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HEALTH PHYSICS ASPECTS OF OPERATION ROLLER COASTER

William D. Burnett
Harold L. Rarrick
George E. Tucker, Jr.

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ABSTRACT

Discussed here are the radiological safety problems related to the joint AEC-DOD-UK research program, Roller Coaster, for the evaluation of the storage, handling, and transportation criteria of plutonium-bearing weapons and to the post-test cleanup. The program included four experimental detonations: Double Tracks, in which the biological hazard of scattered plutonium was investigated; Clean Slates One, Two, and Three, in which the scavenging effect of earth covering of storage structures was evaluated.

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The assistance of the Reynolds Electrical and Engineering Company Radiological Safety (REECo Rad Safe) group in pre-shot planning and post-shot radiological surveys is gratefully acknowledged.

HEALTH PHYSICS ASPECTS OF OPERATION ROLLER COASTER

Introduction

Operation Roller Coaster is the name applied to a joint AEC-DOD-UK research program for the evaluation of storage, handling, and transportation criteria for plutonium-bearing weapons. The operation consisted of two parts: Double Track, in which the biological hazard of scattered plutonium was to be investigated, and Clean Slate, in which the scavenging effect of earth covering of storage structures and the hazard reduction resulting from this scavenging were to be evaluated. Sandia participation in the operation ran from April 15 to June 30, 1963. The Double Track experiment was conducted on the Nellis Air Force bombing range, located approximately 200 miles north of Las Vegas, Nevada, and about 40 miles southeast of Tonopah, Nevada. The three Clean Slate tests were held on the Sandia Corporation Tonopah Test Range (TTR), about 60 miles southeast of Tonopah, Nevada.

The Sandia Corporation Health Physics organization was involved in Operation Roller Coaster (1) to provide radiological safety for Corporation personnel involved in technical support of the Operation and (2) afterward, to restore the Tonopah Test Range to its pre-Roller Coaster condition. Where this was not possible, the job was to minimize the personnel hazards remaining and their interference with future range operations.

The experimental detonations yielded molten plutonium metal which combined rapidly with the device-encapsulating material, as well as with ground zero materials such as earth, concrete, and metal. The expanding shock wave threw these materials into the air in the form of highly contaminated concrete and metal missiles, and of less highly contaminated dust in the rising cloud. The concrete and metal debris and most of the dirt fell to the earth at relatively short ranges, up to 2500 feet, but some of the dirt was spread by the wind over large areas for a distance of roughly 10 miles downwind. After each experimental detonation, it was necessary for Roller Coaster personnel to make various re-entries into this plutonium-contaminated environment for experimental recoveries. Finally, at the conclusion of the Operation, removal of the plutonium contaminate was required insofar as practicable.

Purpose

Direct Sandia Corporation participation in Roller Coaster centered around three projects. The first involved providing balloon arrays to support a large number of air samplers for cloud measurements. The second was to provide technical photography of the explosion and subsequent cloud passage. The third was to provide device preparation, emplacement, arming, and post-shot survey for undetonated high explosive.

Planning

With 20 to 50 Sandia personnel involved in these three projects, the Sandia Health Physics organization felt it wise to provide full-time rad-safe support in the field for these people. This support was in addition to the usual health physics program, which was available in the field and was supervised and staffed by Reynolds Electrical and Engineering Company (REECo) personnel from Nevada Test Site. Generally, although the Health Physics organization relies upon the resident rad-safe group for most routine problems, it provides people who are knowledgeable in severe radiation problems. It is standard procedure to provide this type of support in field operations where there is a probability of exposure to fairly large internal or external radiation doses.

To keep the plutonium contamination from interfering with the operation of the test range as much as possible: (1) rad-safe procedures were implemented during Roller Coaster to prevent the extensive spread of plutonium outside the actual test areas; (2) those areas that were contaminated by Roller Coaster were posted, and access was denied; and (3) the TTR people were trained and procedures were set up to confine the plutonium to the isolated or posted areas when normal operations were resumed. Preliminary criteria for restoring TTR to a satisfactory condition were established before any of the tests took place (Appendix A). These criteria provided a base line for planning the roll-up of Roller Coaster. As actual data became available from the tests, these criteria were changed slightly.

Test Activities

The number of Sandia personnel involved in Operation Roller Coaster fluctuated from an estimated low of 20 to a possible maximum of 50. These individuals were assigned to one of three Sandia projects, all of which required almost immediate re-entry into possibly contaminated areas to complete their operations.

The Sandia Health Physics representatives supported the REECo health physics program by: (1) coordinating Sandia project activities with the available health physics program, (2) indoctrinating Sandia personnel in rad-safe problems and possible solutions, and (3) providing monitoring service for special problems.

General Support

Most of the Sandia personnel involved in Roller Coaster operations were unfamiliar with the problems of plutonium contamination and had never dressed out in full anticontamination clothing, which included the necessary respiratory protection devices.

Some of the personnel were required to enter the test area through a point other than the normal re-entry point and to go to areas where the contamination level was not yet defined. In order to prevent an overexposure under these circumstances, the following health physics activities were performed:

Pre-Shot Activities -- The Project Leaders were contacted concerning their re-entry plans. The location of personnel in the area during shot time was checked to assure that they were away from the "hot" line, that they were equipped with a qualified monitor, and that radio communication was available. The routes of re-entry personnel were plotted to assure that they could complete their

mission with a minimum of exposure to contamination. The location of material left in the exposure array was discussed to assure that it was as far away from the anticipated "hot" line as possible and was packaged to prevent gross contamination of the item.

A list of personnel performing re-entry functions was acquired. Assistance was given in "Event Card" filing.

The re-entry personnel were contacted individually to determine that they had no respiratory restriction which would prevent them from wearing respiratory protective gear. The following details of re-entry were checked: (1) location during shot time, (2) time of re-entry, (3) location of re-entry point, (4) availability of transportation with approved radio communication, (5) areas to be re-entered, (6) routes of re-entry, (7) jobs to be performed after entry, (8) the name of the accompanying monitor, and (9) the problems of leaving the contaminated area with or without possibly contaminated material. All of this information was reviewed with emphasis on health physics considerations. Since all re-entries were performed after dark, daytime dry runs of re-entry routes were performed.

Shot-Time Activities -- The adequacy of anticontamination dress and the fit of the respiratory protective device were checked.

Advance information on contamination levels on re-entry routes or in re-entered areas was obtained.

Monitoring for special recoveries was provided.

Contamination levels were observed in entered areas and were reported to the Test Director and/or the REECo monitors.

Vehicles, personnel, and recovered material were monitored as they left the area.

Post-Shot Activities -- Material, contaminated at various levels, was removed from the contaminated area and installed in "clean" areas for the next shot. Sandia Health Physics personnel either accompanied the REECo personnel as monitors or, if the levels were low enough, defined the amount of anticontamination clothing required and the route to be taken by the individual himself. Spot decontamination was performed on delicate equipment or equipment requiring early removal from contaminated areas.

Support of Project 2.7 - Balloon Array

The purpose of Project 2.7 was to provide a mobile vertical support mechanism suitable for positioning cloud sampling instrumentation downwind from the source. This cable curtain was 750 feet high by 1500 feet wide for the first shot and 1800 feet high by 1500 feet wide for the remaining three shots.

The curtain was located 2500 feet downwind from ground zero, remaining mobile until as late as H - 20 minutes, and was removed from the contaminated area as soon as permitted by the Project Manager (H + 2 to 3 hours). The support activities peculiar to this project were:

Pre-Shot Activities -- Special emphasis was placed on re-entry route planning to assure that the route near the curtain was well-defined and to assure avoidance of the "hot" line if at all possible. (Catenary cables were at each side of the curtain at levels hazardous to motor vehicles.)

The last three shots involved assembly of contaminated cable. A mobile anticontaminated clothing exchange facility was used at each assembly location to ease the load on the main decontamination facility and to provide a speedier clothing exchange for personnel.

Personnel were continually encouraged to leave as small an amount of equipment near the "hot" line as possible and to package or secure the items to minimize the amount of decontamination required prior to removal from the area.

Shot-Time Activities -- A monitor was provided to accompany a project man to the center of the base of the curtain to shut down a generator supplying power to the curtain sampling equipment. This equipment was in a highly contaminated area. Maximum protection was required (i.e., two suits of anticontamination coveralls, rubber foot wear, rubber gloves, cotton gloves, full-face mask and hood, with all seams and openings closed with masking tape).

A monitor was provided to accompany project personnel in the removal of the curtain to an uncontaminated location. At least four people and two vehicles were required to cross the "hot" line at least once. Maximum protection was required.

Post-Shot Activities -- Decontamination activities were prescribed for the cable and equipment that were in the contaminated cloud. Washing cables and vehicles with plain water and detergent was found to be as effective as more stringent measures. This procedure, however, removed only the looser contamination, and the equipment had to be considered as contaminated for the balance of the test. However, the contamination was then fixed enough that one pair of coveralls, gloves, and rubber shoe covers were all that were required to work on the cable.

Transfer of contaminated material from contaminated areas to clean areas for reassembly for the next shot was coordinated with REECo rad-safe personnel.

Continued monitoring of personnel and equipment during curtain reassembly was required to assure that spread of contamination was at a minimum. Readings from cotton gloves used in handling cable during reassembly were frequently as high as 100,000 counts per minute (cpm) on a PAC-3G.

