727313

PROPOSED SITE MONITORING PROGRAM
SNAPTRAN DESTRUCTIVE TESTS

P. Nelson 10-7-82
Rusty Grant 2-6-85

REPOSITORY INEL
COLLECTION INEL Pub Reading Room Human Radiation Experiments and Related Collections
BOX No. U.S. DOE Public Reading Room IDO
FOLDER Proposed Site Monitoring Program SNAPTRAN Destructive Tests PTR-621

R. R. Landolt

This report belongs to the INEL Technical Library. It has been loaned to you, and you are accountable for it. The library may recall it after two weeks for use by another employee. Please return this report to the library when it is recalled or when you are no longer using it.

INEL Technical Library-IF
Report Section

PHILLIPS PETROLEUM COMPANY

ATOMIC ENERGY DIVISION

1188919

NATIONAL REACTOR TESTING STATION

US ATOMIC ENERGY COMMISSION

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

Printed in USA

1189920

PTR-621
Issued: February 13, 1963

PROPOSED SITE MONITORING PROGRAM
SNAPTRAN DESTRUCTIVE TESTS

by

R. R. Landolt

PHILLIPS
PETROLEUM
COMPANY

Atomic Energy Division
Contract AT(10-1)-205
Idaho Operations Office
U. S. ATOMIC ENERGY COMMISSION

1189921

PROPOSED SITE MONITORING PROGRAM
SNAPTRAN DESTRUCTIVE TESTS

SUMMARY

Measurements will be made of the direct radiation, airborne radioactivity, and beryllium released from the SNAPTRAN 2/10A destructive tests. These measurements will be taken by various equipment located on an extensive grid monitoring system. Attempts will be made to distinguish between the dose (both gamma-ray and neutron) of the transient and the dose from the decay of the fission products produced by the transient. The direct dose from the cloud will be measured as well as the dose from fallout downwind of the test. The radioactive (isotopic) air concentration of the cloud and the beryllium concentration will be measured. Attempts will also be made to measure relative concentrations of the radioactive noble gases in the cloud as well as taking particle-size measurements of cloud radioactivity.

1189922

PROPOSED SITE MONITORING PROGRAM

SNAPTRAN DESTRUCTIVE TESTS

CONTENTS

SUMMARY ii

I. INTRODUCTION 1

II. RADIOLOGICAL MEASUREMENTS 2

A. Grid System 2

B. Specific Measurements 2

C. Power Supply for the Grid System 11

D. Physical Operation of the Monitoring System 11

E. Analyses 12

F. Control Procedure 13

G. Future Uses of Equipment 13

H. Measurements Farther than the STEP Grid 14

APPENDIX A 15

APPENDIX B 16

APPENDIX C 17

1189923

PROPOSED SITE MONITORING PROGRAM
SNAPTRAN DESTRUCTIVE TESTS

I. INTRODUCTION

One of the experimental objectives of the STEP Project is to measure and evaluate the radiological hazards resulting from a maximum credible accident to the SNAP 2/10A reactor. In addition, the nature of the components of this reactor, in particular the beryllium reflectors, necessitates a measure of the release of some toxic substances of a non-radiological character. This report will explain, in as much detail as is presently possible, AED Health and Safety's proposed methods of accomplishing the above objectives during the SNAPTRAN 2/10A destructive test series.

1189924

II. RADIOLOGICAL MEASUREMENTS

A. Grid System

Appendix A is a drawing of the proposed grid system for monitoring and measuring the radiological consequences of the destructive tests.

Appendix B is a tabular listing of the grid instrumentation.

Appendix C is a cost estimate of the equipment that will need to be purchased to properly instrument and operate this grid.

B. Specific Measurements

1. It is felt that the instrumentation of the grid system will provide the following information:

a. Gamma-Ray Dose-Rate from Residual Fission Product Decay as a Function of Distance from the Reactor and Time After the Transient

This information will be obtained from dose-rate recording ionization chambers located at 25, 50, 100, 200, and 300 meters upwind of the reactor. These instruments will be automatically actuated at the end of the transient. The STEP Instrumentation Section will be responsible for designing and installing this actuation mechanism into the reactor control system. The datum will be recorded near the control room on the same panel as the IET area monitoring system. The recorder to be used is being decided upon by the STEP Instrumentation Section.

