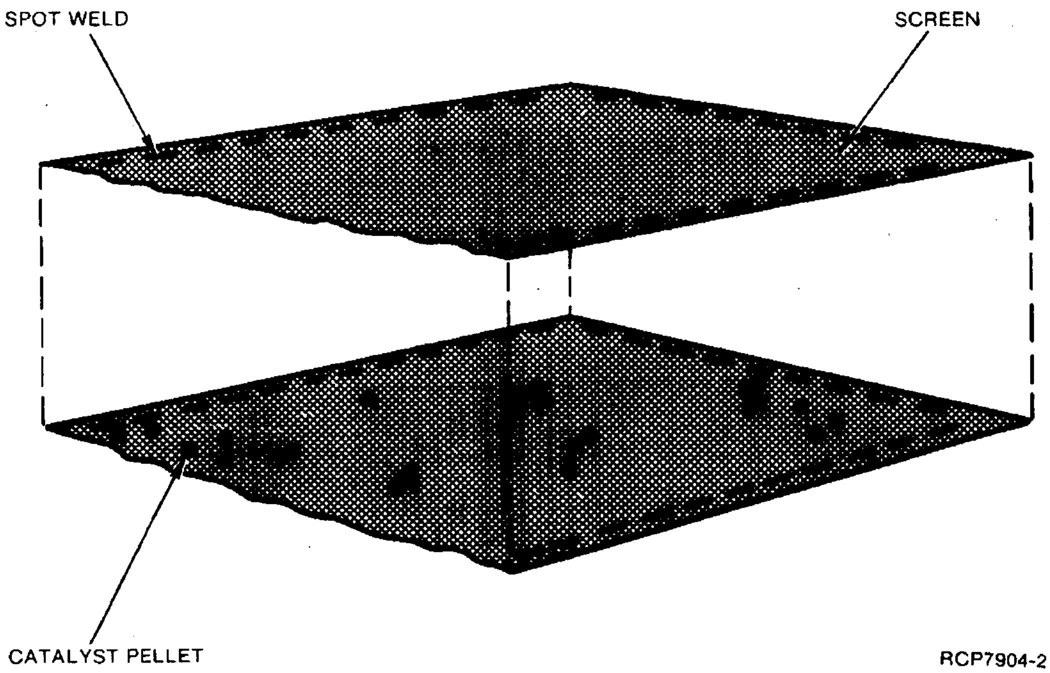

FIGURE 7. Packet of 216-Z-9 Hydrogen/Oxygen

The vent and catalyst were not used until sometime after mining operations began. As a result, of the approximately 600 drums produced during mining, 460 did not originally contain catalyst and 150 of these were not vented. In order to provide vents and/or catalyst packets, a retrofit program was begun in September 1978. The lid of each drum was to be punctured with a hydraulically operated puncture press and simultaneously purged with nitrogen. After the drums were provided with a vent and/or catalyst, they were resealed with a new lid and returned to the burial ground.

Carbon Dioxide Production from Carbonate Bearing Soil

Several plastic bags containing canisters of Z-9 soil were found to be bulging due to internal pressurization. The bags showed signs of inflation only a few days after the soil had been mined and only the soil mined near the trench wall was associated with the bag inflation. Subsequent mass spectroscopic analysis of the gas contained within the bags showed a 4 M% carbon dioxide (CO_2) level in air. Levels of hydrogen were 0.4% at most. The inflation of the bags was concluded to be caused by nonradiolytic production of CO_2 since hydrogen concentrations were negligible and the plutonium concentration of the soil was also relatively small.

The soil had been removed from areas adjacent to the wall of the crib which contained a large amount of carbonate in the form of concrete sloughed from the wall during construction of the mining facility. This carbonate bearing soil was mixed with the moist acidic soil from other areas of the mine producing large amounts of CO_2.

The decision was made to selectively mine the remaining soil from the sloughed areas to eliminate its mixing with the acidic soil. Soil that had already been mined was repackaged after CO_2 production ceased.

ANALYSES OF RADIOLYTICALLY PRODUCED GAS IN 216-Z-9 SOIL

In June of 1977, two drums with Z-9 soil were fabricated to sample the gas from within the soil canisters and the drum, as shown in Figure 8. One of the drums (Z-9-D-C-1) was fitted with a vent device, while the other drum had no vent device (Z-9-D-C-2). Gas samples were taken from an inner canister and the drum and analyzed using mass spectroscopy as shown in Tables 4 through 7.

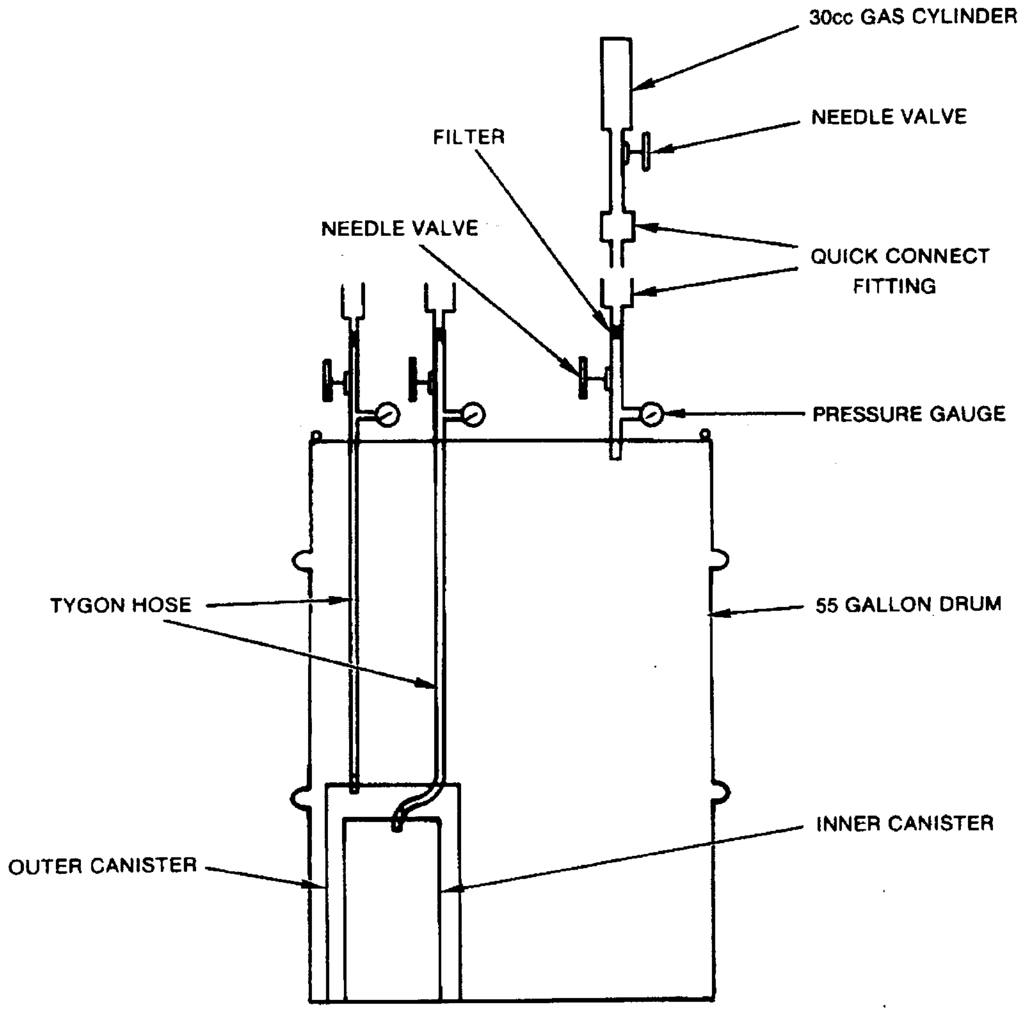

FIGURE 8. Drum for Sampling Gas Produced Radiolytically from 216-Z-9 Soil.

TABLE 4. Gas Analyses from Vented Drum Z-9-D-C-1.

Sample Date	Mole Percent									
	CO_2	Ar	O_2	N_2	CO	He	H_2	CH_4	C_2H_x*	C_xH_9*
7-07-77	1.25	0.95	18.5	77.9	<0.1	<0.01	1.38	<0.01	<0.1	<0.1
8-15-77	1.24	0.96	18.2	78.5	<0.1	<0.01	1.08	<0.01	<0.1	<0.1
8-30-77	1.12	0.94	18.5	78.4	<0.1	<0.01	0.90	0.04	<0.1	<0.1
10-14-77**	2.08	0.97	14.8	80.0	<0.1	<0.01	1.83	0.01	0.2	0.2
11-07-77	0.08	0.92	20.6	78.4	<0.1	<0.01	0.04	<0.01	<0.1	<0.1
12-06-77	2.21	1.00	14.0	78.8	0.90	<0.01	2.41	0.08	0.26	0.34
1-06-78	0.99	0.95	18.2	78.6	<0.1	<0.01	1.09	0.03	0.1	0.1
2-10-78	--	--	--	--	--	--	--	--	--	--
3-17-78	0.10	0.90	20.7	78.3	<0.1	<0.01	<0.01	<0.01	--	--
4-27-78	0.11	0.91	20.8	78.1	<0.1	<0.1	<0.01	<0.01	--	--
5-10-78	2.52	1.01	12.67	78.5	<0.01	<0.01	4.09	0.08	0.6	0.5
6-15-78	1.99	0.96	14.4	79.5	1.0	<0.01	1.50	0.06	0.3	0.3

*Values for C_2H_x and C_xH_9 are estimates.

**On 8-31-77, drum was opened to add vermiculite then resealed.

NOTE: The drum held a total of seven canisters representing 179.6 g of plutonium. The drum was sealed on 6-01-77, then reopened on 8-31-77 for the addition of vermiculite and resealed. This drum was fitted with a vent.

TABLE 5. Gas Analyses from Inner Can of Vented Drum Z-9-D-C-1.

Sample Date	Mole Percent									
	CO_2	Ar	O_2	N_2	CO	He	H_2	CH_4	C_2H_x*	C_xH_9*
7-07-77	6.97	1.02	3.18	84.6	<0.1	<0.01	3.74	0.11	0.3	0.3
8-15-77	1.50	0.94	17.1	78.9	<0.1	<0.01	1.34	0.05	<0.1	<0.1
8-30-77	1.93	0.94	14.7	80.5	<0.1	<0.01	1.45	0.19	0.2	0.2
10-14-77**	1.03	0.95	17.3	79.9	<0.1	<0.01	0.60	<0.01	<0.1	0.1
11-07-77	4.91	1.03	2.22	85.6	<0.1	<0.01	5.03	0.13	0.3	0.6
12-06-77	4.56	1.00	2.93	83.1	1.41	<0.01	5.36	0.27	0.6	0.81
1-06-78	3.56	1.03	4.04	84.4	1.0	<0.01	4.82	0.14	0.6	0.4
2-10-78	0.22	0.89	20.3	78.3	<0.1	<0.01	0.24	<0.01	--	--
3-17-78	4.78	1.03	2.00	84.4	<0.1	<0.01	5.23	0.21	1.2	1.2
4-27-78	0.12	0.92	20.9	78.2	<0.1	<0.01	0.19	<0.01	--	--
5-10-78	5.20	1.05	1.83	80.0	2.2	<0.01	7.60	0.18	1.2	1.2
6-15-78	5.32	1.03	4.32	82.1	2.0	<0.01	3.45	0.14	0.8	0.8

*Values for C_2H_x and C_xH_9 are estimates.