Support of Project 9.5 - Technical Photography

Project 9.5 was initiated to provide (1) photographic measurements of burst phenomenology and initial cloud growth, (2) cloud trajectory measurements from ground zero to as far downwind as the cloud is visible, and (3) photogrammetric positioning of the airborne instrument arrays. Camera stations were located 1500 feet from ground zero at 90, 180, and 270 degrees from the line of direction of the cloud path; 4500 and 20,000 feet from ground zero and 3500 and 15,000 feet from the proposed "hot" line; and 18,000 feet from ground zero in line with the "hot" line. The stations at 4500 and 20,000 feet from ground zero were manned during shot time.

Pre-Shot Activities -- Personnel in "manned" locations were contacted, and a discussion of plutonium hazards was presented. An evaluation of the hazards existing at their manned station was also discussed.

Project personnel were advised of the proper methods of packaging the equipment in the field to prevent contamination. As a result, no significant contamination was observed on any camera equipment.

Shot-Time Activities -- Monitoring was provided for retrieval of film from the stations at 1500 feet from ground zero. Entry was made through a point other than the re-entry station. The areas visited had not been previously monitored; therefore, maximum protection of personnel was required. All film personnel and vehicles had to be monitored as they departed from the area. Fortunately, these cameras were never in a highly contaminated zone, and contamination was no significant problem as far as they were concerned.

Post-Shot Activities -- Removal of equipment from contaminated areas was coordinated with the REECo Health Physics personnel.

Support of Project 9.93 - Devices

Project 9.93 was initiated to assemble, place, arm, and disarm the devices; to perform post-shot inspections for determining the completeness of device detonation; and to assemble and install flare pots. These required re-entry to areas 1500 feet upwind of ground zero and to within visual range of ground zero from 90 to 270 degrees from the "hot" line near ground zero.

Pre-Shot Activities -- Special methods were proposed for packaging of equipment near ground zero that would withstand the shock of the blast and also permit easy removal and decontamination of equipment. These packaging methods were extremely successful, requiring only minor decontamination of equipment on two of the shots.

Shot-Time Activities -- An entry was made to the location upwind from ground zero to obtain information on the completeness of detonation. Since this was the first survey made after the detonation and nothing was yet known of the contamination levels, maximum protection was required, and a beta-gamma survey was performed to assure that the shot did not go nuclear. No beta-gamma reading was noted, and alpha readings were negligible in all cases.

Monitoring was made of an entry to determine whether any unexploded HE was in the area. Since this entry required movement into areas that permitted visual access to ground zero and other close-in areas, maximum protection was required. Contamination was confined to the vehicle, which had to be decontaminated after three of the shots.

Post-Shot Activities -- Monitoring was provided for the retrieval of the firing units upwind from ground zero. Most of the contamination associated with this operation came from plutonium-plated objects, such as metal and plywood fragments, that were blown into the blast protective devices. The contamination on the recovered items generally came from contact with the area as the relatively heavy items were recovered.

The flares downwind were generally not contaminated and could be removed with a minimum of effort. These were removed several days after the shot, with only a minimum of anticontamination clothing required.

Radiological Roll-up

Problems

The general problem was to restore the test range as nearly as possible to its pre-Roller Coaster condition or, when this was not possible, to minimize the personnel hazards remaining and their interference with future test range operations.

On Clean Slate One, an exposed detonation on top of the ground, radiological health hazards consisted primarily of minor earth throwout up to 100 yards and dust fallout in the arc array up to 10 miles.

On Clean Slates Two and Three, which were bunker shots, the hazards consisted of large volumes of earth scattered over areas of 100-yard radii; great numbers of concrete and metal debris thrown up to 2500 feet (with highest concentrations of debris east of the ground zeros as a result of jetting through the doorways, which were the weakest parts of the bunker structure); and dust fallout in the arc array up to 7 miles.

Immediately following the Clean Slate detonations, the test range experienced extensive rains. The net result was thought to leach the bulk of plutonium fallout from the surface through a depth of a few inches. The problem of low-level contamination and its associated dust resuspension was thus thought to be considerably diminished.

Procedures

The actual roll-up operation was based on agreement with Sandia Corporation and is stated in a letter from the Research Director of Operation Roller Coaster, Continental Test Organization, to the Manager, NVOO, subject, "Radiological Roll-Up: Operation Roller Coaster," wherein the following steps were agreed to and, subsequently, accomplished.

(1) Contamination signs, mounted on stakes, were placed at the intersection of the test array roads and the D-Day 10-micrograms-per-square-meter contour in each event area. Additional signs were placed at the intersection of these contours and previously existing roads leading into the contaminated areas if entry was possible on these roads without encountering contamination signs.

(2) Larger signs, stating that there was a radiation area ahead and directing that a check be made with the Sandia Corporation Control Point prior to entering, were posted at nine strategic positions on key roads leading into the contaminated area.

(3) The debris in the vicinity of each ground zero and fragments out to a range of 2500 feet were collected and buried in a pit inside the fenced ground zero area. The contaminated surface of the compacted areas around each ground zero and areas contaminated by jetting was scraped to a depth of several inches. The spoil was placed in the debris hole or mounded, covered with dirt, compacted, and watered.

(4) Ground zero areas were fenced at a radii sufficient to enclose the ground zero compacted areas contaminated by throwout and jetting. This involved using four-strand barbed-wire fences of roughly 125-yard radii on Clean Slates Two and Three and a fence of smaller radius on Clean Slate One.

(5) Burial pits not inside the fenced ground zero areas were posted and fenced in a manner similar to (4).

The referenced 10-microgram-per-square-meter lines for each shot is represented by the 2000-cpm line on the D-Day contamination plots in Appendix B.

Subsequent to the departure of the Continental Test Organization from the test range, Sandia Corporation personnel at Tonopah were furnished a set of procedures jointly prepared by the Range Manager and Sandia Corporation Health Physics. Essentially, these procedures specify the levels of contamination and type of work that SC/TTR personnel may pursue in the Clean Slate areas; when a rad-safe monitor must be present; and when, where, and what kind of anticontamination clothing must be worn. Generally, travel through the arc arrays is unrestricted. When digging operations are involved, as in test vehicle recoveries, anticontamination clothing is to be worn when a Proportional Air Counter (PAC) reading of 200 cpm is found, and face masks are required above 1000 cpm. Extensive digging in the fenced ground zero areas requires the presence of a health physicist. Vehicle decontamination is required above 100 cpm. Monthly smears are taken in TTR administrative areas as a check on contamination control procedures.

Additionally, SC/TTR has been furnished with a second emergency monitoring kit containing anticontamination clothing, radiation warning signs, and alpha survey meters.

Results of Post Roll-up Inspection

Members of Sandia Laboratory Health Physics and AEC/ALOO Operational Safety visited the Roller Coaster areas a week after the completion of roll-up. Generally, the areas were adequately marked, fenced, and posted. Surprisingly, the rains that followed the detonations of Clean Slates One, Two, and Three did not do as efficient a job of leaching out all the plutonium into the lower depths of the soil as had been expected. At the intersection of the dust fallout pattern with the barbed-wire fence around ground zero, PAC-3G readings greater than 20,000 cpm were found. Apparently, this contaminate was fixed on the larger particles of dirt, for personnel walking through the area with regular, rather than anticontamination, clothing did not transfer any of the contamination to their persons; no contamination was found, even on their shoes. It is important to realize that until this plutonium-contaminated dust becomes respirable, it is not a personnel hazard. Thus, if the remaining ground contamination is indeed fixed on large particles, it is a small hazard.

Conclusions

Almost any type of radiation problem can be handled if there is adequate preplanning, later tempered by actual data. On Roller Coaster, there were no plutonium uptakes by personnel involved in the operation. This was because of proper planning for and indoctrination and continual monitoring of people working in these areas. On the range, the contamination was confined to the testing areas and was isolated from personnel access with reasonable expense. By training and follow-up monitoring, there has been very little effect on the operation of the range.

It is important for Health Physics groups to work directly with project people to assist them in minimizing radiation hazards. This can best be done in the planning stage of the field experiment by Health Physics people scrutinizing the plans from the standpoint of radiation hazards during recovery and subsequent handling and by their operating directly with the project people during operations in contaminated fields. Under these conditions, the project people are fairly free to attend to their experiments because the Health Physics group is continually assessing the radiation hazards during the operation. Because of the stress and time limitations usually encountered in field tests and because the largest total exposure and largest risk for overexposure of personnel exists in field operations, Health Physics people are justifiably placed in field operations for extended periods of time.

The photographs included herein illustrate selected aspects of Operation Roller Coaster.

Figure 1. An aerial oblique of the Roller Coaster encampment. The Double Tracks area is 15 miles in the background. The Clean Slate areas are in the near foreground.

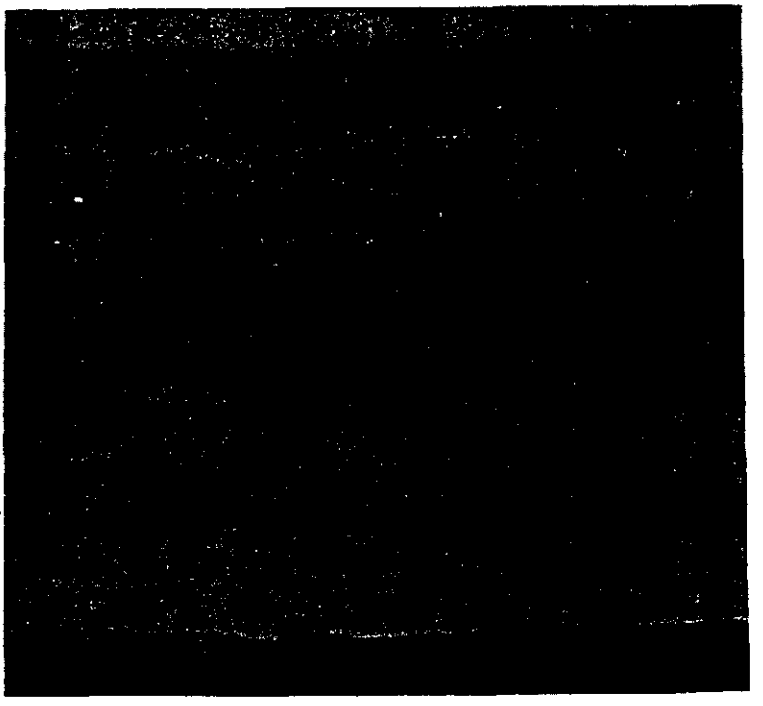


Figure 2. Nine UK balloons serving as instrumentation, weather, and fallout balloons on Double Tracks.

