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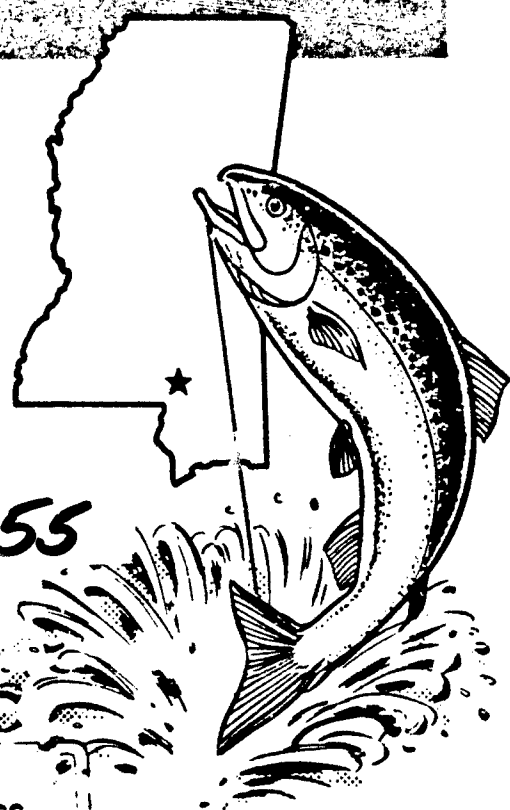
VUF-3016  
FINAL REPORT

**VELA UNIFORM PROGRAM**  
**PROJECT DRIBBLE**  
**SALMON EVENT**  
TATUM SALT DOME, MISSISSIPPI  
22 OCTOBER 1964  
part of an experiment in seismic decoupling at the nuclear level  
SPONSORED BY THE ADVANCED RESEARCH PROJECTS AGENCY  
OF THE DEPARTMENT OF DEFENSE AND THE U. S. ATOMIC  
ENERGY COMMISSION

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**Vent-Gas  
Treatment Plant**

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D. Snoeberger & R. Heckman, Editors  
Lawrence Radiation Laboratory

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VUF 3016

PROJECT DRIBBLE  
SALMON EVENT

VENT-GAS TREATMENT PLANT

D. Snoeberger and R. Heckman, Editors

Lawrence Radiation Laboratory  
University of California  
Livermore, California

March 1966

## VENT GAS TREATMENT PLANT

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R. Holzman, C. Hannon, J. Harrar, C. Morris, L. Rigdon,  
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## INTRODUCTION

As part of the Vela Uniform program, Project Dribble was concerned with the measurement of seismic signals generated by nuclear detonation in a salt dome. The principal objective of the project was a test of the decoupling theory proposed by Latter et al.<sup>1,2</sup>

In September 1962, after resumption of underground nuclear testing, Project Dribble was redefined. Certain technical responsibilities including the detailed design of the experiment, development of the technical program and execution of the on-site portion of the technical program were assigned to the Lawrence Radiation Laboratory through the Atomic Energy Commission.

The planned 5-kiloton detonation occurred October 22, 1964, in the Tatum Salt Dome near Hattiesburg, Mississippi.

Technical objectives of the post-shot program for this event were to:

- 1) Obtain samples of radioactive debris for yield determination.

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<sup>1</sup>Latter, A. L., E. LeLevier, E. Martinelli, and W. McMillan, "A Method of Concealing Underground Nuclear Explosions," J. Geophys. Research, 66, 943-946 (1961).

<sup>2</sup>Werth, G., and P. Randolph, "Prepared Statement on the Theory of Decoupling and the Status of Project Dribble, for the Joint Committee on Atomic Energy, Congress of United States," UCRL-7323, March 6, 1963.

- 2) Sample the gas in the cavity to determine whether radioactive material which might cause a public safety problem had escaped.
- 3) Examine the feasibility of re-use of the cavity for firing decoupled nuclear shots. Measurements to be made included distribution of radioactivity, temperature, volume, geophysical logging, and television survey.
- 4) Extract core from a second drill hole passing close to the cavity for property measurements.