**On 8-31-77, drum was opened to add vermiculite then resealed.

NOTE: The canister contained 47.8 g of plutonium. The soil had initial moisture and organic content of 7.6 and 19.2%, respectively. The canister was sealed on 6-01-77.

TABLE 6. Gas Analyses from Drum Z-9-D-C-2.

Sample Date	Mole Percent									
	CO_2	Ar	O_2	N_2	CO	He	H_2	CH_4	C_2H_x*	C_xH_9*
7-07-77	0.77	0.94	19.7	77.4	<0.1	<0.01	1.12	0.02	<0.1	<0.1
8-15-77	1.49	0.94	17.1	78.4	<0.1	<0.01	1.85	0.3	0.1	<0.1
8-30-77	1.08	0.92	18.5	78.1	<0.1	0.01	1.12	0.03	0.1	<0.1
10-14-77**	1.72	0.96	15.2	79.0	<0.1	<0.01	2.68	<0.01	0.2	0.2
11-07-77	1.06	0.96	17.6	78.7	<0.1	<0.01	1.37	0.04	0.1	0.1
12-06-77	3.46	0.98	8.89	76.5	2.6	<0.01	6.42	0.11	0.51	0.48
1-06-78	1.83	0.97	15.4	79.3	<0.1	<0.01	1.86	0.06	0.4	0.2
2-10-78	2.61	0.93	12.8	79.4	<0.1	<0.01	3.26	0.10	0.5	0.4
3-17-78	2.48	0.93	12.0	78.8	<0.1	<0.01	4.07	0.12	1.0	0.6
4-27-78	0.1	0.89	20.7	78.1	<0.1	<0.01	0.17	<0.01	--	--
5-10-78	--	--	--	--	--	--	--	--	--	--
6-15-78	5.14	1.02	5.49	76.6	2.7	<0.01	5.83	0.18	1.7	1.3

*Values for C_2H_x and C_xH_9 are estimates.

**On 8-31-77, drum was opened to add vermiculite then resealed.

NOTE: The drum held a total of five canisters representing 183.7 g of plutonium. The drum was sealed on 6-01-77, then opened 8-31-77 for the addition of vermiculite and resealed. This drum was not fitted with a vent.

TABLE 7. Gas Analysis from Inner Can of Drum Z-9-D-C-2.

Sample Date	Mole Percent									
	CO_2	Ar	O_2	N_2	CO	He	H_2	CH_4	C_2H_x*	C_xH_9*
7-07-77	5.30	1.02	4.60	83.0	<0.1	<0.01	4.49	0.26	0.8	0.5
8-15-77	1.50	0.94	16.8	78.6	<0.1	<0.01	1.84	0.04	0.1	0.1
8-30-77	7.42	1.00	3.04	80.6	<0.1	<0.01	5.52	0.20	1.2	1.1
10-14-77**	6.04	1.02	3.43	80.2	<0.1	<0.01	6.78	<0.01	1.4	1.2
11-07-77	3.96	0.97	9.46	78.6	<0.1	<0.01	5.09	0.16	0.9	0.8
12-06-77	3.93	0.97	9.52	75.8	1.45	<0.01	6.52	0.30	0.93	0.63
1-06-78	6.32	1.00	2.06	76.4	1.7	<0.01	8.60	0.30	2.2	1.4
2-10-78	6.72	0.99	2.20	78.4	2.1	<0.01	7.75	0.29	2.0	1.6
3-17-78	3.82	0.97	6.46	77.9	<0.1	<0.01	6.75	0.27	2.4	1.4
4-27-78	3.18	0.95	11.6	76.5	<0.1	<0.01	4.62	0.22	1.7	1.2
5-10-78	7.31	1.06	1.18	66.1	3.7	<0.01	13.0	0.30	3.7	3.6
6-15-78	8.31	1.09	2.15	69.3	4.8	<0.01	2.98	0.40	2.9	3.1

*Values for C_2H_x and C_xH_9 are estimates.

**On 8-31-77, drum was opened to add vermiculite then resealed.

NOTE: The canister contained 55.7 g of plutonium. The soil had initial moisture and organic contents of 2.0 and 10.8%, respectively. The canister was sealed on 6-01-77.

In September 1978, the vented drum had no pressure buildup while the non-vented drum contained a pressure of about 80 mm Hg-gauge. As shown in Figure 9, the rate of hydrogen concentration buildup is approximately constant for the two inner canisters: 0.7 to 0.9%/mo reaching the 4% explosive limit in five months. However, the hydrogen production rate in the drums is significantly different: 0.4%/mo in the vented drum and 0.7%/mo in the non-vented drum. The lower hydrogen production rate in the vented drum may be attributed to two factors. The first factor is the higher molecular diffusivity of hydrogen as opposed to other gases such as oxygen and nitrogen. The hydrogen simply diffuses through the vent device more readily than oxygen. The second factor may be due to atmospheric "breathing" of the drum, i.e., expansion of the gases on hot days followed by drawing in air as the drum cools effectively diluting the hydrogen concentration.

RETROFIT OF THE 216-Z-9 SOIL DRUMS WITH CATALYST AND VENT

The final configuration of the packaged drum was as shown in Figure 5. Drums sealed prior to February 21, 1978, were lacking vents and/or packets of Engelhard Type D hydrogen/oxygen recombination catalyst. Approximately 460 drums had no catalyst and 150 of these were not equipped with vents. A study of the radiolytic gas production showed that potentially explosive concentrations of hydrogen could exist within the drums, posing a safety threat to personnel when the drums are retrieved in some 20 years and reopened. So a retrofit program was devised to reopen the drums lacking the catalyst and/or vents to provide the drums with these devices.

The retrofit facility was constructed in the packaging and assay room of the Z-9 Building, as shown in Appendices E-8 and E-9. The punching jig, shown in Figure 10 and Appendix E-10, was used to punch two holes simultaneously in the drum lid and purge the cover gas with nitrogen. After the metal drum lid was removed, the polyethylene lid of the drum liner was pried open. A packet of catalyst was placed on top of the vermiculite and the drum was sealed with a vent device as previously described.

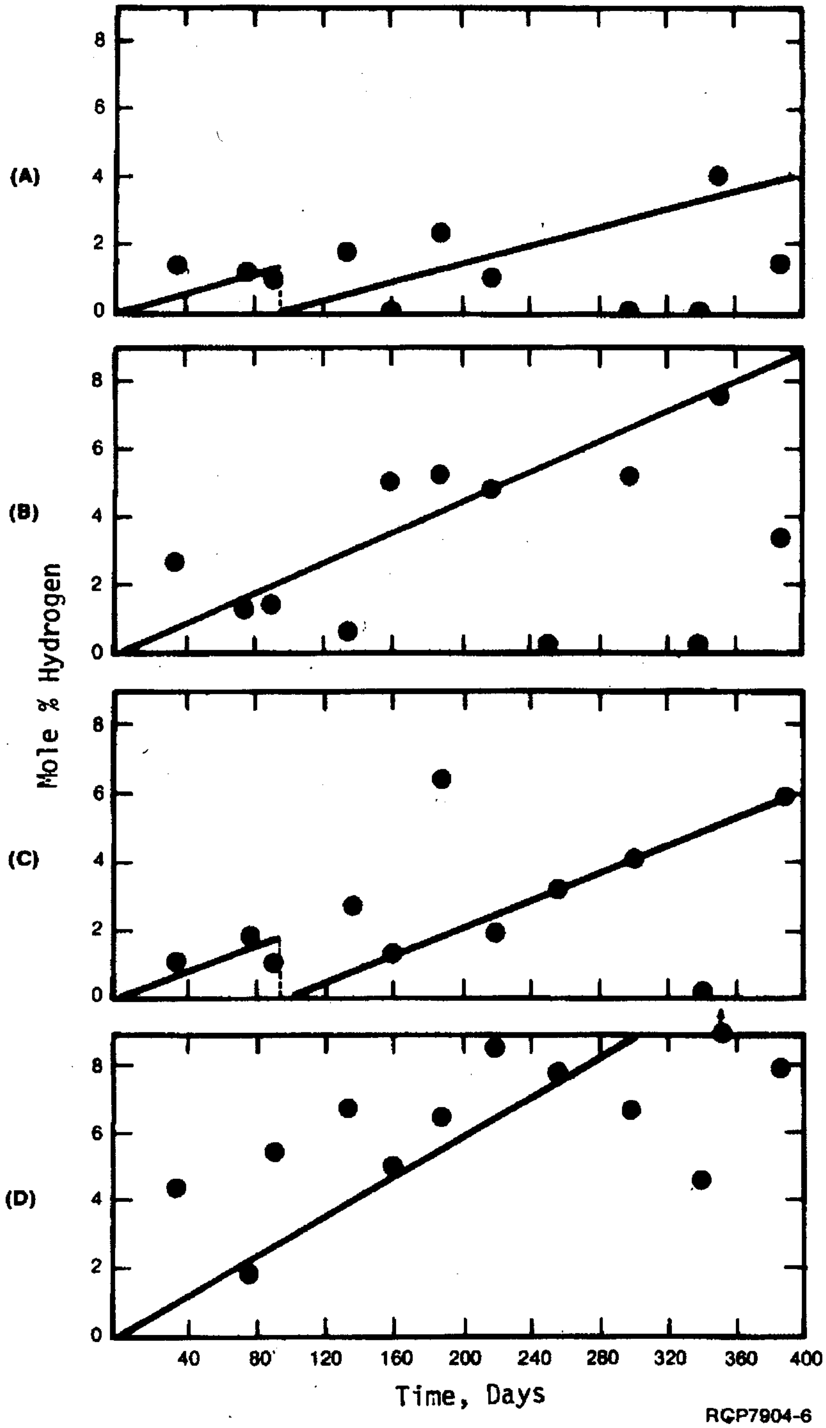

FIGURE 9. Rates of Hydrogen Generation in 216-Z-9 Soils.

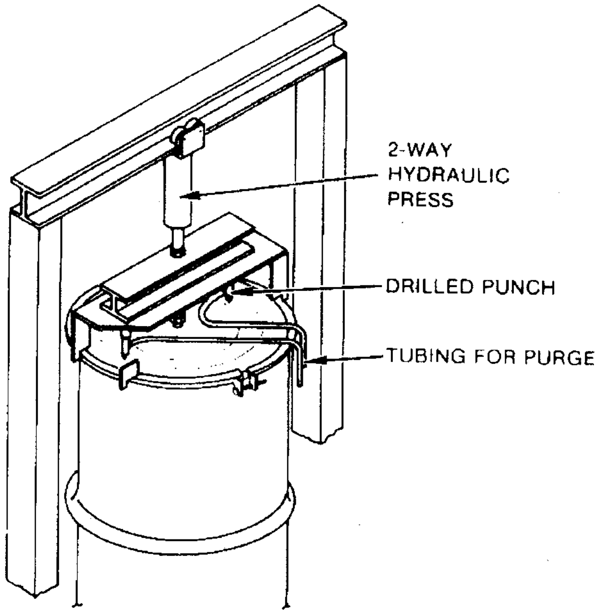

FIGURE 10. Punching Jig Used for Purging 216-Z-9 Soil Drums Prior to Retrofitting.

Drums were handled in a manner to provide the maximum safety for personnel in the unlikely event of a hydrogen explosion. A forklift with a heavy plastic shield and padded jaws loaded the drums onto the truck at the burial pad. After the drums were removed from the truck at Z-9, they were transfered to a dolly which was pushed inside the building and used to position the drum under the punching jig. The punching jig was inside a "greenhouse" to prevent contamination of the room in case contaminated material inside the drum spewed out. The hydraulically operated punch and nitrogen purge were operated from the adjoining room.