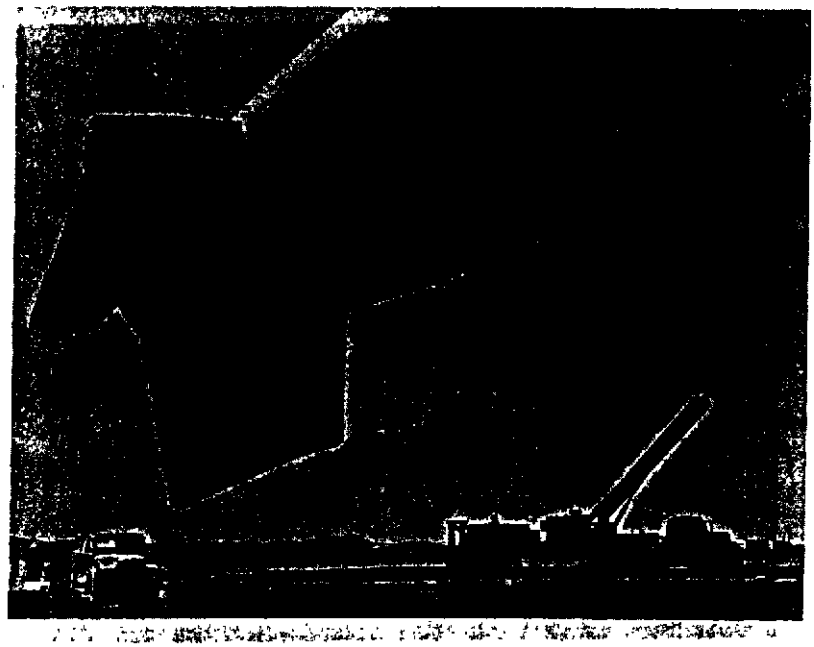


Figure 3. General view of balloon dirigible underside. Used to support catenaries to which cloud sampling gear was attached.

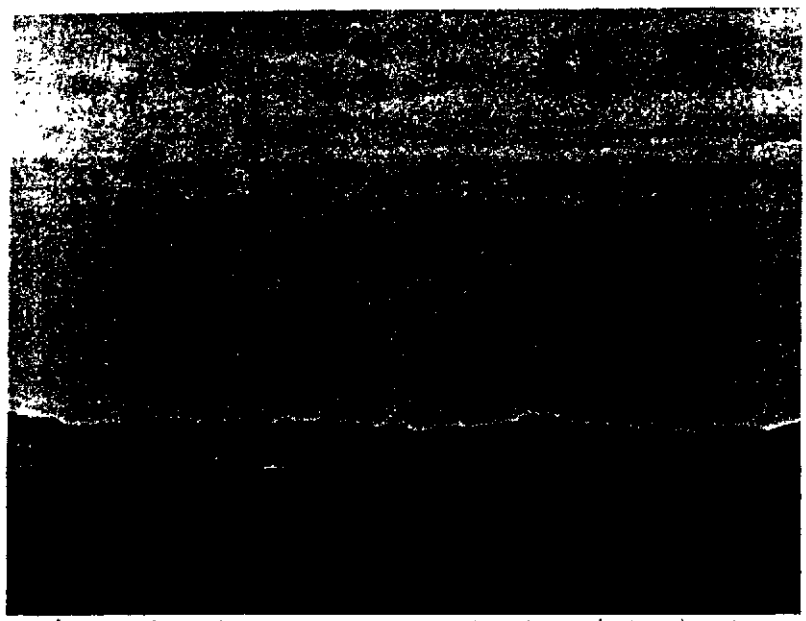


Figure 4. Balloon rigging crew lowering balloon curtain on Clean Slate Three.

Figure 5. Administration of smoke test to check fit of full-face respirator.

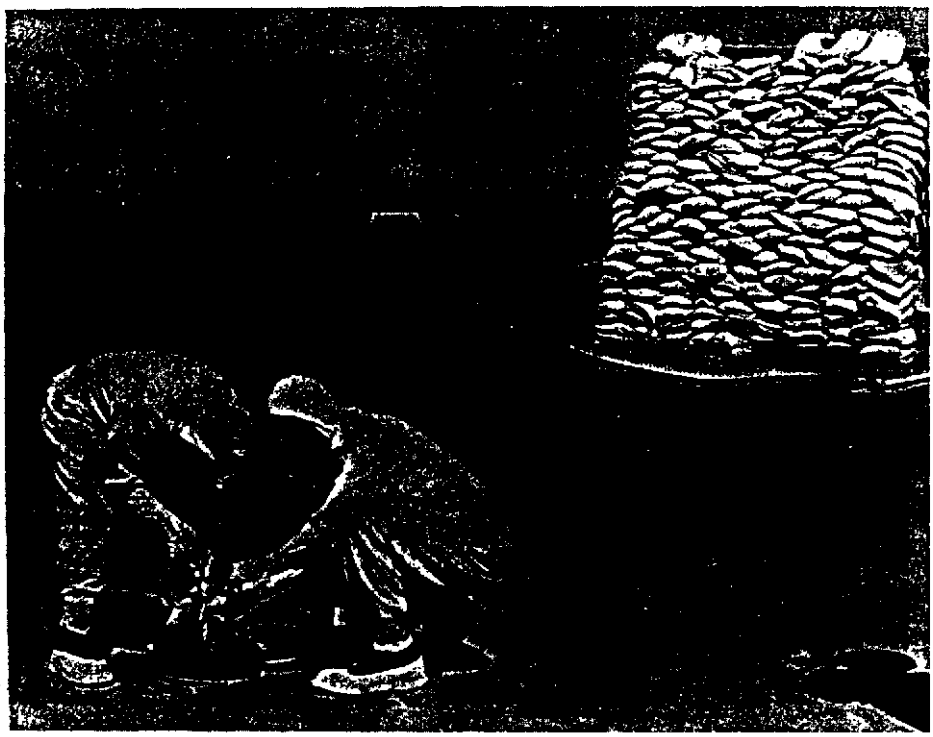


Figure 6. Personnel in full protective clothing recovering earth throwout sample.

Figure 7. Camera station (1500-foot) on Double Track event.

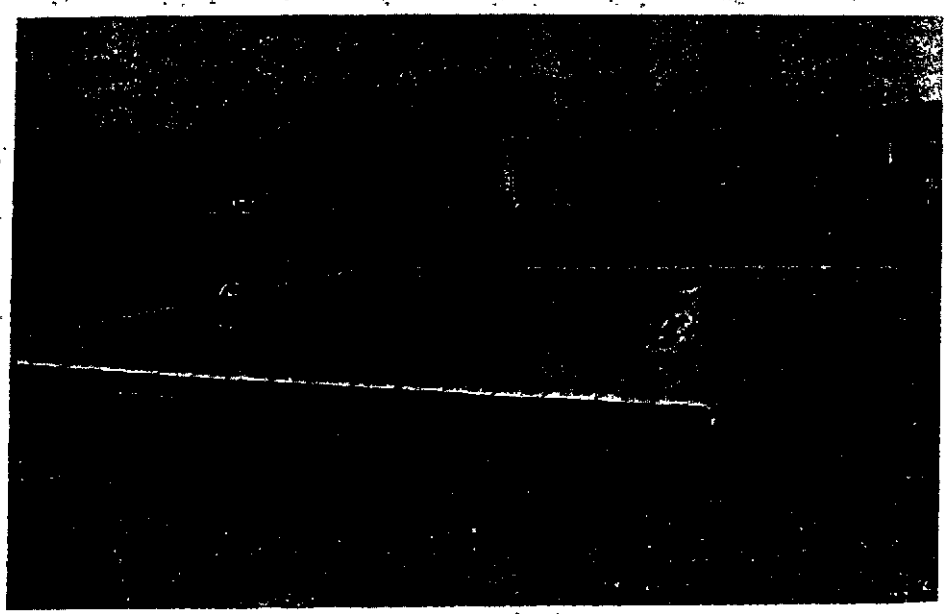


Figure 8. Double Track ground zero before event.