The information will be reported in the form of a graph showing millirem per hour versus minutes after the transient, and distance from the reactor as a third parameter.

b. Gamma-Ray Dose from Residual Fission Product Decay as a Function of Distance from the Reactor and Time After the Transient

This information will be obtained by graphically integrating the dose-rates determined by the above method (Part a). It will be presented in graphical form showing millirem versus minutes after the transient, with distance from the reactor as a third parameter.

c. Gamma-Ray Dose from the Transient Plus that from Residual Fission Product Decay as a Function of Distance from the Reactor

This information will be recorded by either film badges, chemical dosimeters, or polymerization dosimeters located at the 25, 50, 100, 200, and 300 meter upwind stations. The type of dosimeter used at a particular station is determined by comparing its sensitivity range with the expected dose at that station. Film badges (30 mrem to 1000 mrem) will be used at the 100, 200, and 300 meter stations; chemical dosimeters (25 rem to 10^6 rem) will be used at the 50, 100, and 200 meter stations; and polymerization dosimeters (50 rem to 10^7 rem) will be used at the 25 and 50 meter stations.

The film badges will be obtained from ID and will be processed by their Personnel Metering Section. The chemical dosimeters are contained in the Nuclear Accident Dosimeters (NAD's). They will be borrowed from ID and will be analyzed by their Analysis Group. The polymerization dosimeters will be obtained from the University of Kansas and will be read by a STEP Health Physicist.

The information will be reported in the form of a graph showing millirem versus the distances of the five stations from the reactor.

d. Gamma-Ray Dose from the Transient as a Function of Distance from the Reactor

This information will be obtained by a difference method in which the gamma-ray dose after the transient (Part b) will be subtracted from the total gamma-ray dose of the entire test (Part c). The time at which the dosimeters in Part c are recovered will be the point on the time coordinate of the graph of Part b which is used in applying the difference method.

A supplemental method for determining this information will be to drop film badges into shielded containers at the moment of reactor destruction. The film will be held above the shield by electromagnets and automatically dropped at this designated time.

This information will be presented in the form of a graph showing millirem versus distance from the reactor, and will be extrapolated

1189926

between the five stations to give the dose from the transient as a continuous function of distance from the reactor.

e. Gamma-Ray Dose from the Transient Plus that from Residual Fission Product Decay as a Function of Distance from the Reactor and Time After the Beginning of the Test

This information may be obtained by adding that found in Part d to the time-doses of Part b. The results will then be a continuous function of time as well as distance and may be presented graphically in that manner.

f. Total Neutron Dose from the Transient as a Function of Distance from the Reactor

This information will be determined to a limited extent by a combination of fission foils, activation foils, sulfur, and neutron pencil dosimeters. These devices will be placed on the dolly as well as at 25, 50, 100, 200, and 300 meters.

Part of this equipment is contained in the NAD's used in Part c. The NAD system uses bare gold, cadmium covered gold, three fission foils and sulfur. This combination allows an approximate measurement of the neutron spectrum, which must be known before a dose in millirem can be determined. Calculations using the induced activity of the gold and cadmium covered gold give the thermal flux. A Pu^{239} fission foil gives the neutron flux > 1 Kev. A Np^{237} fission foil gives the flux > 0.75 Mev. A U^{238} fission foil gives the neutron flux > 1.5 Mev. A sulfur bar gives the neutron flux > 2.5 Mev from the S^{32} (n,p) P^{32} reaction.

The foils are contained in a boron ball for removing thermal neutrons. The inside of the ball is lined with cadmium to capture any neutrons thermalized by the boron.

The film badges used in gathering gamma-ray dose data also contain gold, cadmium covered gold and a sulfur stick. Measurements obtained from these items will supplement those obtained by the NAD's. The film badges also contain fast neutron sensitive film. This film dose is measured by counting the tracks of proton recoils from the hydrogen (n,p) reaction, and applying this data to a known calibration curve.

1189927

The individual results of these dosimeters will be correlated to give an approximate energy distribution of the transient neutron flux. The thermal and fast fluxes will then be converted to millirem using the appropriate Relative Biological Effectiveness (RBE) factors. These doses will then be summed to give the total neutron dose in millirem. This information will be included in the graph of Part d.