RETROSPECT ON PLUTONIUM MINING

The Z-9 mining program had a two-fold purpose. The first and most obvious purpose was simply the removal of 30 cm of plutonium bearing soil. The second purpose was to develop techniques and identify problems associated with the remotely operated removal of plutonium contaminated soil. The second purpose was not identified until after startup; thus many opportunities for planning experiments were lost and only observations could be made. This section highlights the accomplishments of this mining program.

The major observations on plutonium bearing soil removal are:

- It is feasible to remove plutonium bearing soil remotely and to any depth required.
- The mining equipment can be designed to operate reliably so the need for maintenance of the equipment in the radioactive environment can be kept to a minimum.
- The corrosive nature of the acidic soil does not cause marked deterioration of the equipment if standard precautions are taken to avoid this problem.
- Little dust is generated in the operation and does not interfere with the equipment operation.
- The nondestructive assay of the soil in the canisters can be done precisely.
- Radiolytic generation of hydrogen, oxygen, and other gases is a problem in the packaged soils but can be alleviated through the use of drum venting and hydrogen/oxygen recombination catalysts.
- The generation of carbon dioxide can occur by chemical means if carbonate bearing soil is not segregated from the moist acidic soil during mining.

- It is feasible to open drums which contain radiolytically produced gases and make them safe for retrieval in 20 years.
- The mining equipment has been used for the removal of radioactive soil from an enclosed trench, but its use should not be thought of as being limited to this one application. The mining equipment can be used in any environment requiring remote operation to protect personnel from radiation exposure.

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2. S. R. Bierman, Pulsed Neutron Source Measurements of the Z-9 Crib, HW-80913, Hanford Works, Richland, WA, 1964.
3. M. C. Jacobs and D. L. Uebelacker, Radioactive Liquid Wastes Discharged to Ground in the 200 Areas During 1970, ARH-2015, Part III, Atlantic Richfield Hanford Company, Richland, WA, April 1971.
4. A. E. Smith, Nuclear Reactivity Evaluations of 216-Z-9 Enclosed Trench, ARH-2915, Atlantic Richfield Hanford Company, Richland, WA, December 1973.
5. T. D. Reilly and J. L. Parker, A Guide to Gamma-Ray Assay for Nuclear Material Accountability. LA-5794-M, Los Alamos Scientific Laboratory, Los Alamos, NM, March 1975.
6. H. E. Smith, Evaluation of Nondestructive Assay System Performance on Z-9 Crib Soil Measurements, Phase 1, ARH-CD-811, Part 1, Atlantic Richfield Hanford Company, Richland, WA, October, 1976.
7. D. M. Rees and L. H. Taylor, Evaluation of Nondestructive Assay System Performance on Z-9 Crib Soil Measurements. Phase 1, ARH-CD-811 Part 2, Atlantic Richfield Hanford Company, Richland, WA, December, 1976.
8. A. L. Pajunen, Radiolytic Evolution of Gases from Z-9 Soils, RHO-CD-13, Rockwell Hanford Operations, Richland, WA, July 1977.
9. W. J. Cruice, Resistance of Soil Packages to Internal Gas Explosions, HRC-3808 (II), Hazards Research Corporation, Denville, NJ, June 1977.

APPENDIX A

Request for Approval to Place in Retrievable Storage - 216-Z-9 Mining Products

Blank

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
RICHLAND OPERATIONS OFFICE
P. O. BOX 550
RICHLAND, WASHINGTON 99352

Letter #8411
Action: DCB, w/att.
Reply Due: N/A
Info: GB MFR
DEK GBKuklinski
ATW C.File
CWM TES
EJK RBG
JWJ

All W/Att.

DEC 1 3 1976

Mr. G. Burton, Jr., President
Atlantic Richfield Hanford Company
Richland, Washington

Dear Mr. Burton:

REQUEST FOR APPROVAL TO PLACE IN RETRIEVABLE STORAGE - 216 Z-9 MINING PRODUCTS - PLUTONIUM, REQUEST NUMBER AR-304

Please refer to the subject request, to my letter to you on October 19, 1976, and Mr. C. W. Malody's reply dated November 4, 1976.

ARHCO's data on economics were helpful in reaching the following conclusions.

I am not returning the original AR-304 request as is usual but keeping it for reference. This letter is in reply and authorizes appropriate disposition of the Z-9 soil as given in Table I.

Please note that uncertainties of plutonium values, recovery costs, inflation, storage space availability and final dispositions of waste and marginal scrap result in these rounded limits. If uncertainties become sufficiently clarified that the limits must be changed, the contractor will be so advised.

Very truly yours,

O. J. Elgert, Director
Nuclear Fuel Cycle and
Production Division

NFCP:MJR

Enclosure:
Table I

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

49

TABLE I

AUTHORIZED DISPOSITION OF Z-9 CRIB SOIL

g Pu/Canister	Classification	Disposition in Drums
<20	Waste	Burial in 20-yr retrievable storage without expectation of Pu recovery.
20-50	Potentially recoverable	Segregate as a separate group in 20-yr retrievable storage. Pu recovery is probable but uncertain.
>50	Recoverable	Hold in Pu scrap storage for recovery if space permits. If burial is necessary for space or other reasons, segregate as a group for Pu recovery which is almost a certainty.

Drums are to contain material of only one classification as given above.

Maximum limits are up to 8 canisters per drum and up to 400g Pu (total) per drum.

ERDA Nuclear Materials Management is to be advised monthly of the increase and total material in the Recoverable classification.

All plutonium sent to burial as retrievable storage will be treated as Normal Operational Loss (NOL).

MJR:12/7/76

APPENDIX B

Z-9 Clamshell Operability Test Report

Blank

Atlantic Richfield Hanford Company

Date: August 15, 1975

To: M. L. Short

From: R. D. Wenner/N. J. Englund

Subject: Z-9 CLAMSHELL OPERABILITY TEST REPORT

During the week of August 4, through August 8, 1975, Product Handling and Special Services operated the Z-9 digger, TV equipment and bucket converyor on XYZ shift, to identify operational problems associated with the equipment.

The actual operating time for the week totaled 96 hours which was 87 percent of the total time (~ 110 hours) available.

Problems encountered during the test which contributed to a total of 13 percent downtime were:

1. The clamshell (raise-lower) hydraulic cylinder shaft was bent during operation. (cylinder was replaced)

2. The clamshell (open-close) hydraulic cylinder broke a seal. Cylinder was replaced. Cylinder was defective.

3. The hydraulic pump motor breaker overheated on two occasions. A new heater has been procured and will be installed.

4. The clamshell tilt hydraulic cylinder fitting loosened. Fitting was tightened.

5. The pin connecting the boom and center column worked itself partially out. Pin was welded in place.

Several other problems were identified during the test. Although they didn't significantly interrupt the operation they will be listed as required maintenance items.

1. Repair or replace limit switches on boom trolley, and calmshell elevator.

2. Install a brake on the trolley and conveyor motors.

Atlantic Richfield Hanford Company

M. L. Short
Page 2
August 15, 1975

3. Redesign of clam shovel raise and lower guide forks for more precise movement and to prevent damage to hydraulic cylinder rod and rod gland.

4. Weld and grind extension on clam shovel tilt mechanism.

5. Paint trolley boom white or yellow with black vertical reference lines at one foot intervals.

6. Put bubble level on boom and paint vertical index stripe on boom column joint when boom is horizontal.

7. Replace or repair shovel tilt hydraulic valve.

8. Rearrange hydraulic lines to prevent them from hanging-up on the boom.

9. Install hose protectors on hydraulic lines around digger.

10. Install bellows on all cylinders.

11. Install shroud over winch.

12. Drill hole in work gear for oil to drain through.

13. Install a boom radiant indicator system for use in circular grid point mining.

In an hour the miner completed 50 cycles on the average. That is, lower - bite - raise - trolley backward - rotate - trolley forward - tilt forward dump and tilt back.

Based on a total elapsed operating time of 94 hours the miner completed about 4,700 cycles.

In actual operation if the miner takes 1/4 ft^3 per bite it will take 7,200 cycles to dig the trench.

Based on the nature and amount of maintenance which was required, we conclude that the miner successfully completed it's endurance test.

RDW:NJE:sls

cc: NJ Englund (2)
AH Hinkson
GA Nicholson
RD Wenner (2)

APPENDIX C

Analysis of Radiolysis Hazard of Z-9 Mining

Blank

Atlantic Richfield Hanford Company

Date: April 27, 1976

To: R. B. Gelman

From: R. E. Felt, 942-2792

Subject: ANALYSIS OF RADIOLYSIS HAZARD OF Z-9 MINING

References:

(1) Tipton, C. R. Jr., Editor, Reactor Handbook Volume I Materials, Interscience Publisher, Inc., New York, 1960.

(2) Johnson, Everett R., The Radiation Induced Decomposition of Inorganic Molecular Ions, Gordon and Breech Science Publisher, New York, 1970.

(3) ARH-2915 (unclassified), December 1973, A. E. Smith, "Nuclear Reactivity Evaluations of 216-Z-9 Enclosed Trench".

The potential hydrogen buildup in Z-9 soil canisters and drums has been calculated as requested during the Z-9 startup review meeting. The results of these calculations are attached. Calculations are based on a gas generation value G of 1.6 molecules H_2 per 100 ev of energy absorbed by moisture in the soil (References 1 and 2).

Under maximum credible conditions of 400 grams plutonium per drum and 32 percent water content, (Reference 3) the storage drum will reach a combustible hydrogen level of 4 percent in 6.2 weeks. This should present no problem in controlling the storage time in the facility.

Calculations for the maximum credible conditions for a single canister of 200 g plutonium and 32 percent moisture show 0.36 weeks (2 days) is required to reach the combustible limit. However, the nominal conditions of <25 grams plutonium and 8 percent moisture requires 11.4 weeks to attain a combustible level. Thus, the potential of creating an unsafe condition is dependent upon 1) the credibility of the assumed maximum conditions, 2) estimation of a G value and 3) void volume. All of these parameters could be measured for verification once mining has started.

Until such time that a better estimate of the time required to attain a combustible level can be measured or calculated, I would recommend that administrative controls be placed on the length of storage permitted within the Z-9 storage area or 234-5 Building before burial.

I would be happy to answer any questions you might have on these calculations and estimated credible conditions.