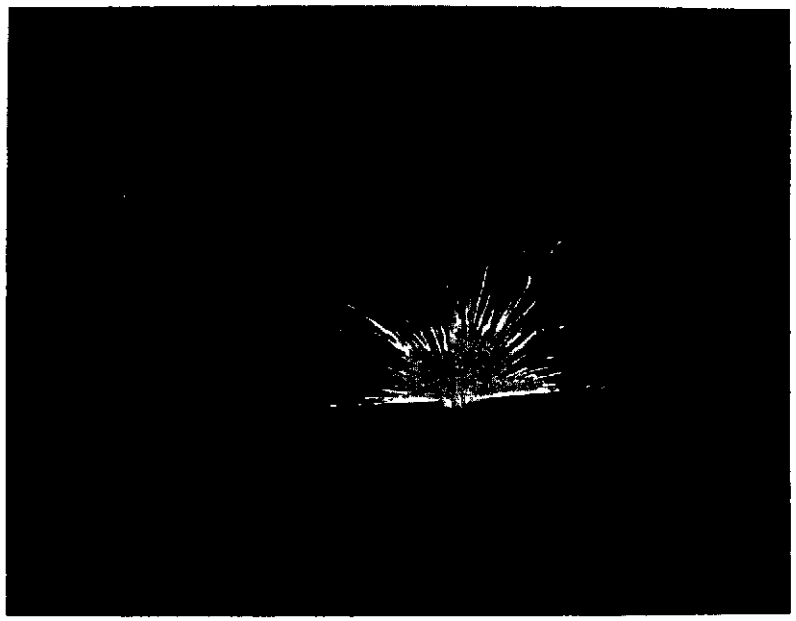


Figure 9. Molten metal being thrown out a fraction of a second after detonation of Double Track event. This material is all highly contaminated with plutonium. A similar problem existed with Clean Slates One, Two, and Three, except that on Clean Slates Two and Three, the bunkers added greatly to the amount of debris.

Figure 10. Another view of the Double Tracks event a bit later.

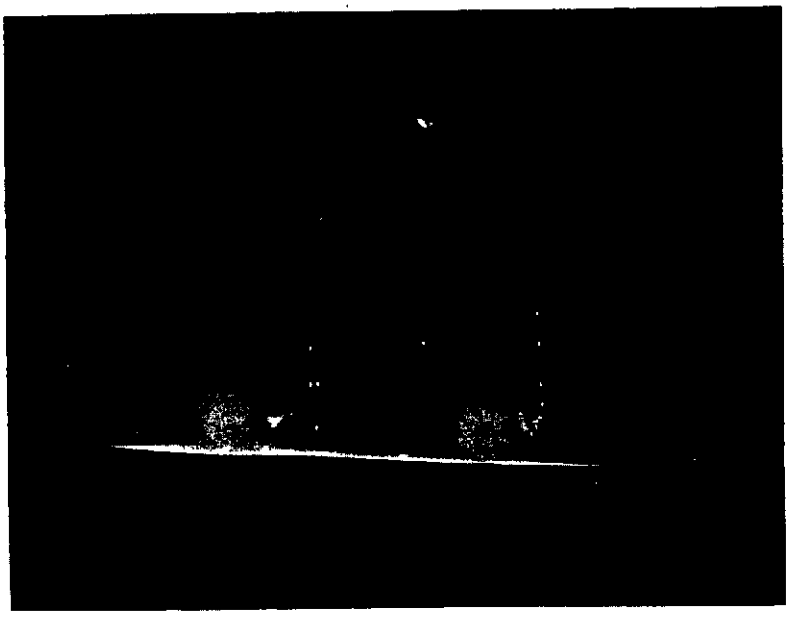


Figure 11. Flares used in following the cloud passage through the arc array are shown igniting.

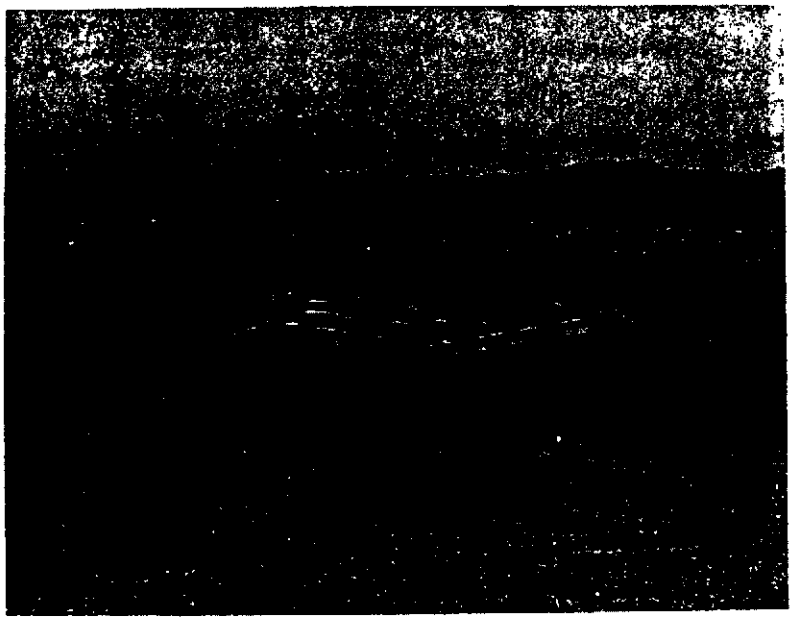


Figure 12. Double Track ground zero at D + 12 days.

Figure 13. Vehicle-mounted gamma scanner used for plutonium surveys immediately after a shot.

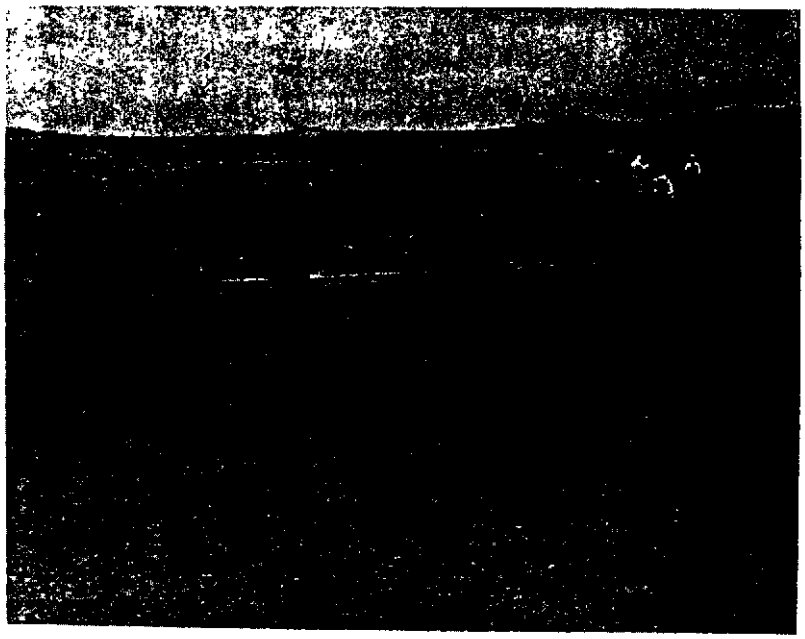


Figure 14. The Clean Slate One ground zero at D + 3 days. The dirt throwout is widespread over the cleared area. The three workers are dressed out in complete anticontamination clothing with full-face mask.

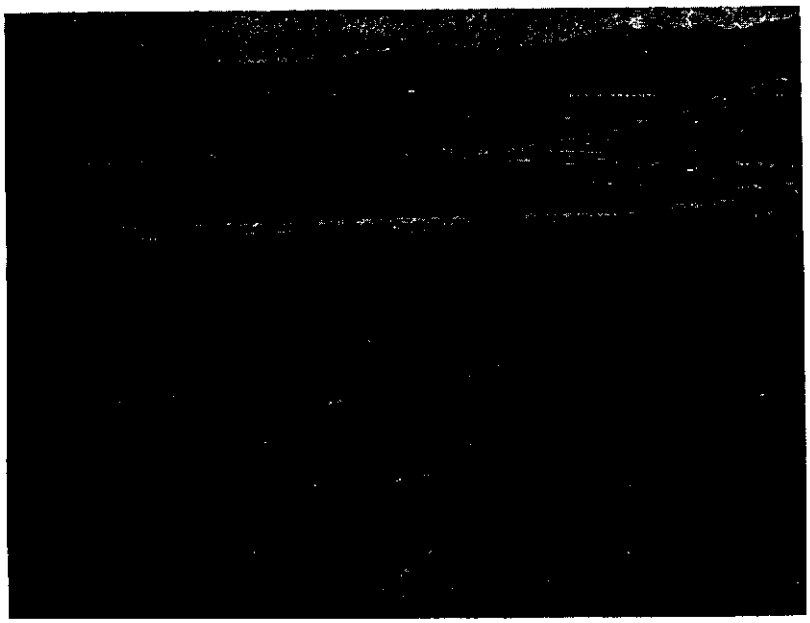


Figure 15. The Clean Slate One ground zero after roll-up. The throwout and debris have been collected, buried, and covered with clean dirt. Where count rates above 200 cpm were encountered in the cleared area, additional scraping and earth removal were employed. The fence is four-strand barbed wire and encloses the ground zero area.

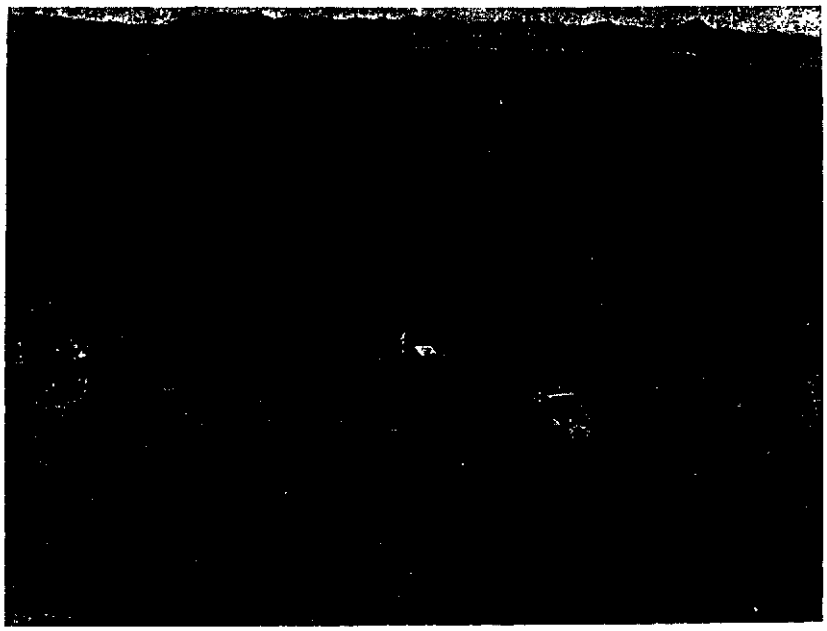


Figure 16. Clean Slate Two bunker before the event. Clean Slate Three was similar to this.