The MTR Bonner Counter, a neutron flux measuring instrument, will also be used at one location (not decided yet) to give additional neutron dose information.

g. Total Dose from the Transient as a Function of Distance from the Reactor

This dose will be determined by adding the neutron dose to the gamma dose obtained in Part d. The sum of the neutron and gamma-ray dose from the transient will be included in the graph showing the information obtained in Parts d and f.

h. Total Gamma-Ray and Neutron Dose from the Transient Plus the Gamma-Ray Dose from Residual Fission Product Decay as a Function of Distance from the Reactor and Time After the Beginning of the Test

This information may be found by adding the total dose during the transient (Part g) to the total dose found in Part e. It will be presented in a separate graph showing millirem versus time after the test with distance from the reactor as a third parameter.

i. Gamma-Ray Dose-Rate from the Cloud as a Function of Distance from the Reactor at Various Times After the Excursion

This dose-rate out to 300 meters will be determined by ion-chambers placed downwind from the reactor at 25, 50, 100, 200, and 300 meters. The dose-rate from the cloud at these stations will be determined by a difference method in which the dose-rates measured by the upwind ion-chambers (Part a) will be subtracted from the dose-rates measured by their counterpart downwind ion-chambers. This separates the could dose from the residual fission product decay dose at each

1189928

station. These downwind ion-chambers will be actuated at the end of the transient by the same mechanism which actuates the upwind ion-chambers.

The dose rates from the cloud at several points along the 1500 and 2514 meter arcs will be measured by remote monitoring-telemetering stations. This system, consisting of 25 remote units, was obtained from GE-ANP surplus and is presently being reactivated by the MTR Instrument Development group. Each remote unit has a high and low range ion-chamber of variable sensitivity. The direct current (which is proportional to the dose-rate) from the ion-chambers is placed on a capacitor. At given time intervals the voltage on the capacitor is measured and converted to a tone. The tone is transmitted to a receiving station and reconverted into a voltage. This voltage is converted to a dose-rate by a ratemeter and may be typed out automatically.

The dose-rate from the cloud as it passes the 13,000 ft arc road will be measured by two mobile monitoring stations. These mobile stations are trucks in which are mounted scintillation-type dose-rate meters. They also are equipped with air activity measuring instruments. Barring unsafe exposure-rates these two vehicles will drive along the arc road, locate the center of the cloud, station there, and record the dose-rate as the cloud passes.

The results will be presented in a graph showing millirem per hour versus minutes after the test, with distance from the reactor as a third parameter.

j. Total Dose from the Cloud as a Function of Position on the Grid

At each station on the grid there will be a film badge in a can beneath the surface of the ground. This badge will then be shielded from most of the fallout-dose and will hence record the beta-particle and gamma-ray exposure dose from the cloud. These film badges will be retrieved as soon as the cloud has left the area. This information may be plotted in the form of an isodose graph using the reactor as the origin.

k. Total Dose from Fallout as a Function of Position on the Grid 24 Hours After the Excursion

Three feet above each of the film badges used in Part j there will be another film badge recording both cloud and fallout exposure. The cloud exposure (Part j) will be subtracted from these elevated badge doses to give the exposure to these badges from fallout only. This information will be presented in the form of an isodose graph.

l. Maximum Gamma-Ray Dose-Rate from Fallout as a Function of Position on the Grid and Time After the Excursion

A study of the telemetering air-sampling data should allow an estimate of the time when the cloud has essentially left the grid. After that time it will be assumed that the telemetered ion-chamber dose-rates are from fallout only. This information may then be presented as a continuation of the dose-rates as shown in the graph of Part i.

m. Fallout Distribution, Concentration, and Isotopic Identification as a Function of Position on the Grid

The particulate fallout will be collected on 174 fallout trays located throughout the grid. The trays will be mounted approximately three feet above the ground and will each contain a 12 in. by 15 in. piece of sticky type fallout paper.

After the cloud has passed, these fallout plates will be recovered and analyzed by gamma-spectrometry. Attempts will be made to quantitatively measure the fallout of I^{131}, Cs^{137}, Ba^{140}, Zr^{95}-Nb^{95}, Ru^{103}, Ru^{106}, and Ce^{141}. The plates will also be analyzed for gross gamma-ray and beta-particle activity to aid in deposition velocity calculations. A strontium analysis will also be made on the plates.