REF:vmk

Att. (2)

cc w/att.: DC Bartholomew
G Burton, Jr.
RD Carter
MH Curtis
GL Hanson
DG Harlow
WM Harty, Sr.
CW Malody
BJ McMurray
GC Owens
JV Panesko
DA Reynolds
RC Roal
HP Shaw
RE Wenner
AT White
RA Zinsli

TABLE I

Z-9 SOIL DRUM

RADIOLYTIC GAS PRODUCTION CALCULATIONS

Basis:

1. 400 g plutonium per drum
2. Plutonium isotopic distribution - 94 percent ^{239}Pu, 6 percent ^{240}Pu
3. Moisture content of soil - 8 percent
4. 1900 parts americium-241 per million parts plutonium
5. Free volume of drums - 108 liters
6. G value of 1.6 molecules H_2/(100 ev energy)
7. Combustibility limit of H_2 in air is 4 percent (NFPA 325M)

Sample Dose Calculation:

	1 week	2 weeks
Grams decayed:		
^{239}Pu	2.05×10^{-4}	4.11×10^{-4}
^{240}Pu	4.89×10^{-5}	9.78×10^{-5}
^{241}Am	2.34×10^{-5}	4.68×10^{-5}
Disintegrations in:		
^{239}Pu	5.18×10^{17}	1.36×10^{18}
^{240}Pu	1.23×10^{17}	2.46×10^{17}
^{241}Am	5.85×10^{16}	1.17×10^{17}
Energy, MEV		
^{239}Pu	2.67×10^{18}	5.34×10^{18}
^{240}Pu	0.63×10^{18}	1.27×10^{18}
^{241}Am	0.31×10^{18}	0.63×10^{18}
Total MEV	3.61×10^{18}	7.24×10^{18}
Total (100 eV) increments	3.61×10^{22}	7.24×10^{22}
8 percent adsorbed by H_2O	2.89×10^{21}	5.79×10^{21}
Molecules H_2	4.62×10^{21}	9.27×10^{21}
Moles H_2	7.67×10^{-3}	1.54×10^{-2}
Volume H_2 at STP, liters	0.172	0.345
Pressure (total), atm.	1.002	1.003
Volume percent H_2	0.159	0.318
Percent of Combustible conc.	4	8

REF:vmk
4-27-76

TABLE II

NUMBER OF WEEKS TO ATTAIN COMBUSTIBLE GAS IN CANISTER
(Function of Moisture Content of Soil and Plutonium Content of Canister)

Basis:

1. Plutonium isotopic distribution 94 percent ^{239}Pu, 6 percent ^{240}Pu
2. 1900 ppm ^{241}Am per 10^6 parts plutonium
3. Void volume - 30 percent
4. Canister volume - 10.6 liters
5. G value of 1.6 molecules H_2/(100 ev energy)
6. Combustibility limit of H_2 in air is 4 percent (NFPA 325M)

Moisture content of Soil ↓	25	50	100	200	Grams plutonium → Canister
8 percent	11.4 wks	5.7 wks	2.85 wks	1.42 wks	
16 percent	5.7 wks	2.85 wks	1.42 wks	0.71 wks	
32 percent	2.85 wks	1.42 wks	0.71 wks	0.36 wks	

APPENDIX D

Catalytic Recombination of Hydrogen and Oxygen

Blank

nternal Letter

Rockwell International

Date: January 31, 1978

TO: (Name, Organization, Internal Address)
L. H. Rodgers

FROM: (Name, Organization, Internal Address, Phone)
J. O. Henrie
Research and Engineering

2-1448

Subject: Catalytic Recombination of Hydrogen and Oxygen

Hydrogen/oxygen recombiners have been built by Atomics International and successfully operated for many years. They were designed to allow hydrogen and oxygen molecules to diffuse to the catalyst and the water vapor product to diffuse away from the catalyst. The amount of catalyst used was about three cubic inches per liter of hydrogen and oxygen gasses per hour. This included an overdesign allowance for unknowns such as long term catalyst degradation. Operation was at ambient temperatures (70°F to 100°F), in a water saturated atmosphered, and at pressures from about 1/5 to 1/2 atmosphere. Even though a catalyst heater was installed, it was found to be not required. One cubic inch of catalyst contains about 400 catalyst pellets (1/8-inch diameter by 1/8-inch long cylinders). Therefore, one pellet would recombine at least .02 liters of hydrogen and oxygen per day if the diffusion path was reasonably clear. It is my understanding that hydrogen/oxygen generation rate in the barrels of contaminated soil you are storing are in the order of .06 liter/day (based on hydrogen buildup to eight percent in six months). If an additional factor of 10 is assumed to take care of any uncertainties, about 30 pellets should be packaged in each drum (see attached sheet).

Excessive use of plastic materials in drums containing radioactive materials should be avoided since their decomposition liberates hydrogen but no oxygen. The catalytic recombination would use up the oxygen in the air, then allow a buildup of hydrogen. There would be no storage danger since the oxygen would have been depleted, but in a severe situation, opening the drum would produce a mixture of hydrogen and air. This would necessitate a procedure to assure slow opening and diffusion of the excess hydrogen.

It is recommended that Engelhard Catalyst "D" (Platinum and paladium on alumina) be added to each drum of contaminated soil. About two pounds of this material was given to P. E. Ray.

L. H. Rodgers
Page 2
January 31, 1978

The cover gas from a number of existing drums should be sampled and analyzed for hydrogen to assist in determining the maximum hydrogen evolution rate. A number of drums containing the soil and catalyst should be sealed and the cover gas (air) sampled periodically to assure that no measurable amount of hydrogen is building up.

J. O. Henrie
Research and Engineering

JOH/mls

cc:
J. L. Deichman
R. J. Gimera
J. V. Hurley
E. J. Kosiancic
P. E. Ray
M. D. Swett
LB (2)

APPENDIX E

Drawings

[signature] 1/31/77

Use of Engelhard Catalysts

- Recombination rate (ℓ/min) Vs Catalyst Volume (in^3).

Forced Circulation recombiner, 8 ℓ/min, 36 in^3 = 13 ℓ/hr/in^3

Diffusion Type, 1/3 ℓ/min, 70 in^3 = .286 ℓ/hr/in^3

" " 1/60 ℓ/min, 3 in^3 = .33 ℓ/hr/in^3

Use: 8 ℓ/day per 1 in^3 of catalyst.

- Catalyst Pellets per Cubic Inch

1 in^3 catalyst contains .6 in^3 of pellets.

Pellet Volume = $\frac{\pi}{4} \times (1/8)^2 \times 1/8 = 1.53 \times 10^{-3}$ in^3/pellet.

1 in^3 of catalyst contains $\frac{.6 \ in^3}{1.53 \times 10^{-3} \ in^3/pellet}$ = 392 Pellets

- Recombination rate Per Pellet

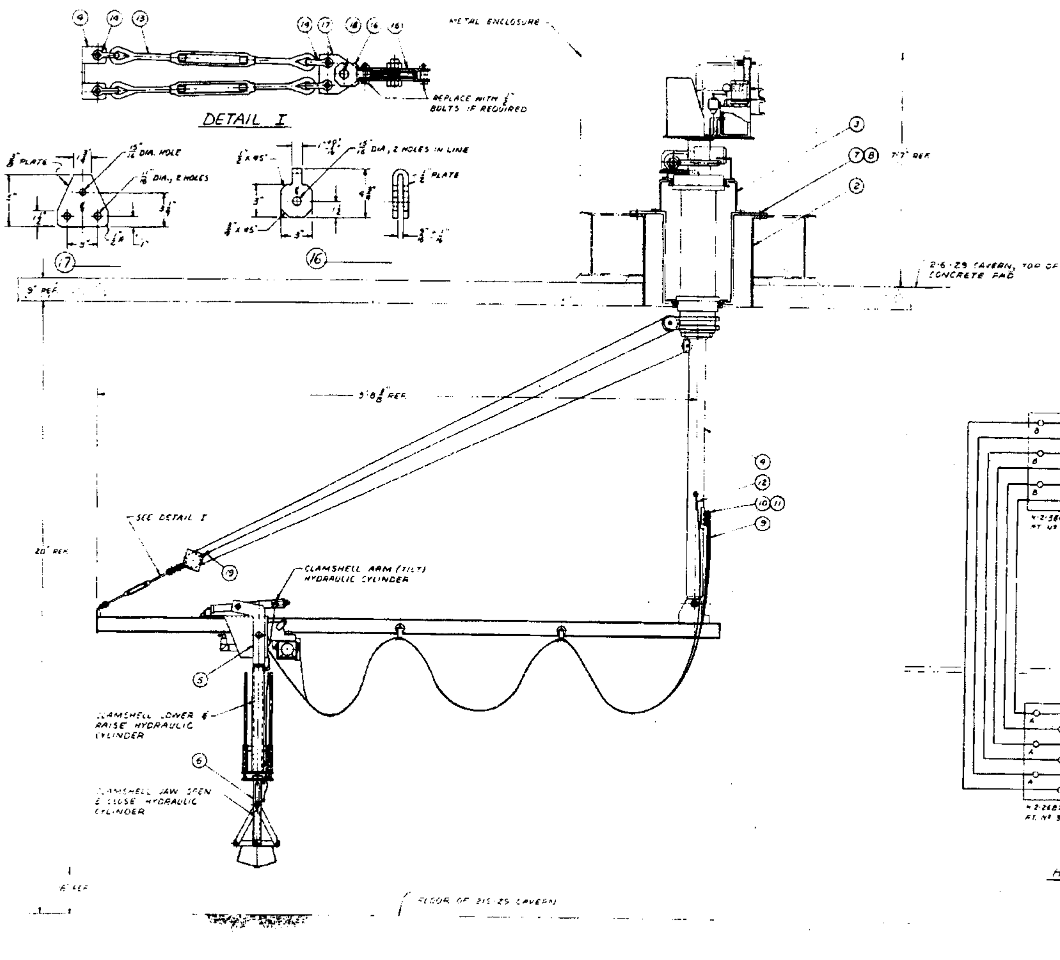
$\frac{8 \ \ell/day}{392 \ Pellets}$ = .02 ℓ/day/pellet.

66

QTY	PT NO.	DESCRIPTION	MATERIAL
☒	1	ARRANGEMENT	
2	2	RISER INSTALLATION	H-2-26872 & H-2-37922
1	3	UPPER SHAFT & EQUIP ASSEMBLY	H-2-38691
1	4	LOWER SHAFT ASSEMBLY	H-2-26875
1	5	TROLLEY ASSEMBLY	H-2-26876
1	6	CLAMSHELL BUCKET ASSEMBLY	H-2-26877
8	7	HEX HD. BOLT, ¾-10UNC-2A, 4" LONG	ASTM-A307 GR A C STL.
8	8	HEX NUT, ¾-10UNC-2B	ASTM-A307 GR A C STL.
AR	9	HYDRAULIC HOSE, MEDIUM PRESSURE, ¼" I.D., "PARKER HANNIFIN" #201Z0-4-5 WITH ¼-MPT FTG'S #201-5	
6	10	ELBOW, ¼"-MPT TO ¼"-FPT	ASTM-A234 GR. WPA C STL.
6	11	BULKHEAD CONN. FEMALE, "PARKER HANNIFIN" #6 WGBTX-S16	
AR	12	ELEC. CONTROL CABLE	H-2-26879 PT. # 18
2	13	TURNBUCKLE, ¾" DIA., 9" TAKE UP, EYE & EYE	"McMASTER CARR" 2997T62
4	14	SHACKLE, ½" BOW, ⅝" DIA. PIN	"McMASTER CARR" 3558T49
1	15	TACKLE BLOCK, SHEAVE 6" x 1" x ¾"	"McMASTER CARR" 3105K
1	16	TACKLE BLOCK, LINK PLATE	ASTM-A36 C STL.
1	17	TURNBUCKLE, LINK PLATE	ASTM-A36 C STL.
1	18	HEX HD BOLT, ⅝"-9UNC-2A, 2¼" LG., W/NUT	ASTM-A307 GR A C STL.
1	19	CLAMP, ⅜ WIRE ROPE	"McMASTER CARR" 3471T15

GENERAL NOTES:

1. ALL PARTS SHALL BE AS SPECIFIED OR APPROVED EQUAL.
2. TOLERANCES: UNLESS OTHERWISE NOTED SHALL BE ± ⅛".
3. AFTER APRIL 6, 1976 ALL FUTURE FABRICATION & MATERIAL SPECIFICATION SHALL BE IN ACCORDANCE WITH QUALITY ASSURANCE LEVEL III.