Figure 17. The Clean Slate Two bunker after the event. Note the concrete debris and metallic fragments, all of which were highly contaminated.

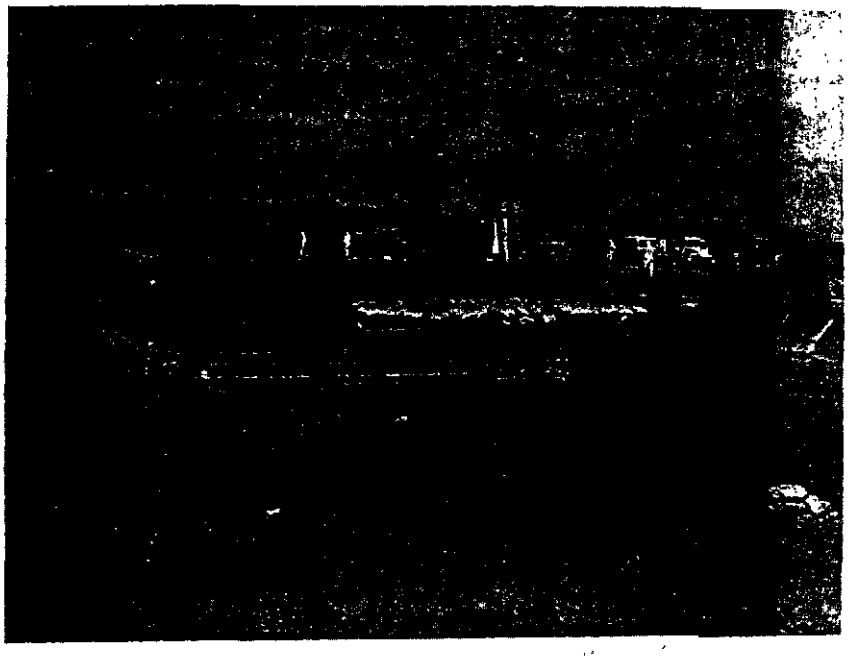


Figure 18. Another view of the Clean Slate Two area after the event.

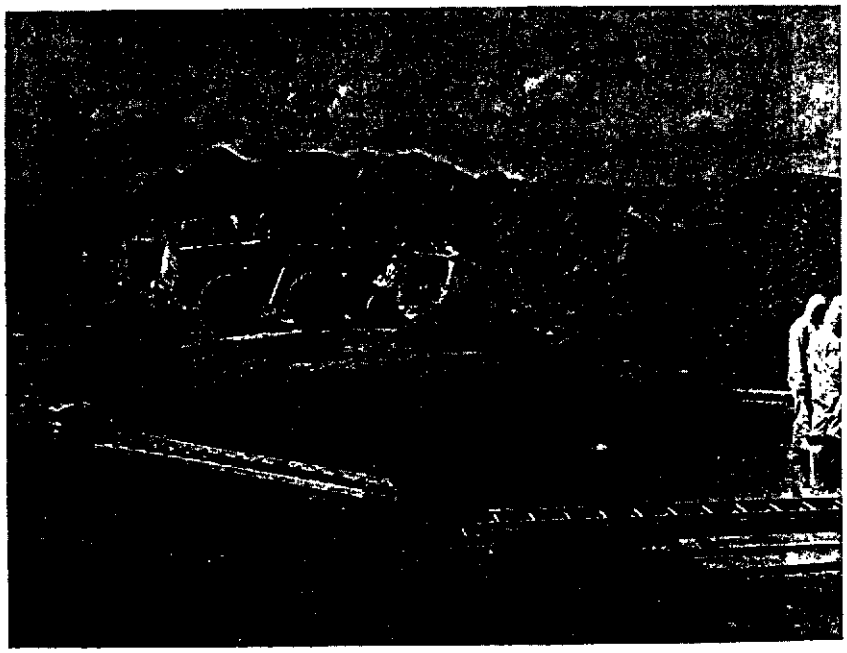


Figure 19. The Clean Slate Three bunker at D + 2 days. The workers are in the process of removing debris and earth throwout.

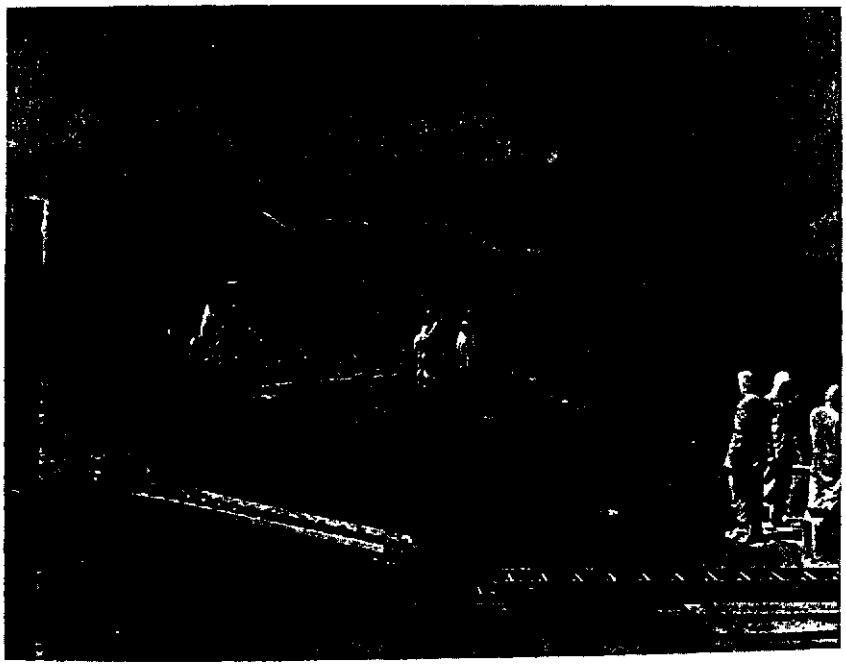


Figure 20. Another view of the Clean Slate Three bunker. Note the full protective clothing with full-face respirator.

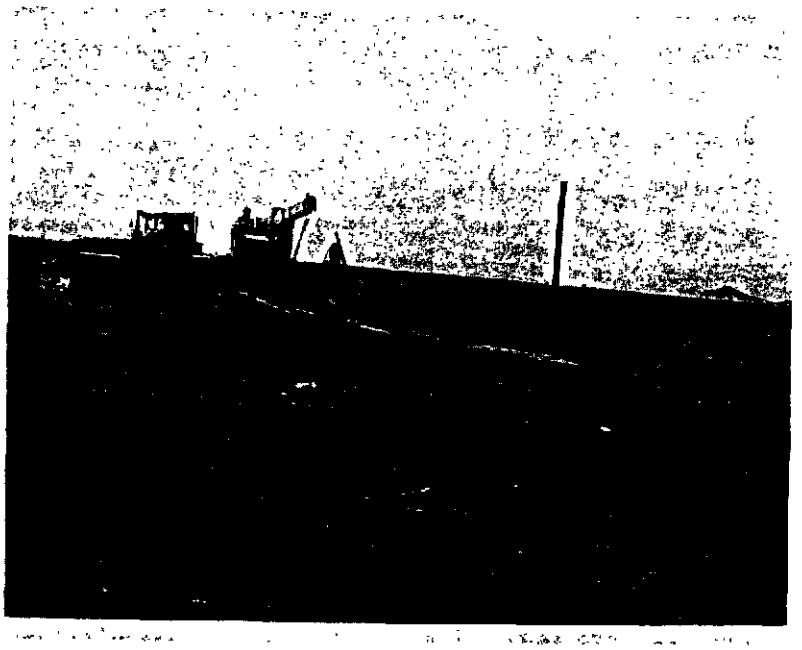


Figure 21. The removal of a large piece of debris from Clean Slate Three. This, like most debris, was buried in a pit inside the fenced ground zero area.