The results of the isotopic identification will be presented in the form of a table in $\mu c/cm^2$. Distribution and concentration of total fallout activity will be plotted as an isopleth on the grid.

1189930

n. Particulate Activity in the Cloud and Isotopic Identification as a Function of Position on the Grid

Particulate activity in the cloud will be collected by 63 high-volume air samplers as shown on the grid drawing. A 6 in. by 9 in. filter holder will be used to accommodate the filter paper, and a carbon cartridge will be set behind this for the collection of iodine isotopes.

The filters and cartridges will be analyzed for gross beta, gross gamma, strontium, and by gamma-ray spectrometry. The results of the isotopic identification will be reported in tabular form in terms of $\mu c/m^3$. These data may be plotted as an isopleth of concentration as a function of position on the grid.

o. Noble Fission Gas Concentration in the Cloud and Their Isotopic Distribution

This information will be obtained by an instrument which utilizes two absolute filters and a delay tank. The air in the lower part of the cloud will be sampled and passed through an absolute filter to remove all fission products except the noble gases. These gases then pass into a delay tank where they remain for a specified period of time in which they partially decay into particulate radioactive daughter products. These daughters then pass through an absolute filter which may be removed and analyzed by a gamma-spectrometer. By analyzing the second filter of the fission-gas system and applying an appropriate mathematical analysis, the cloud concentrations of certain of the radioactive noble gases may be determined.

p. Cloud Concentration and Distribution of Radioisotopes According to Particle Size

Cascade impactors will be used to sample the lower part of the cloud to determine the airborne activity associated with different dust particle sizes. These units separate the aerosols into five distinct groupings with mass median diameters between 20 microns and 1/2 micron.

1189931

The optimum data that could be obtained would yield information regarding the association of certain fission products with a given particle size. In order to obtain this type of information, relatively high airborne activity is required. On the basis of the results obtained by the AEC Health and Safety group during the SPERT destructive test, little difficulty is expected in this regard. The minimum data to be obtained will give a relationship between activity and particle size. Further, it will be possible to use the total activity measurement obtained in this program for comparison with the data obtained by the high volume air samplers.

The Unico Cascade Impactor has been tentatively chosen as the most applicable unit for this program. The air flow will be provided by a Gelman Model 25001 low-volume pump. The individual impactor stages will be analyzed with a gamma-ray spectrometer, by strontium chemical analysis and presented in tabular form.

q. Measurement of Beryllium Release

Twenty-one low volume samplers equipped with Unico Cascade Impactors will be placed five feet above ground level at the stations as shown on the grid. These are the same units which are to be used for particle size measurements. In addition to these samplers, beryllium analyses will also be performed on filters used for collection of radioactive material in the high volume air-samplers and the telemetering system. Also, the filters used by the AEC Site Survey Group will be analyzed for beryllium.

Additional beryllium monitoring stations will be located at the air intake of the IET building and in the occupied areas of the IET.

In order to approximate isokinetic conditions, each cascade impactor head on the low volume samplers will be equipped with a wind vane which will direct the sampling port into the wind.

The AEC-developed adhesive paper, 4 in. by 9 in., will be placed one foot above the ground at all sampler locations. These fallout measurements will be supplemented, after the destructive tests, by swipe tests in the reactor and IET building areas.

As a pre-destructive test procedure, background beryllium, both airborne and fallout, will be measured under the proposed test wind velocities and direction in order to evaluate the natural beryllium contamination from beryl in the soil at the IET test site.

Shortly before the test, sampling equipment will be placed on the grid. Flow rates of the microsorban filter paper equipped air samplers will have been measured and adjusted to approximately 1000 ft/min (12 miles per hour) at the constricted air intakes. Immediately before the test, the samplers will be turned on. Total sampling time would be twice the cloud passage time as indicated by the telemetering systems. In addition, two sequential samplers which have already been purchased will be placed on the 300 meter arc for cloud path data.

Samples directly in the could path will be recovered first. The impactors will be placed in plastic bags, marked as to the location of the sampler, flow rate of the sampler and operating time. Then they will be sent to the spectrographic laboratory at TAN-607 for beryllium analysis. After radiological measurements are performed on the filters from the high-volume air samplers and the telemetering stations, they will be cut in half and analyzed by both the AEC and the AED laboratories. Air samples and surface swipe samples will be collected at the reactor as soon as is safely possible.