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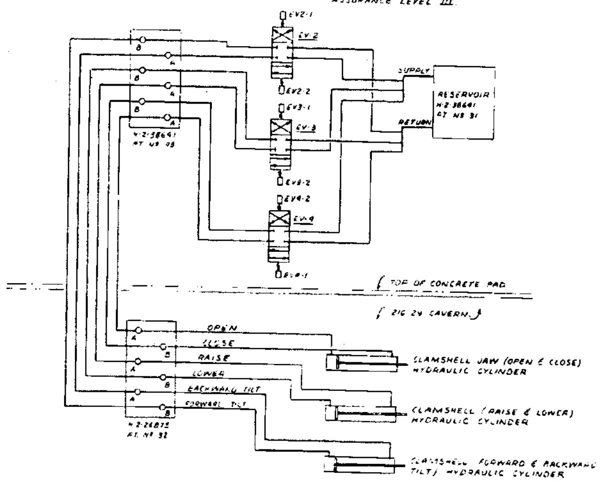
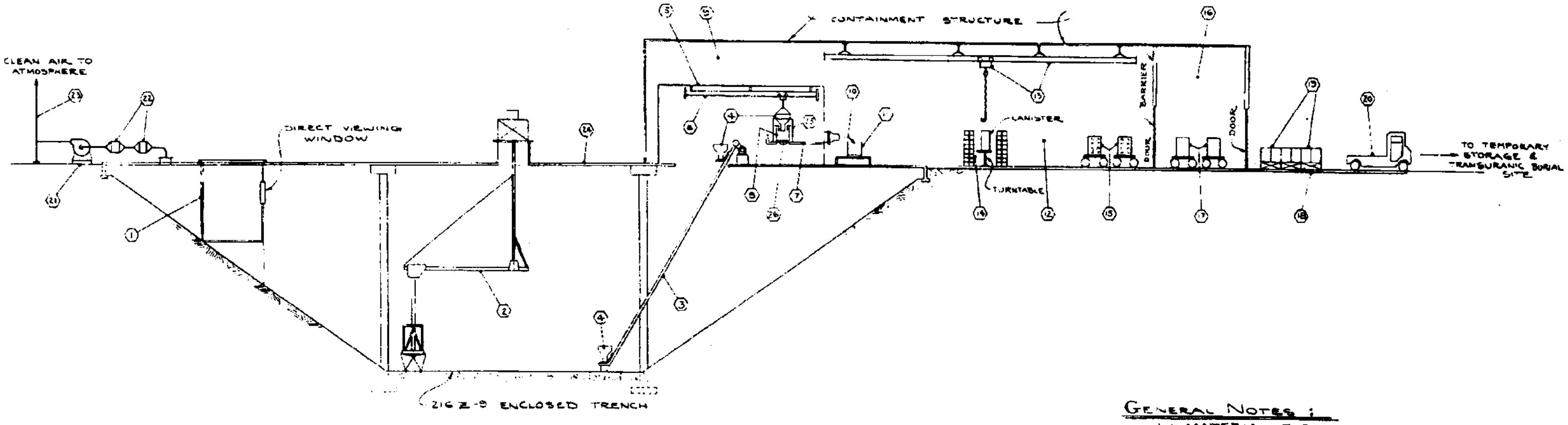


HYDRAULIC CONTROL SCHEMATIC

AS BUILT - RECORD DWG.
NOT FOR FABRICATION

H-2-26873
RCP7903-58



EQUIPMENT LEGEND

1. CUBICLE FOR MINING OPERATOR. WILL CONTAIN MINING EQUIPMENT CONTROLS, TELEVISION SCREEN & WINDOW FOR VIEWING MINING OPERATION.
2. CLAM-SHELL TYPE MINING EQUIPMENT WILL BE SUPPORTED FROM ENCLOSED TRENCH ROOF. THE HORIZ BOOM WILL BE CAPABLE OF 360° ROTATION MINIMUM.
3. INCLINED ELEVATOR.
4. SOIL BUCKETS, SHOWN IN (3) POSITIONS. TWO REQUIRED. PROVIDE WITH SUITABLE GATE IN BOTTOM OUTLET SPOUT & SCREEN TO SEPARATE OVER-SIZE SOIL
5. SOIL PACKAGING GLOVE BOX
6. OVERHEAD MONO-RAIL, ELECTRICALLY OPERATED TROLLEY & CHAIN HOIST FOR CONVEYING SOIL BUCKET BETWEEN TOP OF ELEVATOR & BAGGING OPERATION.
7. WORK BAFFLE WITHIN GLOVE BOX
8. PLASTIC BAG FOR FIRST SOIL PACKAGING
9. WORK ROOM FOR GLOVE BOX OPERATORS.
10. LOAD OUT INTO HEAT SEALED PLASTIC BAG FOR FIRST SOIL CONTAINMENT. OUTSIDE OF SECOND BAG TO BE CONTAMINATION FREE. HEAT SEALER NOT SHOWN
11. 3-GAL, CARBON STL CANISTERS WITH POSITIVE LOCK COVER FOR SECOND SOIL CONTAINMENT.
12. WORK ROOM FOR ASSAYING, SORTING & PLACING METAL CANISTERS INTO DRUMS
13. OVERHEAD MONO-RAIL ELECTRICALLY OPERATED TROLLEY & CHAIN HOIST
14. PLUTONIUM DETECTOR FOR MEASURING PLUTONIUM CONTENT OF 3-GAL METAL CANISTERS. DETECTOR TURN TABLE TO BE EQUIPED WITH SCALE FOR WEIGHING CANISTERS.
15. 55-GAL DRUMS ON DOLLYS IN FILLING POSITION. SEVERAL DOLLYS REQUIRED. SORT WASTE FROM SCRAP CANISTERS AT THIS POINT
16. DRUM STORAGE ROOM
17. 55-GAL DRUMS IN DRUM STORAGE ROOM, FILLED DRUMS ON DOLLYS.
18. OUTSIDE SHIPPING PAD
19. FILLED 55-GAL DRUMS AWAITING SHIPMENT TO TEMPORARY STORAGE OR TRANSURANIC BURIAL SITE. DRUMS ON 4 x 4' PALLETS, (4) DRUMS PER PALLET. PROVIDE EQUIPMENT FOR TRANSFERRING LOADED DRUMS FROM DOLLYS TO PALLETS.
20. TRUCK FOR CONVEYING PALLETIZED SCRAP DRUMS TO TEMPORARY STORAGE OR NON-PALLETIZED WASTE DRUMS TO TRANSURANIC BURIAL SITE. PROVIDE TRUCK LOADING EQUIPMENT. APPROXIMATE WEIGHT OF EACH 4-DRUM PALLET WILL BE ABOUT 7000 LBS. THE TRUCK IS NOT A PROJECT ITEM
21. BLOWER FOR MAINTAINING TRENCH VACUUM (RANGE 0.3" TO 0.5" WATER) & FOR PROVIDING ONCE-THRU CONTAINMENT STRUCTURE VENTILATION.
22. HEPA FILTERS PROVIDE (2) IN SERIES, BOTH UPSTREAM OF BLOWER
23. BLOWER DISCHARGE STACK
24. EXISTING 5 INCH THICK CONCRETE 216-Z-9 ROOF
25. BAG FILLING & SOIL BUCKET SUPPORT STAND
26. BAG SEALING TURN TABLE

GENERAL NOTES:

1 - MATERIAL FLOW
  - (a) ESTIMATED TOTAL MINING REQUIRED 30 x 60' TRENCH AREA x 1' DEEP = 1800 CU. FT.
  - (b) AVERAGE MINING RATE = 7.7 CU. FT/8HR. SHIFT
  - (c) AVERAGE CANISTER FLOW = 15.2 CANISTERS/8 HR SHIFT
  - (d) MINIMUM DRUM FLOW = 2½ DRUMS/8 HR. SHIFT
  - (e) CANISTER CAPACITY = 3 GALLONS SOIL

2 - MAXIMUM DRUM CONTAINMENT = 8 CANISTERS BUT NOT TO EXCEED 300 GRAMS OF PLUTONIUM PER DRUM.

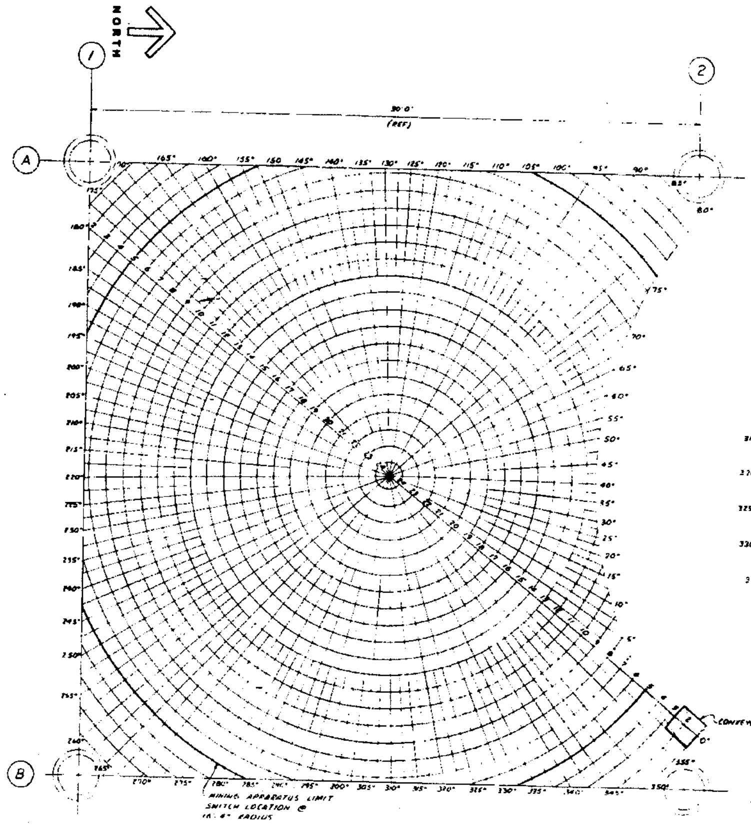
3 - TRENCH AIR PRESSURE = 0.3" TO 0.5 WATER VACUUM

4 — PLUTONIUM DETECTOR & DRUM FILLING & HANDLING TO BE LOCATED OFF OF 216-Z-9 ROOF.