To accomplish this post-shot technical program, an assured means of obtaining access to the cavity was required. Based on studies completed in 1961 on the cost and engineering feasibility of the various means of assuring cavity access, it was decided that a vent-gas treatment facility was needed. This facility was to be connected to the post-shot drilling rig at the well head and was to remove radioactive particulates from the cavity effluents and control release rate of gaseous radioactivity to meet public health safety standards.

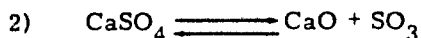
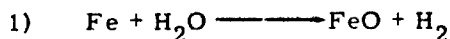
Process engineering studies resumed in September 1962. The problem was redefined with more stringent performance requirements added. The new requirements included the following points: The facility must remove radioiodine to eliminate any possible public safety problems. The release rate for the noble gas fission products, xenon and krypton, must not exceed limitations set by the limited test ban treaty, i. e. , no detectable activity beyond national borders. The plant must be removable before shot time and be quickly reinstalled to prevent damage to the plant components by nuclear seismic shockwave. Absolute reliability and control of plant radioactivity releases was to be accomplished by use of shut-off valves at the well head.

It was recognized that an explosive mixture of gases might be present in the post-shot cavity. To prevent any possibility of catastrophic failure of the plant components with subsequent radioactivity release, an air dilution venturi was added at the plant inlet. The flow rate of cavity gas into the dilution venturi was controlled so that an explosive mixture was never possible beyond the dilution venturi. In addition, all the well head piping upstream of the venturi was designed to contain any gas explosion that might occur.

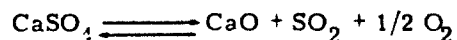
Since drill back into the cavity might occur as early as D + 7 days, the facility must be capable of handling the following fission product activity mixed with the gas: particulate -  $4 \times 10^5$  curies; radioiodine -  $8 \times 10^5$  curies; and radioxenon and krypton -  $1 \times 10^6$  curies; or a total of  $2.2 \times 10^6$  curies.

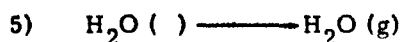
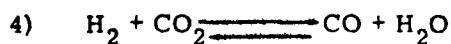
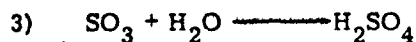
#### GAS TREATMENT PROBLEM

Predictions of the chemical environment of an underground nuclear explosion are very difficult; yet that is the problem with which we were faced in attempting to describe the feed conditions into our vent gas treatment facility. The design of the facility had to be sufficiently flexible to cover any possible situation that could occur in the field. From test hole samples, salt dome composition was estimated to be NaCl 91%,  $\text{CaSO}_4$  8%,  $\text{CO}_2$  0.015%,  $\text{H}_2\text{O}$  <0.01%, and traces of hydrocarbons. The principal gas-producing reactions were thought to be:



or





The iron was present from the emplacement canister. There was an uncertainty in amount of salt melt to be produced by the nuclear detonation and therefore the amount of  $\text{CaSO}_4$  available for reaction.

With these great uncertainties in the general chemical environment, we attempted to make predictions of the chemical state of the radioiodine. These predictions indicated the most likely forms to be  $\text{I}_2$  and  $\text{HI}$ .

Predictions of the cavity volume produced further uncertainties in expected pressures; cavity collapse would radically affect cavity pressure and temperature at the time of re-entry. With no collapse, the cavity temperature was estimated to be below the melting point of salt. The cavity pressure might range from 10 atm to a partial vacuum, depending on which chemical equilibrium prevailed.

With these considerations as background, we chose the following as design criteria for the facility: The problem was to release at controlled and safe rate approximately  $5.6 \times 10^5 \text{ ft}^3$  of gas initially at a pressure of 10 atmospheres or less. Release was to begin one to four weeks after the shot, depending upon time required to drill the postshot well. The vented gas temperature would be at ground ambient temperature because of heat transfer to the earth and well casing during passage up the well. There might be enough hydrogen and oxygen present to constitute an explosive mixture, possibly in a detonation range. The gas was expected to be acidic, corrosive

and saturated with water. It might carry suspended salt particles capable of plugging flow passages. Radioactivity was estimated to be a maximum of 4.0 curie per cubic foot of gas fed to the plant.

Later times of re-entry and bleed down would allow further decay of radioactivity. Radioiodine activity,  $I^{133}$ , predominates after 10 days, but decreases by a factor of 10 per month. Xenon activity falls off a little faster but krypton 85 activity predominates over those of xenon and iodine after roughly three months, contributing approximately a total of 200 curies.