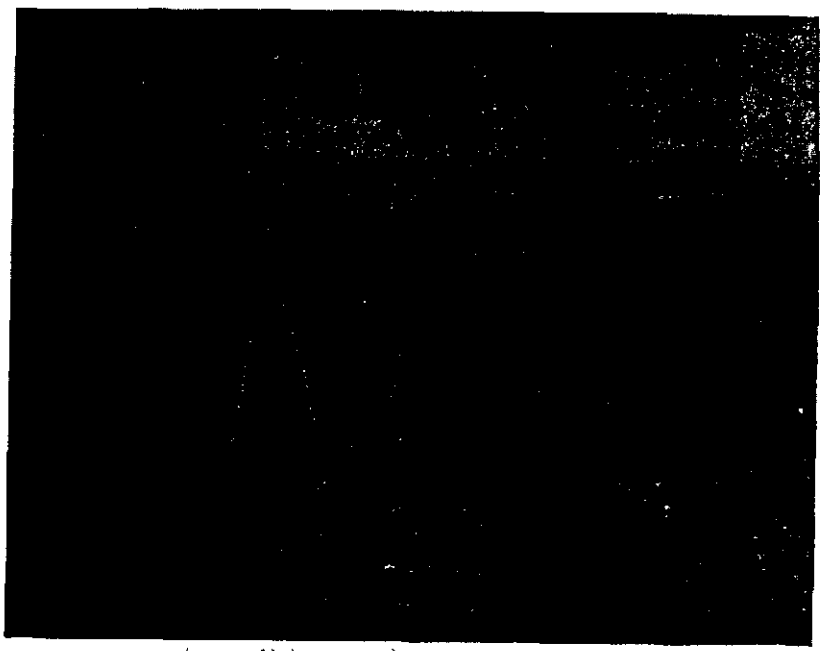


Figure 22. The fenced ground zero area of Clean Slate One.

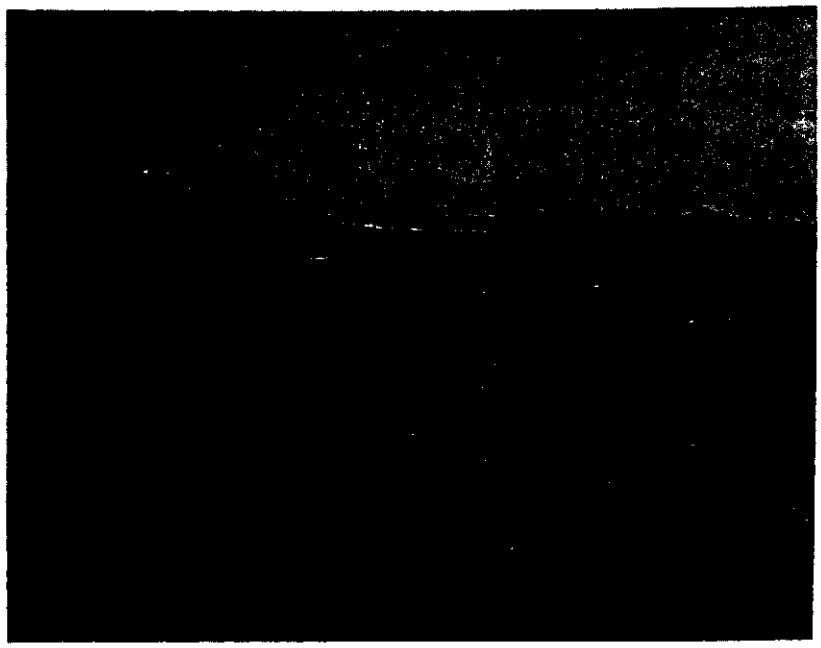


Figure 23. The fenced ground zero area of Clean Slate Two. The radiation warning sign is one of many placed throughout the test arrays. The debris in the right foreground is uncontaminated, the fallout occurring along a narrow sector some 100 yards farther to the right.

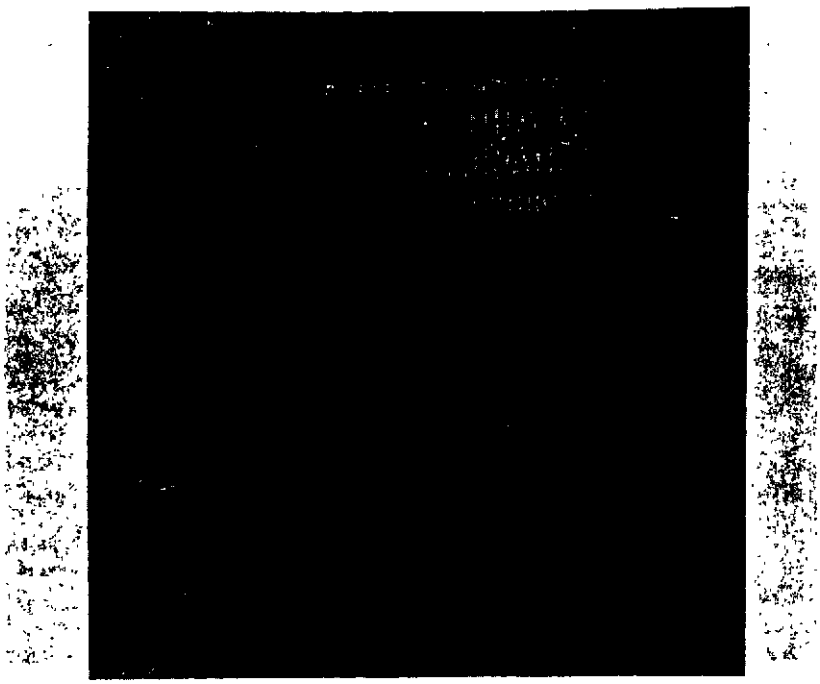


Figure 24. A closeup view of a warning sign placed throughout the arc array.

Figure 25. One of the larger (4' x 4') signs placed on additional arterial roads leading into the general area of Roller Coaster areas.

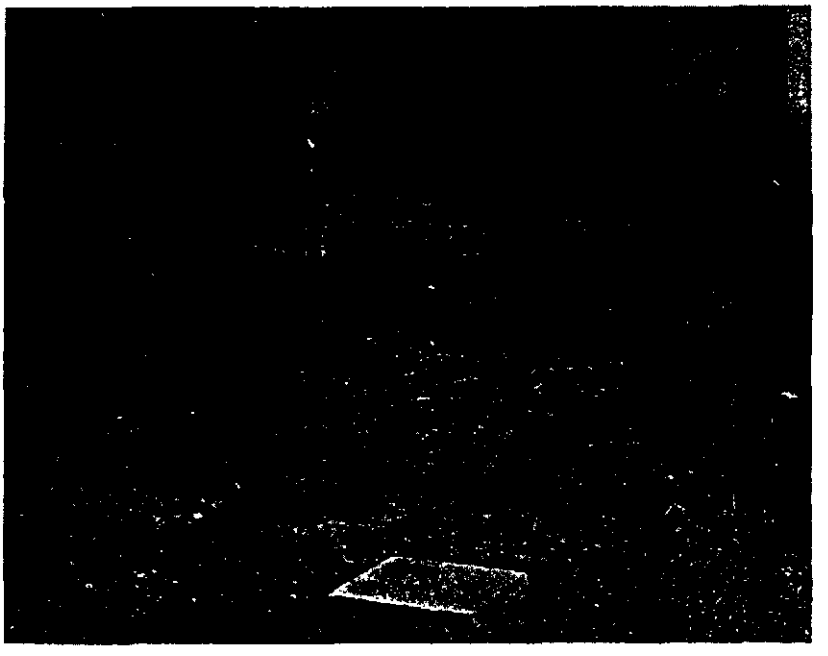


Figure 26. An example of metallic debris thrown 1600 feet east of Clean Slate Three ground zero. The brushed concrete flat is part of the experimental array for measuring fallout patterns.

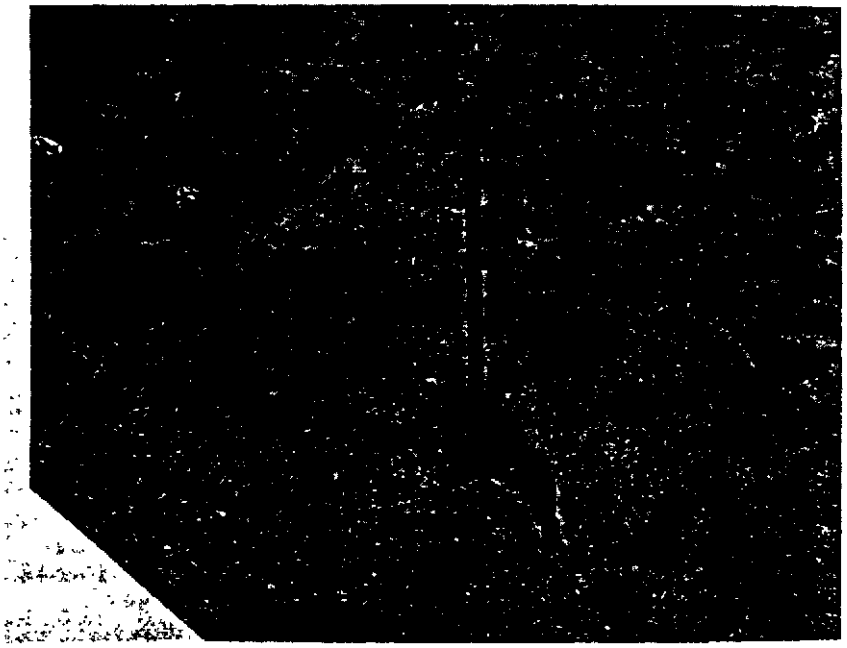


Figure 27. Examples of metal and concrete debris thrown 1700 feet east of Clean Slate Three ground zero.