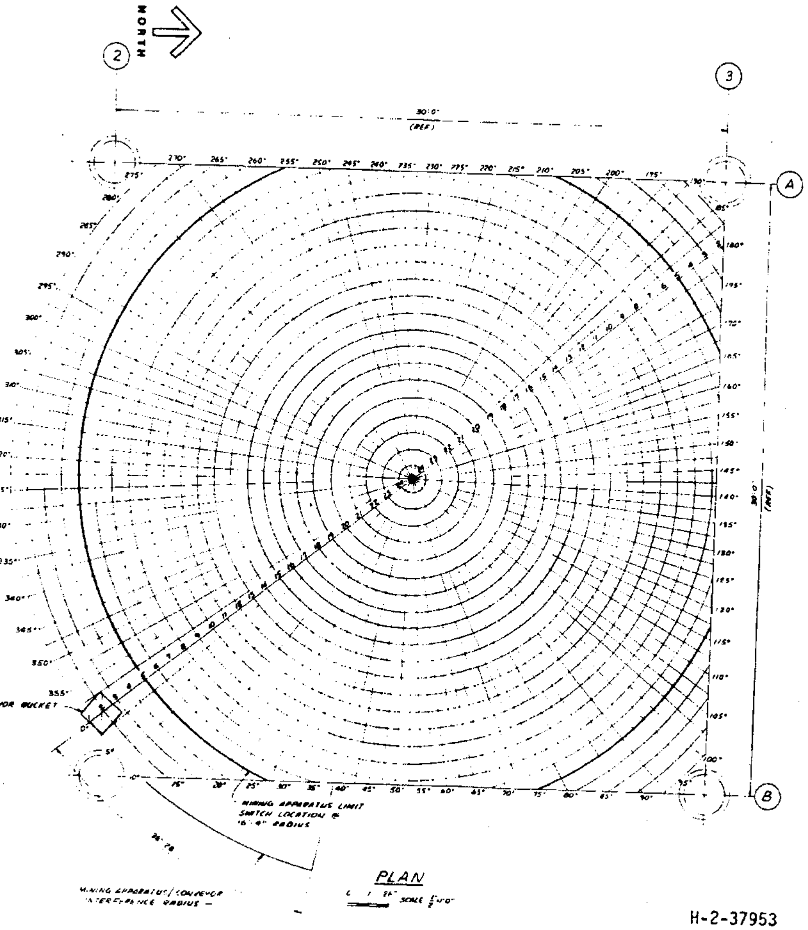
5 FOR AIR-FLOW PATTERN SEE SK-2-22321

SK-2-22319

RCP7903-56



PLAN



PLAN

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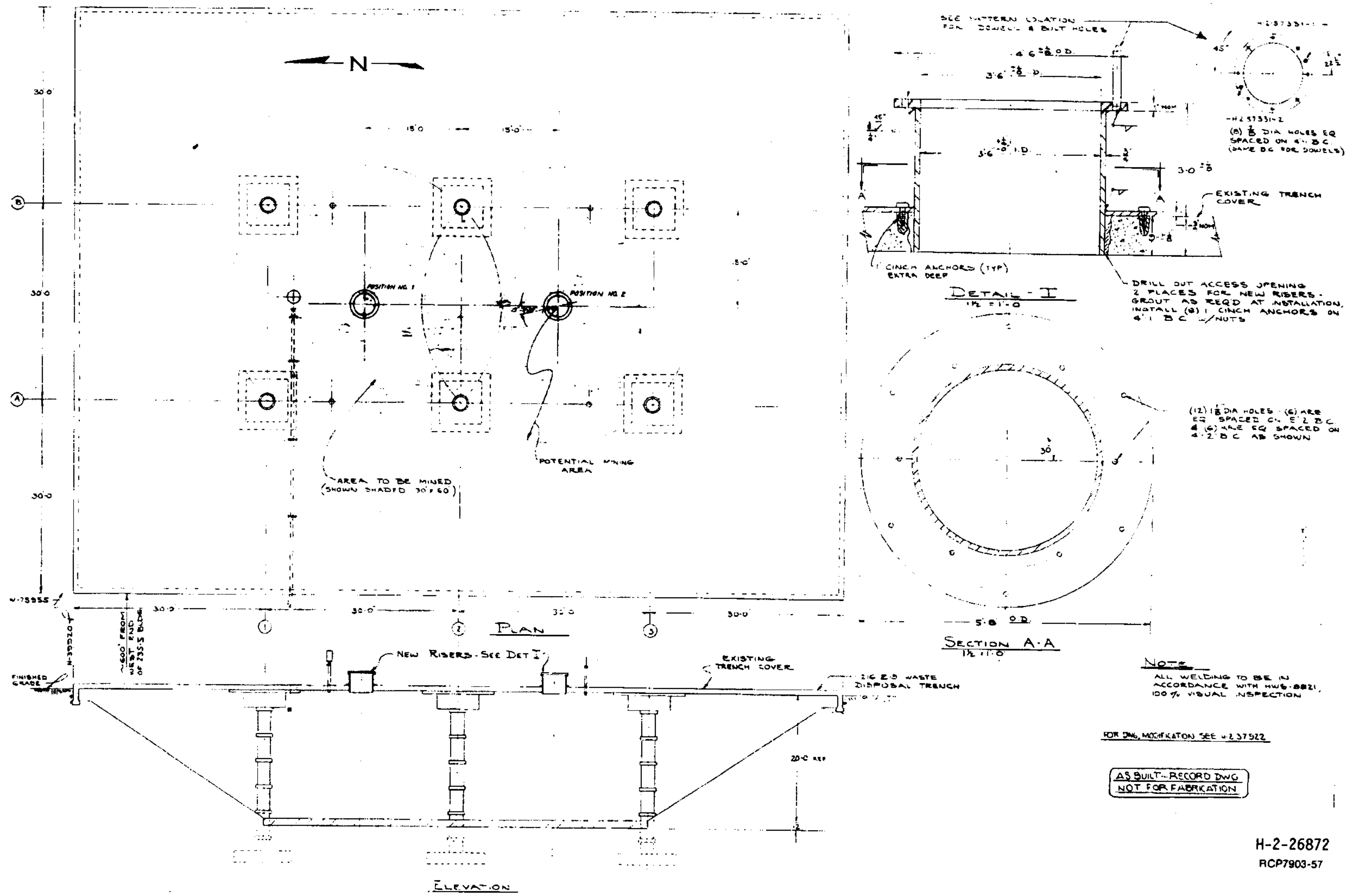

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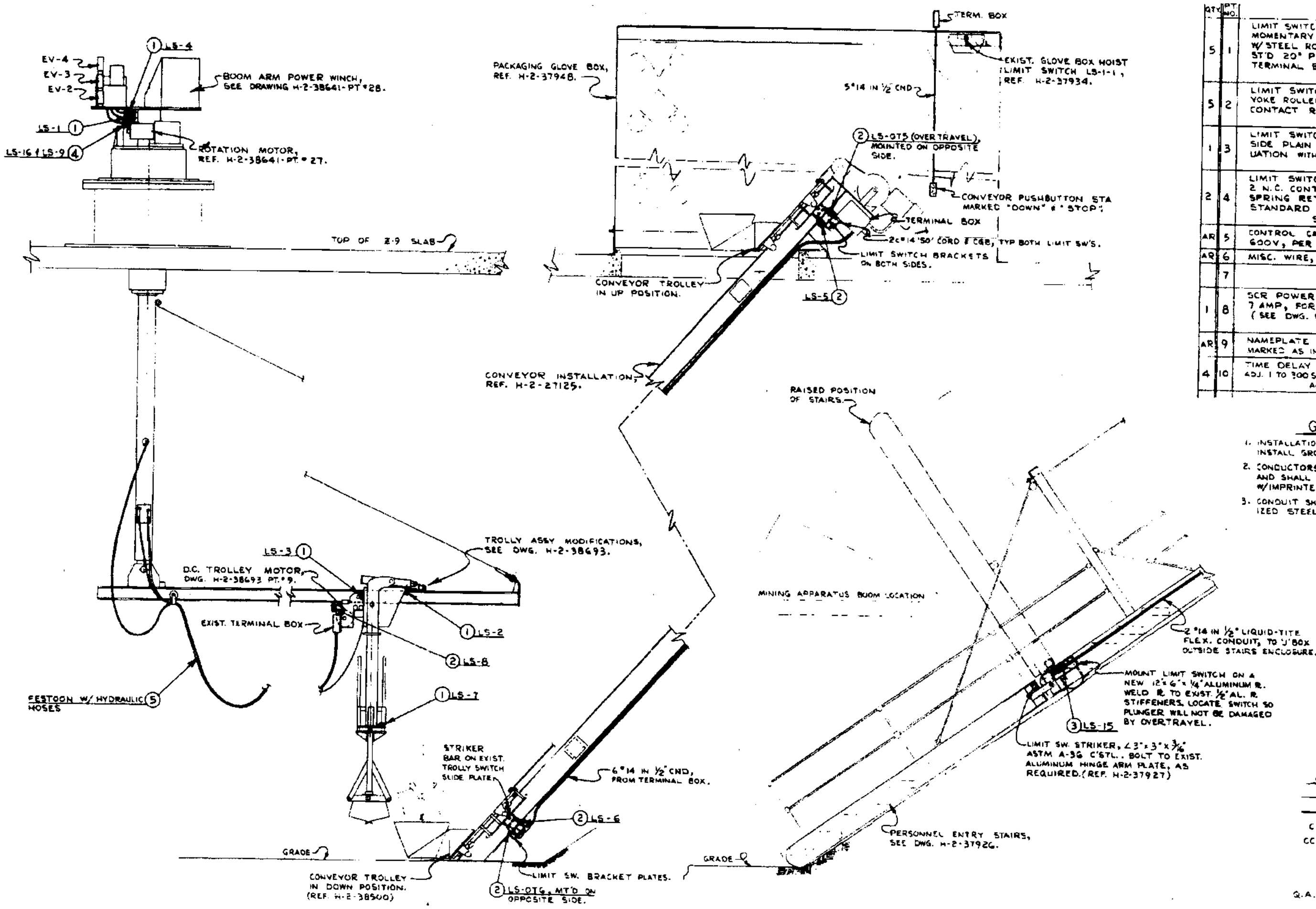


QTY	PT. NO.	DESCRIPTION
5	1	LIMIT SWITCH - 120 VAC, 10 AMP, 1 N.O. - 1 N.C. MOMENTARY CONTACTS, ROLLER LEVER ARM W/ STEEL ROLLER ROTARY MOTION ACTUATED, ST'D 20° PRETRAVEL, PLUG-IN TYPE WITH TERMINAL BLOCK. MICROSWITCH # 201LS1-18PA1
5	2	LIMIT SWITCH - SAME AS ABOVE, EXCEPT YOKE ROLLER (FORKED) LEVER ARM MAINTAINED CONTACT ROTARY MOTION ACTUATION. MICROSWITCH # 206LS1-18PA1
1	3	LIMIT SWITCH - SAME AS PART # 1, EXCEPT SIDE PLAIN PLUNGER IN-LINE MOTION ACTUATION WITH ¼" MIN. PLUNGER OVERTRAVEL. MICROSWITCH # 204LS1-18PA1
2	4	LIMIT SWITCH - 120 VAC, 10A, 2 POLE 2 N.O. - 2 N.C. CONTACTS, TOP ROLLER PLUNGER SPRING RETURN ACTUATOR, HEAVY DUTY, STANDARD PLUG-IN BOX. SQUARE 'D', CLASS 9007 TYPE B62D
AR	5	CONTROL CABLE - 14c # 14 AWG, COPPER, 600V, PER HANFORD STD. SPEC. HPS-314-E
AR	6	MISC. WIRE, CONDUIT, BOXES AND FITTINGS.
	7	
1	8	SCR POWER CONTROLLER - 115VAC, 1 Ø, 60HZ, 7 AMP, FOR ½ HP D.C. TROLLY MOTOR. (SEE DWG. H-2-26879 SHT. 2, PT. # 34)
AR	9	NAMEPLATE - PER HANFORD STD. E-14-15, MARKED AS INDICATED
4	10	TIME DELAY RELAY - 120VAC 60HZ COIL, 20A, DPDT, ADJ. 1 TO 300 SEC. DELAY AFTER ENERGIZATION. AGASTAT # 7012 AK