The telemetering system and data from the sequential samplers will be used to approximate cloud arrival and passage time. Based on cloud passage time, filter analysis, and particle sizing, the data will be interpreted in the following ways:

(1) The total collected beryllium at each station will be converted by means of a breathing rate factor into the total amount of beryllium that would have been inhaled by a standard man at that location.

(2) The average concentration will be calculated in micrograms per cubic meter using the ratio of beryllium collected to air volume sampled during the cloud passage.

(3) The impactor equipped low-volume air samplers will allow measurements to be made of the particle sizes of the airborne beryllium. From this information a determination of the percent of particles in the respirable range (less than 10 microns) will be made.

(4) An evaluation will be made of surface contamination based on adhesive paper and swipe test samples in the vicinity of the reactor.

C. Power Supply for the Grid System

Power will be supplied to the grid system from three sources.

(1) The 25 telemetering stations will be supplied with power from the 2.5 kilowatt generators located within the units.

(2) Power for all arcs out to and including the 300 meter arcs will be supplied from the IET building.

(3) Thirty 3.5 kilowatt generators will be used to power the high-volume air samplers, fission gas detectors and low-volume samplers on all arcs past the 300 meter arc.

A separate generator will be used to provide electrical power for the mobile field station trailer.

D. Physical Operation of the Monitoring System

When weather conditions are favorable for a test, the grid will be actuated. Collecting media such as filters and fallout plates will be placed in position. As conditions become more favorable the powered equipment will be actuated and the area cleared to await the test.

As soon as re-entry to the grid is possible, the following priority items will be recovered and will be rushed to their respective analysis locations in an attempt to identify as many short-lived isotopes as is possible. See note for identification of abbreviations.

ARC	H.V.	L.V.	F.P.	I_2	F.G.	NAD	P.S.
A			1			1	
B			1			1	
C	1	1	1	1		1	1
D	1	1	1	1		1	1
E	1	1	1	1		1	1
F	1	1	1	1	1		1
G	1	1	1	1	1		1
H		1	1		1		1
I	1		1	1			
J	1		1	1			
TOTAL	7	6	10	7	3	5	6

NOTE: H.V. = High volume air samplers
L.V. = Low volume air samplers
F.P. = Fallout plates
I_2 = Charcoal iodine filters
F.G. = Fission gas detectors
P.S. = Particle sizing stages

The filters and fallout plates which are the most radioactive will be the ones recovered from each arc.

The NAD's, film badges, and polymerization dosimeters on the upwind 25, 50, 100, 200, and 300 meter arcs will be recovered by the locomotive. They will be mounted on large rings on the third track from the north. A protruding metal pole from the locomotive will pick off these rings and return them as quickly as possible to TAN-607 for analysis.

E. Analyses

The priority items listed in Part D will be analyzed by the following departments.

(1) The MTR Radiation Measurements Section will provide a gamma scintillation spectrometer at TAN-607 for quantitative analysis of the seven high-volume air sampler filters, the ten fallout plates, the seven charcoal cartridges, the three fission gas detector filters, and the six particle sizing detector stages.

(2) The Spectroscopy Section of CPP will analyze the six low-volume beryllium filters, using an emission spectrograph.

(3) The ID Analysis Section will analyze the five Nuclear Accident Dosimeters.

The remaining filters, fallout plates, charcoal cartridges, and fission gas detector filters will be analyzed by the MTR Radiation Measurements Section. Since these items will be analyzed for the longer-lived fission products less emphasis will be required for quick analysis.

In addition, the CPP Special Analysis Section will analyze all filters and fallout plates containing significant radioactivity for strontium.

F. Control Procedure

An 8 ft by 37 ft trailer has been purchased for $300 from AEC surplus. This trailer will act as the radio control center for installation, recovery and dispatch of various sampling media from the downwind section of the grid. In addition, the trailer will provide:

(1) "hot" and "cold" change areas,

(2) protective clothing storage,

(3) portable monitoring instrument storage,

(4) first aid facilities,

(5) respiratory equipment storage, and

(6) decontamination facilities.

The trailer will be located at the north gate of the obstruction fence, a central location from which there are four separate roads.