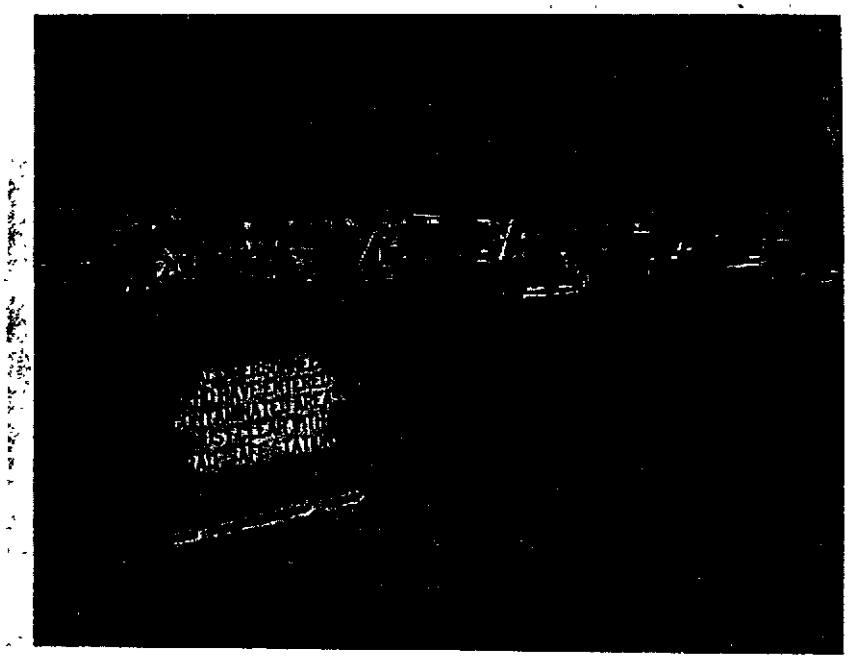


Figure 28. Rear view of REECo rad safe and decontamination facility.

APPENDIX A

Action Required by Operation Roller Coaster Organization to Restore Tonopah Test Range to Satisfactory Condition Following Shots

APPENDIX A

Action Required by Operation Roller Coaster Organization to Restore Tonopah Test Range to Satisfactory Condition Following Shots

On April 15, 1963, a meeting was held in Dr. J. D. Shreve's office, Sandia Corporation, to discuss the above subject and attempt to arrive at a procedure mutually satisfactory with Sandia Corporation health personnel and Roller Coaster personnel. Those persons in attendance were:

J. D. Shreve, Jr., Sandia Corporation and Scientific Director, Operation Roller Coaster

Harold Rarrick, Sandia Corporation, Environmental Health Division

George Tucker, Sandia Corporation, Environmental Health Division

Everett R. Mathews, ALO Operational Safety Division and ALOO Coordinator, Operation Roller Coaster

It was agreed that the Roller Coaster Organization should decontaminate in accordance with standards established by the Nuclear Safety Working Group, since these are the only standards that apply to contamination accidents involving plutonium-bearing weapons. Furthermore, they have been officially adopted by the AEC and the DOD.

The following procedures were agreed upon as being appropriate and reasonable:

1. Decontaminate all areas showing more than 1000 $\mu g/M^2$ of plutonium deposition based on survey results immediately following detonations.
2. Disk for contamination dilution any areas showing over 100 $\mu g/M^2$ when measured with PAC-3G instrument at the time the Roller Coaster areas are returned to Sandia Corporation after the experiments (approximately 3 months). Note: No such areas are expected to exist following the decontamination listed under No. 1 and the natural weathering over a 3-month period.
3. Fence ground zero areas for 125-yard radius arc with 4-strand barbed-wire fence. Also post fence with suitable radiation signs.
4. Post areas showing detectable contamination as measured with PAC-3G instrument at the time the Roller Coaster areas are returned after experiments. It is believed that these areas can be effectively posted by erecting signs along all roads and trails entering and leaving areas, along main access road at half-mile intervals throughout contamination zone, and around contamination

zone perimeter at half-mile intervals. The entrance signs should indicate that areas beyond the roadway are contaminated, and personnel working in these areas must be monitored at the Control Point following exit.

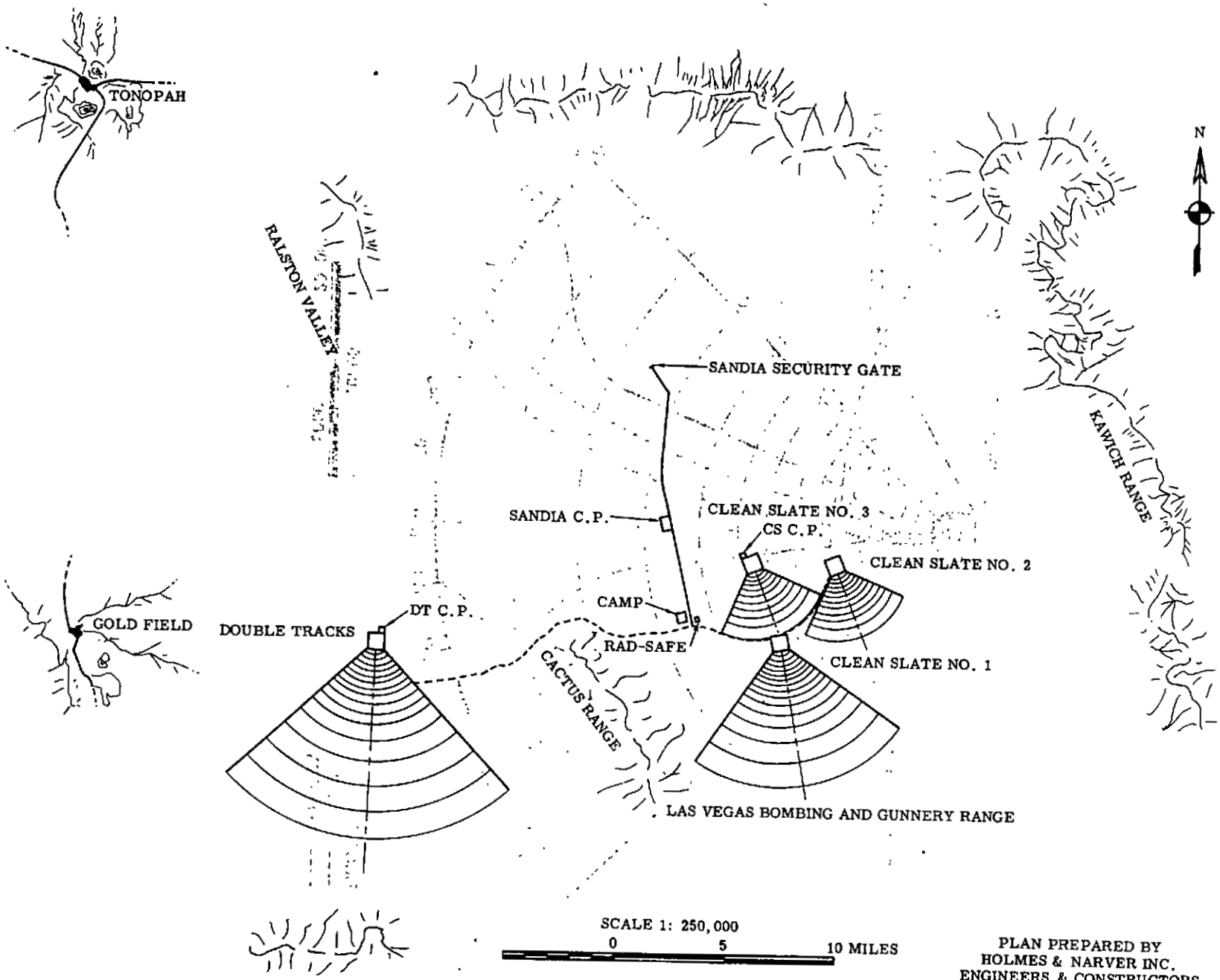
5. Special decontamination efforts will be performed on roads, instrument locations, and hazardous unit target areas that require regular access. (Natural weathering caused by high winds may recontaminate such areas to very low but still detectable levels. Additional decontamination may be required at a later date by Sandia Corporation as a result of this weathering.)

The proposed decontamination procedures listed above will be presented to the Research Group Director by the ALOO representative for approval. If approved, they should become a part of the requirements for Project 9.64, Roll-up and Extended Control.

The proposed procedures were adopted by the Research Group Director, Lt. Col. J. L. Dick, on May 7, 1963.