GENERAL NOTES

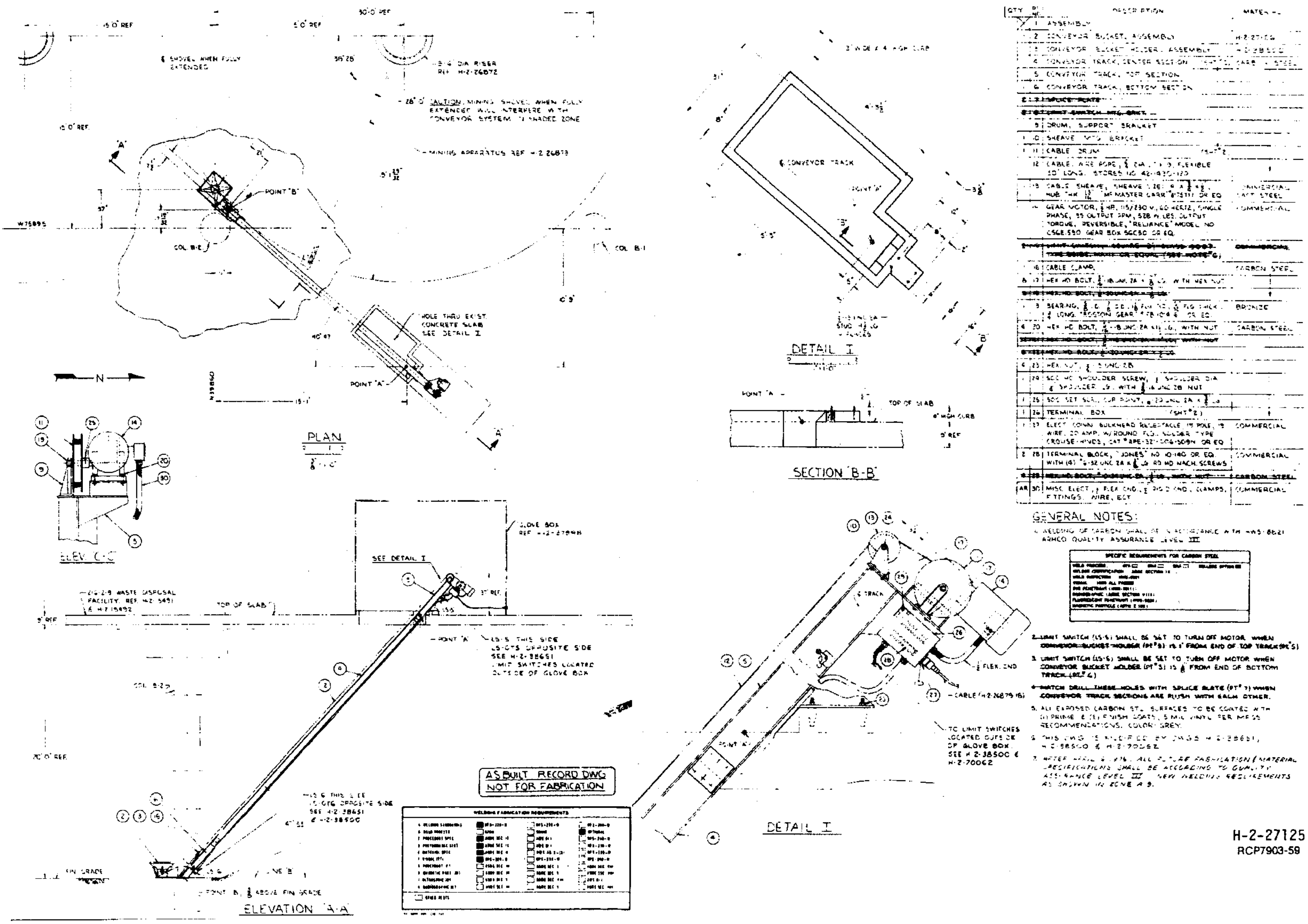
1. INSTALLATION SHALL BE PER THE 1975 N.E.C.. INSTALL GROUNDING PER HANFORD STD. E-12-1.
2. CONDUCTORS SHALL BE 'THW' OR 'THWN', COPPER AND SHALL BE IDENTIFIED AT ALL TERMINATIONS W/IMPRINTED TUBLAR PLASTIC WIRE MARKERS.
3. CONDUIT SHALL BE RIGID, HEAVY WALL, GALVANIZED STEEL, UNLESS OTHERWISE SPECIFIED.

LEGEND

———	EXISTING
▬▬▬	MODIFICATION
CW -	CLOCKWISE
CCW -	COUNTER CLOCKWISE

Q.A. LEVEL III

H-2-38651
RCP7903-64



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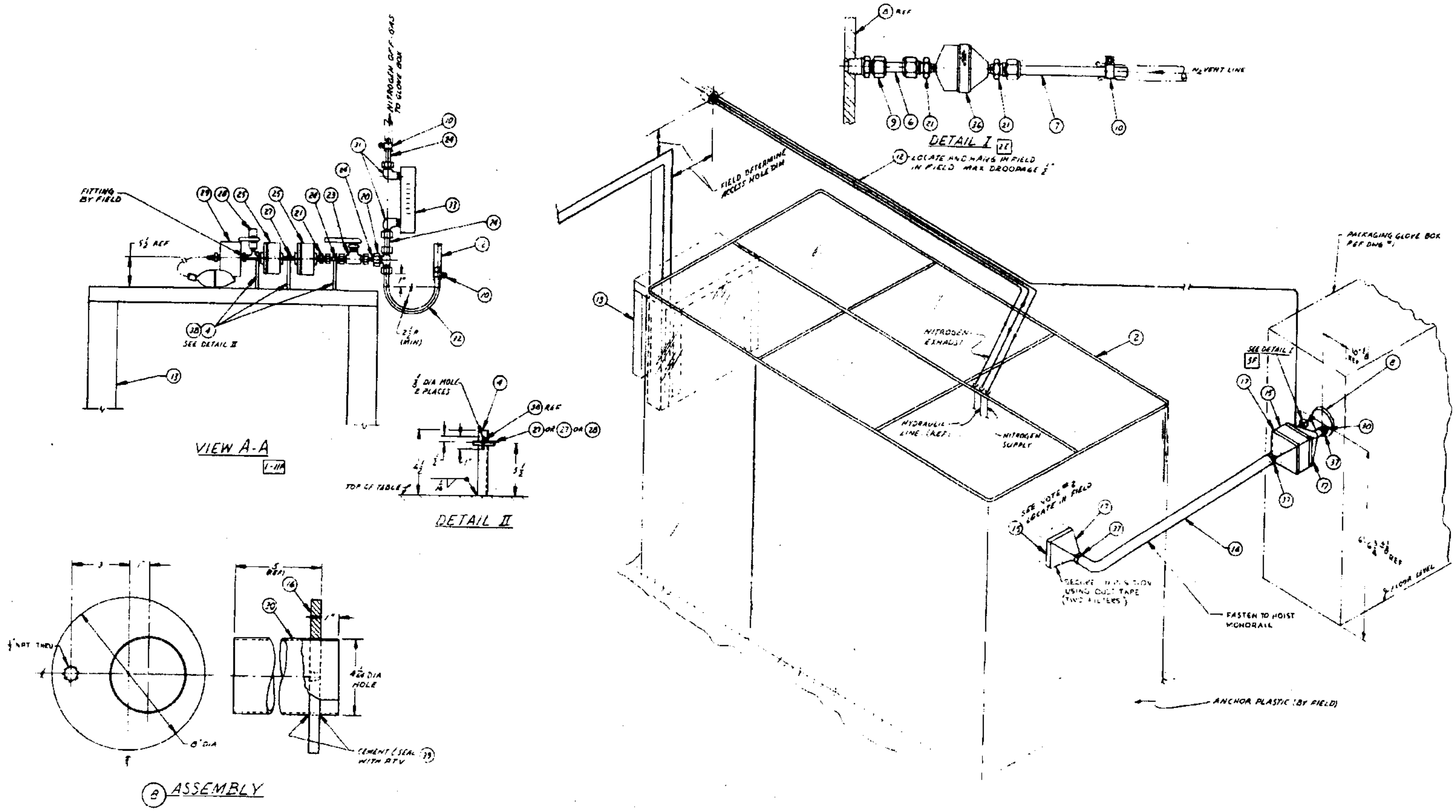
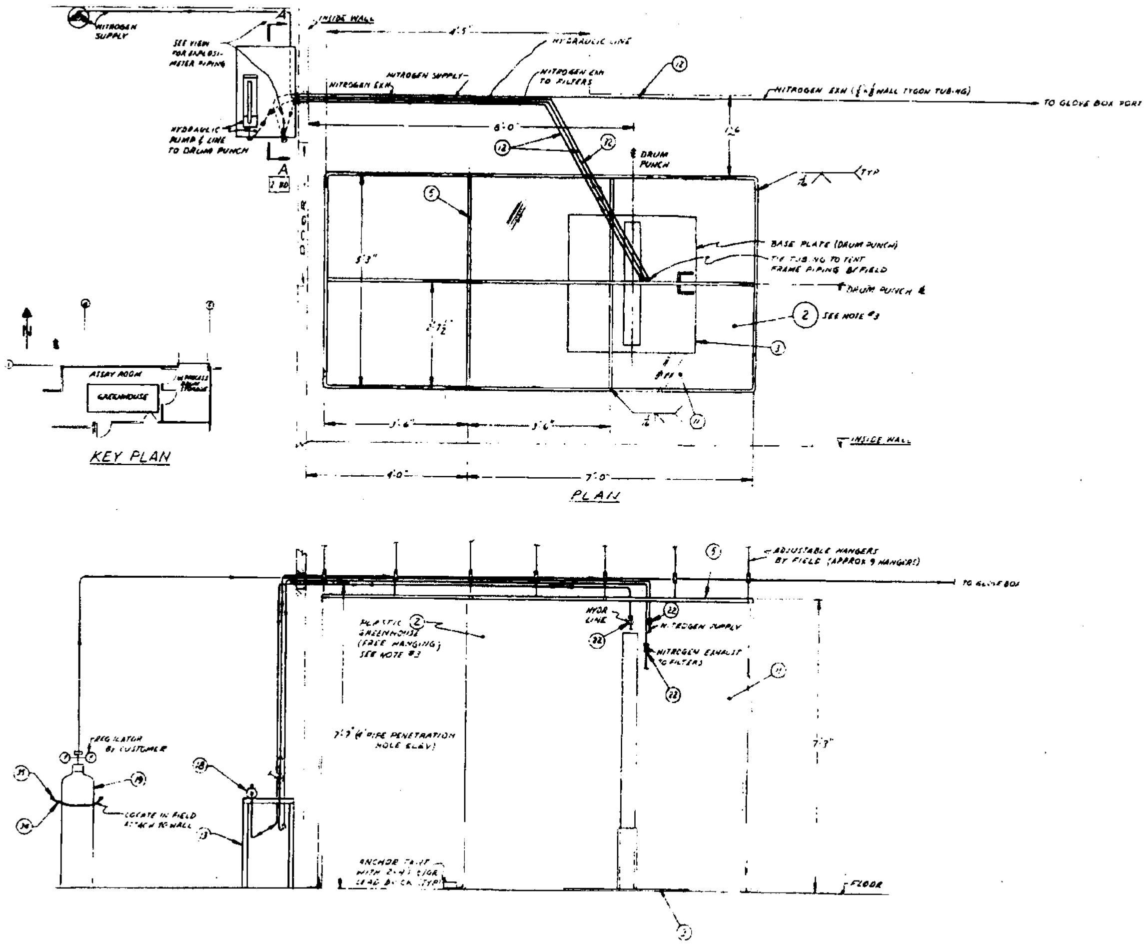


FOR ML, GENERAL NOTES & TOLERANCES SEE SHEET #1

QUALITY ASSURANCE LEVEL II

RCP7903-62

H-2-28682 Sht 2.