G. Future Uses of Equipment

The grid monitoring equipment can be used for all of the SNAPTRAN tests as well as the proposed LOFT and NTF programs. In particular, the portable telemetering system may be used at any location in the TAN area.

1189936

H. Measurements Farther than the STEP Grid

ID has been asked (McC-117-62A) to provide the following measurements as a part of their site monitoring program at distances farther than the STEP grid:

(1) Direct gamma and beta exposure from the cloud as determined by film badges at two positions within the cloud path.

(2) Total gamma exposure and gamma dose rates from two positions on each arc within the cloud. Vehicles could be used to position recording dose-rate instruments and air sampling equipment within the path of the cloud in order to reduce the number of stationary sampling stations.

(3) Total exposure from fallout as determined by dose-rate instruments and film badges at two points within the cloud path and a fallout and dose-rate profile along the area.

(4) Fallout concentrations in curies/m^2 and complete isotopic identification of activities (fallout plates) from two positions within the cloud path.

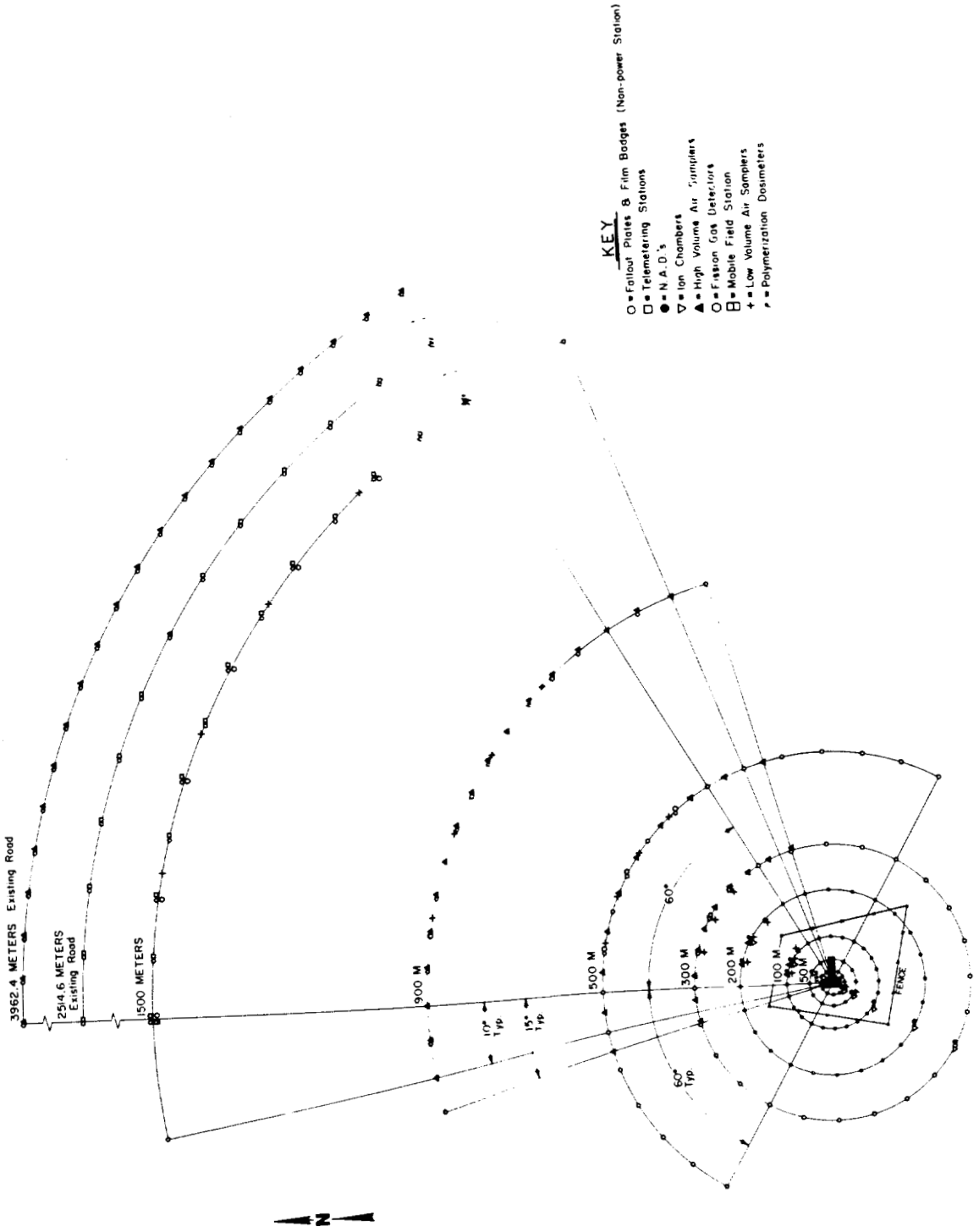
(5) Particulate activity at two positions in the cloud (curies/m^3) and complete isotopic identification of the activity.