APPENDIX B

Project Roller Coaster Sites



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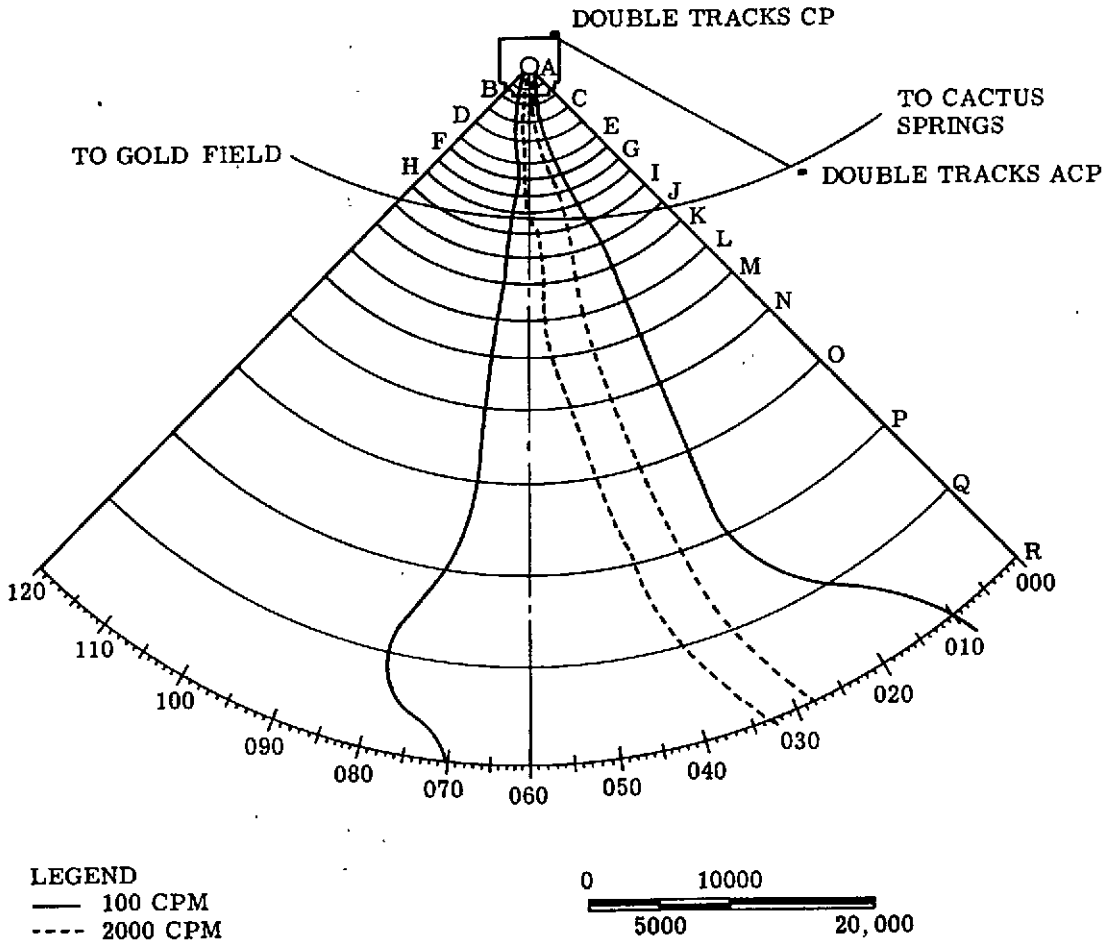
DOUBLE TRACKS CP
TO CACTUS SPRINGS
DOUBLE TRACKS ACP
TO GOLD FIELD
A
B
C
D
E
F
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J
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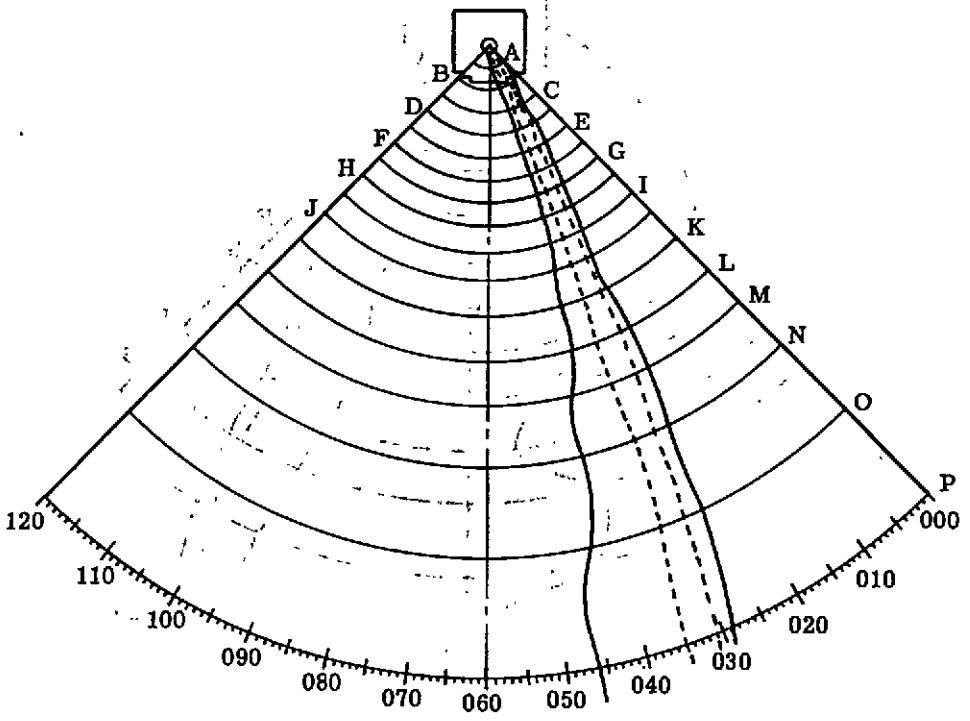
010
020
030
040
050
060
070
080
090
100
110
120
LEGEND
100 CPM
2000 CPM
0
10000
5000
20,000

CLEAN SLATE 1 GZ



LEGEND

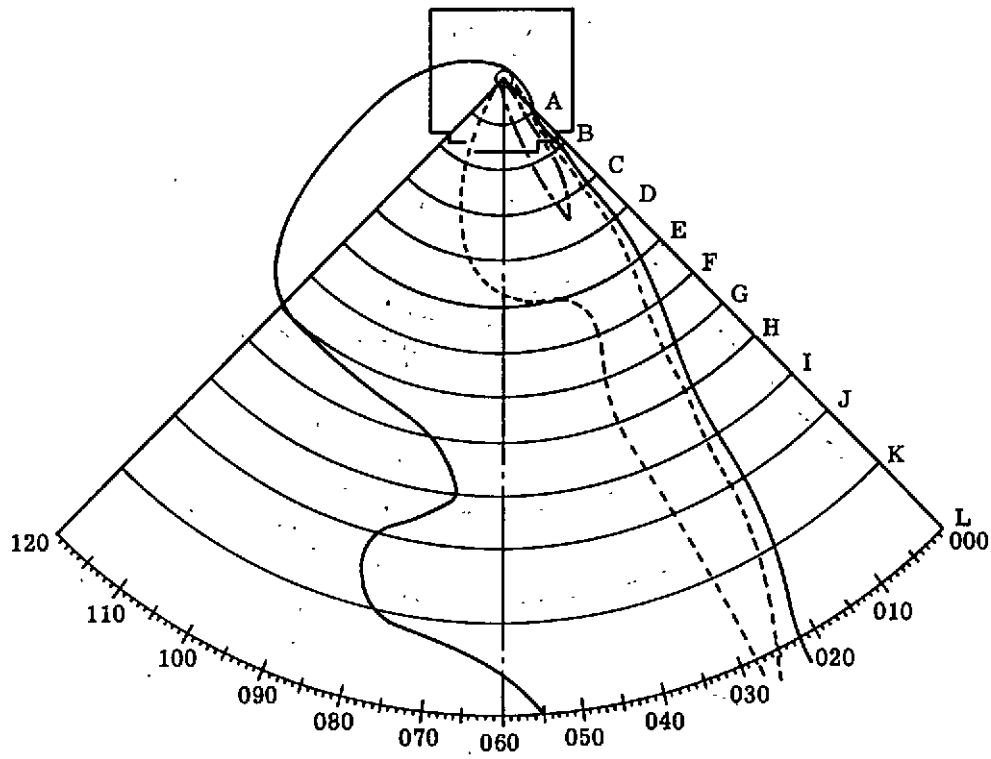
—— 100 CPM

---- 2000 CPM

0 8,000

4,000 16,000

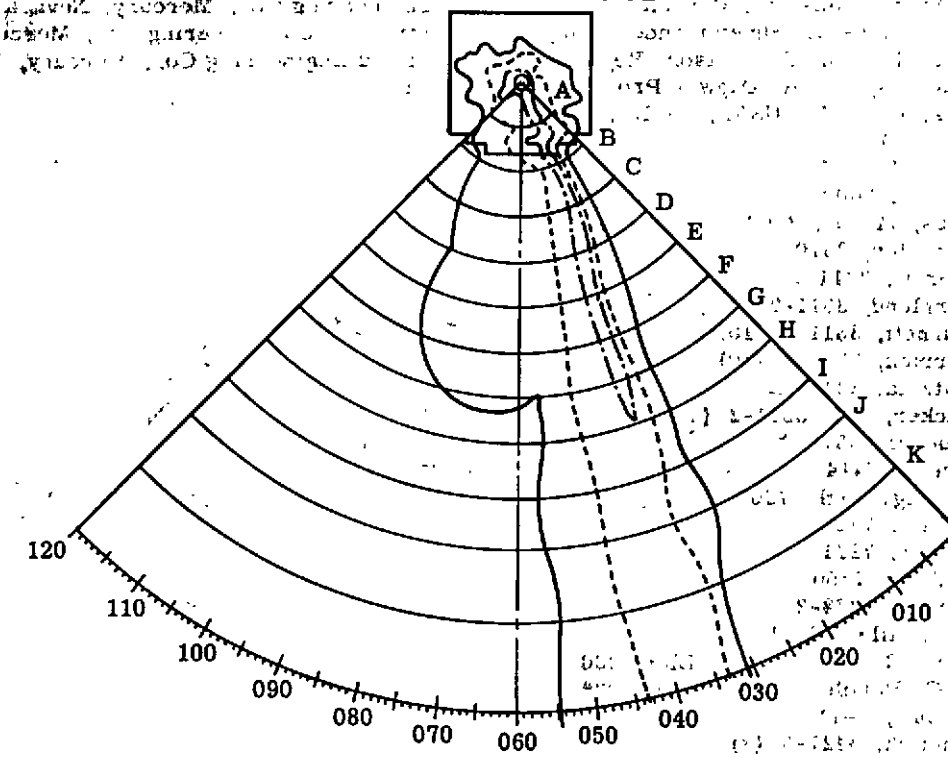
CLEAN SLATE 2 GZ



LEGEND
—— 100 CPM
---- 2000 CPM
—-- 40,000 CPM

0 4,000
2,000 8,000

CLEAN SLATE 3 GZ



LEGEND
—— 100 CPM
---- 2000 CPM
—·— 20,000 CPM

0 4,000
2,000 8,000

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