ELEVATION

(1) ARRANGEMENT

CA	QTY	QTY	PART NO	DESCRIPTION	MATERIAL
			1	ARRANGEMENT	
			2	GREENHOUSE ASSY	
		1	3	ASSEMBLY DRUM PUNCH	H-2-28588/1
		AR	4	ANGLE 1×1×⅛	ASTM A36 CS
	AR		5	PIPE FRAME ½ SCH 40	ASTM A53 TYPE F GR A SEE NOTE #7
		1	6	TUBING ⅜OD×.035 WALL×7.80 LG	ASTM A269 TYPE 304L SST
		1	7	TUBING ⅜OD×.035 WALL×6.80 LG	ASTM A269 TYPE 304L SST
		1	8	ADAPTER PLATE ASSEMBLY	
		1	9	MALE CONNECTOR ⅜T×¼P	SWAGELOK #SS-810-1-8
		3	10	CLAMP, WORM DRIVE HOSE	McMASTER-CARR #5416K32
	AR		11	PLASTIC COVER	FURN BY CUSTOMER
		AR	12	TUBING ⅜OD×⅛WALL	TYGON
		1	13	TABLE 30 LG×15 WIDE×30 H	FURN BY CUST
		AR	14	4" FLEX PIPING	FURN BY CUST
		2	15	FILTER-50 CFM 8×8×5⅞	TYPE 2 HEPA
	1		16	ADAPTER PLATE ¼ THK	PLEXIGLASS
		3	17	TRANSITION SEE NOTE 8	FURNISHED BY CUST
		1	18	HYDRAULIC PUMP	PART OF PUNCH PRESS FURN BY CUST
		1	19	GAS BOTTLE 224 CU FT	NITROGEN 99.5%
		1	20	UNION TEE ½	SWAGELOK SS-810-3
		6	21	MALE CONNECTOR ½T×¼P	SWAGELOK SS-810-1-4
		3	22	UNION ½OD TUBE	SWAGELOK SS-810-6
		1	23	VALVE-BALL TYPE ½"	WHITEY SS-45S8
		3	24	TUBE ½OD×.035 WALL×2½ LG	ASTM A269 TYPE 304L SST
		2	25	FILTER ¼ IN THE LINE TYPE B	MSA NO. DB-92878 SST
		1	27	NIPPLE ¼ SCH 40S×2¼ NPT ENDS	ASTM A312 TYPE 304L SST
		1	28	VALVE ¼ BALL TYPE	WHITEY SS-43F4
		1	29	EXPLOSIMETER MODEL 3	MSA #43351
	1		30	SLEEVE, 16 GA 4"OD×6"LG	PLEXIGLASS
		2	31	MALE ELBOW ½T×¼P	SWAGELOK #SS-810-2-8
		AR	32	TUBE ½OD×.035 WALL	ASTM A269 TYPE 304
		1	33	FLOWMETER 5-70 CFH	BROOK R-1LM-25-5F
		AR	34	CHAIN #4 STRAIGHT LINK	CS
		2	35	BOLT ANCHOR ¼ SHANK	COMMERCIAL
		1	36	AIR SAMPLE HOLDER CLOSED	47 MM ALU B&L INC
		3	37	CLAMP, WORM DRIVE HOSE	McMASTER-CARR #5416K26
		3	38	UBOLT, ¼×1" WIDE/NUTS	COMMERCIAL STEEL
		AR	39	CEMENT	RTV

GENERAL NOTES

1. BARREL VENT LINES (PART 12) SHALL BE TESTED TO 5 PSI. PLUG OPENING AT GLOVE BOX AND CONNECT PIERCERS TOGETHER WITH ⅜ INCH TYGON TUBING. TEST FOR 10 MINUTES, MAX PRESSURE LOSS 0.1 PSI.
2. VENTILATION BALANCE SHALL ADJUST THE AIR FLOW TO ASSURE AN INWARD FLOW OF AIR AS REQUIRED BY RHP 76-8-1.
3. THE GREEN HOUSE SHALL BE INSTALLED PER ARH-MA-120 SOP 201.6.
4. CONSTANT AIR MONITORS SHALL BE INSTALLED AS REQUIRED BY RHP 2-72-1-1
5. NITROGEN TK. PT (19) SHALL BE CHAINED SECURELY TO THE WALL. REGULATORS SHALL BE PROVIDED AS REQUIRED TO REDUCE THE SUPPLY PRESSURE TO FIVE (5) PSIG.
6. EXHAUST LINE SHALL BE INSPECTED AT SYSTEM PRESSURE WITH SYSTEM FLUIDS TO ASSURE THERE ARE NO LEAKS OR COLLAPSED PORTIONS IN THE LINE.
7. MANUFACTURE GREEN HOUSE FRAME PART #5 BY BENDING ALL CORNERS AND WELDING ALL INTERSECTIONS
8. SECURE TRANSITION PART #17 TO GREEN HOUSE WITH WATERPROOF SEALING TAPE
9.

WELDING REQUIREMENTS

AWS 1005?

OTHER SCOPE VT 3 FINAL PASS

QUALITY ASSURANCE LEVEL II

H-2-28682 Sht 1.

RCP7903-61

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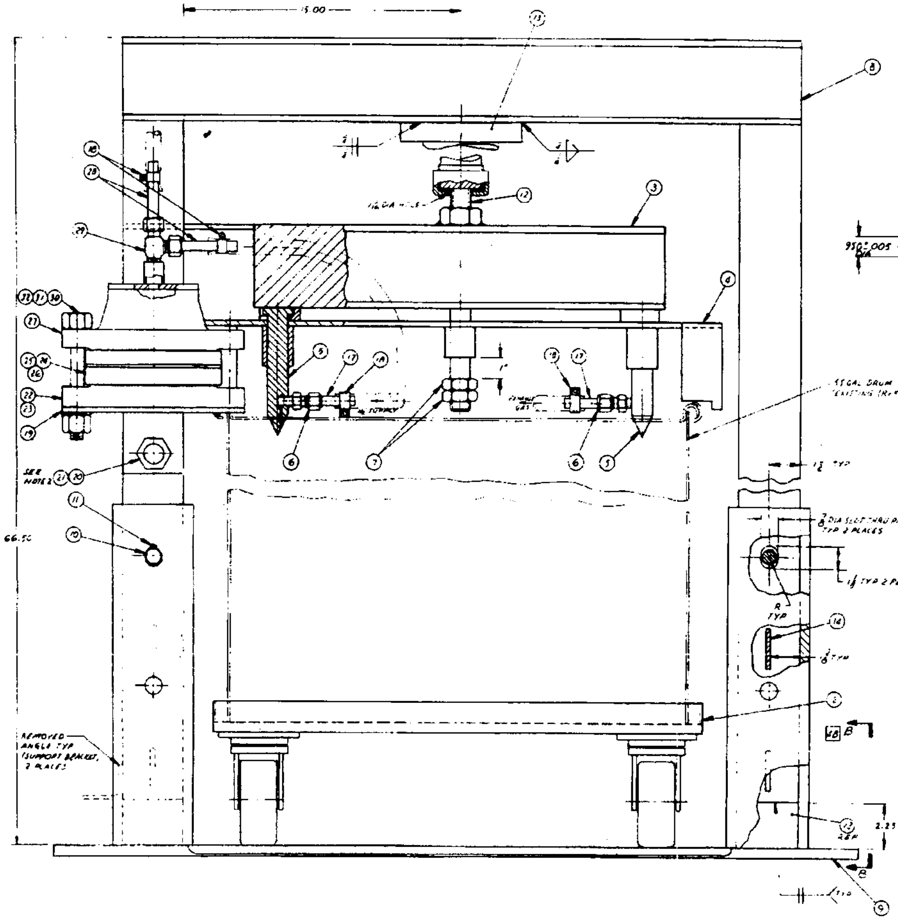
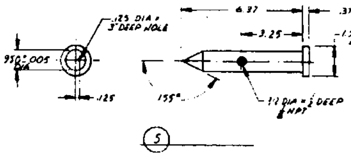
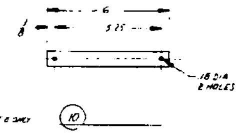
		PART NO	DESCRIPTION	MATERIAL
X		1	ARRANGEMENT	
	1	2	DOLLY ARRANGEMENT	H-2-20615
	1	3	DRUM PUNCH WELDMENT	H-2-28589 PART 2
	1	4	PUNCH SUPPORT WELDMENT	H-2-28589 PART 1
	2	5	PUNCH 1 1/2 DIA ROD SEE NOTE 1	ASTM A276 304 SST
	2	6	MALE CONNECTOR 1/4 T - 1/4 P	SWAGELOK #SS-400-1-4
	2	7	NUT, 1-12UNF-2B JAM TYPE	ASTM A307 GR A CS
	1	8	HYDRAULIC PRESS	C & H DISTRIBUTORS INC PART NO 23-300/5H
	1	9	BASE WELDMENT	H-2-28589 PART 3
	2	10	PIN 3/4 DIA ROD	ANY 300 SERIES SST
	4	11	COTTER PIN 1/8 x 2 LG EXTENDED PRONG	COMMERCIAL STL
X	1	12	PLUNGER ASSEMBLY	ASTM A36 CS
	4	13	PLATE 4 x 1/2 x 2 1/2 LG	ASTM A36 CS
	4	14	PLATE 2 x 1/4 x 3 LG	ASTM A36 CS
1		15	PL 3/16	ASTM A36 CS
1		16	STEM BAR 1 DIA	ASTM A108 CS
	2	17	TUBE 1/4 DIA x .035 WALL x 2 LG	ASTM A269 TYPE 304L
	4	18	CLAMP, WORM DRIVE HOSE	McMASTER-CARR #5416K32
	1	19	BRACKET	H-2-28589 PART 21
	2	20	BOLT, HEX HD, 3/4-10UNC-2A x 5 LG	ASTM A193 TYPE 304 SST
	2	21	NUT, HEX, 3/4-10UNC-2B	ASTM A194 TYPE 304 SST
	1	22	FLANGE 4" 150# SO RF	ASTM A182 GR F304 SST
	2	23	GASKET 6.7500 x 4.00 ID x .06 THK	TEFLON
	1	24	BURST DISC INSERT HOLDER 4"	CONTINENTAL DISC CORP ASTM A182 GR F304 SST
	1	25	BURST DISC GASKET RING 4"	CONTINENTAL DISC CORP ASTM A182 GR F304 SST
	1	26	RUPTURE DISC 4"	CONTINENTAL DISC CORP ALUMINUM
	1	27	ADAPTER WELDMENT ASSY	H-2-28589 PART 18
	3	28	TUBE 1/4 OD x .035 WALL x 4.00 LG	ASTM A269 TP 304 SST
	1	29	MALE RUN TEE	SWAGELOK #SS-400-3-4TMT
	8	30	BOLT, HEX HD, 5/8-10UNC-2A x 7 LG	ASTM A193 TYPE 304L SST
	8	31	WASHER, 5/8 STD FLAT	ANY 300 SERIES SST
	8	32	NUT, HEX 5/8-10UNC-2B	ASTM A194 TYPE 304L SST



(1) ARRANGEMENT



(5)



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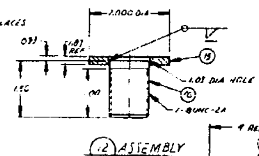
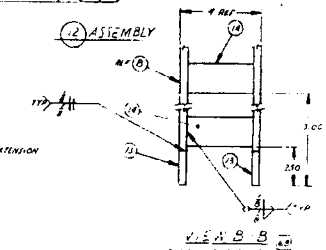


(12) ASSEMBLY



VIEW B-B
BASE WELDMENT PT 9 OMITTED FROM DELINEATION

GENERAL NOTES

1. DYE PENETRANT TEST THE PUNCH END OF PART #5. ANY VISABLE CRACKS SHALL NOT BE ALLOWED
2. USE EXISTING 1" DIA HOLES IN PART #8 TO SECURE BRACKET

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON,

DECIMALS	ANGLES	FRACTIONS
.XX ± .03	± 30'	± 1/32
.XXX ± .010		

DO NOT SCALE PRINT

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