(6) Iodine concentrations at two positions in the cloud (curies/m^3) and iodine isotopic identifications.

ID has agreed by letter to perform these six measurements in such a manner as to provide adequate correlation of ID's data with AED Health and Safety's data.

1189937

APPENDIX A


KEY
O = Fallout Plates & Film Badges (Non-power Station)
□ = Telemetering Stations
● = N.A.D.'s
▽ = Ion Chambers
▲ = High Volume Air Samplers
O = Fission Gas Detectors
⊟ = Mobile Field Station
+ = Low Volume Air Samplers
r = Polymerization Dosimeters
3962.4 METERS Existing Road
2514.6 METERS Existing Road
1500 METERS
900 M
500 M
300 M
200 M
100 M
50 M
10° Typ
15° Typ
60° Typ
60°
FENCE
N

APPENDIX B

SNAPTRAN MONITORING EQUIPMENT

Arc	Radius (meters)	Arc Angle	F.B.& F.O.P.*	Hi-Vols	Lo-Vols	T-M**	Ion-Chamber	NAD	F.G.D.***
A	25	360					2		
A	25	360	12					1	
B	50	360					2		
B	50	360	12					1	
C	100	360		2	3		2		
C	100	360	24					1	
D	200	360		2	3		2		
D	200	360	24					1	
E	300	90		10	3		2		
E	300	360	24					1	
F	500	90		10	4				3
F	500	180	19						
G	900	80		17	4				3
G	900	90	10						
H	1500	60		0	4	13			7
H	1500	80	15						
I	2515	60		1		12			
I	2515	60	13						
J	3962	60							
J	3962	60	21	21					
	TOTAL		174	63	21	25	10	5	13

* Film badges and fallout plates
** Telemetering units
*** Fission gas detectors

1189939

APPENDIX C

COST ESTIMATE

Description	Quantity	Unit Price	Total Estimated Cost
Fallout plates	160	$ 38	$ 6,080
Fission gas detectors	12	150	1,800
Beryllium detectors and particle sizing equipment	21	250	5,250
High volume air samplers	59	150	8,850
Ion chambers	10	1,194	11,940
Power generators	30	500	15,000
Radios	5	500	2,500
Renovation of telemetering system	25		24,550
Trailer renovation	1		1,000
Mobile monitoring vehicle	2	3,000	6,000
Power cable			4,050
Contingency (15%)			13,053
TOTAL			$ 100,073

1189940

DISTRIBUTION

1. R. W. Thomas
2. R. L. Doan
3. J. P. Lyon
4. J. R. Huffman
5. L. J. Weber
6. M. H. Bartz
7. B. F. Boardman
8. F. H. Tingey
9. J. F. Kaufmann (6)
10. W. E. Nyer
11. M. E. Thomas
12. G. O. Bright
13. F. Schroeder
14. J. C. Haire
15. T. R. Wilson
16. F. L. Bentzen
17. E. C. Newman
18. F. C. Haas
19. J. W. McCaslin
20. J. F. Sommers
21. R. E. Hayden
22. B. D. Johnson
23. B. L. Rich
24. I. J. Wells
25. A. L. Smith
26. O. L. Cordes
27. R. R. Landolt (10)
28. O. M. Hauge
29. G. F. Brockett
30. W. J. Neal
31. R. W. Decker (2)
32. R. I. Kuehl
33. D. G. Reid
34. J. H. Ronsick
35. W. D. Laney
36. J. M. Waage
37. G. B. Matheney
38. W. E. Kessler
39. G. L. Smith
40. STEP Internal (25)
41. Technical Library (10)

1189941