A controlled release of the cavity gas these further effects were expected: Excess water vapor would condense on the wall or on cold salt, dissolve salt, and return to the cavity. This process might continue by reflux. There may be a net beneficial effect in separation of gases and particulates by this "wetted wall column." There might be problems with salt plugging in the well.

Radioactive particulates and iodine were to be removed from the vented gas; xenon and krypton were to be dispersed in the atmosphere.

The release rate was limited to allowable rates for iodine, xenon and krypton as determined by public safety and limited test ban treaty consideration. It was important to complete bleed down in as short a time as possible to minimize cost and degradation of data for the post shot programs.

Pre-operational tests with radioactive iodine were made in July 1964. The plant was removed to avoid shock damage, then reinstalled after the test detonation. Operational use began in February 1965, and continued intermittently through May 1965. Figure 1 shows the plant piped to the re-entry well late in the operational period. The plant is now in caretaker status pending development of requirements in connection with re-use of the cavity for further experiments.



Prior to the actual detonation the decision was made to delay start of post-shot drill back for 60 days to accomplish additional technical requirements for the detection program. Because of this delay a large fraction of radioactivity decayed, and the cavity cooled to 204°C. At the time of cavity penetration, the cavity was found to be under a partial vacuum of 313 millibars.

On the basis of pre-operational performance tests and the actual operating experience, we feel that we successfully designed and built a vent gas treatment facility whose performance exceeded our original design specifications. The desired flexibility was demonstrated by our ability to support a wide variety of down-hole operations that resulted from actual conditions found in the field. However, our ability to predict the chemical environment of an underground nuclear explosion leaves something to be desired. We recognized our ignorance in this area and by use of a very conservative design we did conduct a post-shot technical program successfully without endangering the public safety or violating the limited test ban treaty.

#### DESCRIPTION OF PROCESS AND PLANT

The process is a remotely operated gas scrubbing and filtering system with charcoal adsorption units incorporated with the filters. It is sized to take up to 200 ft<sup>3</sup>/min of cavity gas mixed with 2000 ft<sup>3</sup>/min of air to dilute hydrogen. Effluent gas is discharged from a 150-foot stack after mixing with 20,000 cfm of additional air. Liquid wastes from the scrubbers are stored in four 25,000-gal tanks for later disposal. Figure 2 shows the shutdown, flow control and main process units.

##### Well Head

The well head includes the cavity gas shut-off valves. There are six, two in series plus a sampling valve on each of the two connections to the plant.

These valves are remotely operable. They are designed to fail to a closed position and will close automatically on loss of electric power or failure of the process equipment.

#### Flow Control and Dilution

Flow control valves, adjacent to the well, limit flow to rates based on the hydrogen dilution requirement or radioactivity release limit. The venturi serves to dilute cavity gas to below the lower explosive limit for hydrogen and provide suction for faster flow at low cavity pressures. Equipment working pressure ratings are 3000 psig prior to dilution and 150 psig after dilution.

#### Gas Scrubbers

The two scrubbers, in series, are a venturi-type and an impingement plate type. Their purposes are to remove particulates, protecting the filters from excess loading, and remove iodine. The scrubbing liquid is aqueous sodium hydroxide.

#### Filter Adsorbers

Each of three units installed in parallel consists of an activated charcoal bed with an "absolute" type filter preceding and following. A prefilter is used with each to avoid caustic damage to the glass fiber media of the high efficiency filters. These are modified Cambridge Filter Company C. B. R. \* units. Their purpose is to remove particulates carrying radioactivity and to adsorb radioiodine. One of the three is a reserve unit.

#### Stack

The stack is 150 feet high, clearing local trees and hills by 50 to 100 feet. A stack blower adds air at 20,000 ft<sup>3</sup>/min for local dilution. All effluent and contaminated tank vent gas is discharged through the stack.

\* Chemical Biological Radiological.

### Laboratory Trailer

A gas chromatograph provides feed gas analysis by sample pipe or bottle. Scrubbing solution analysis is provided by "auto analyzer" and pH and density instruments.

### PREOPERATIONAL TESTS

During the course of the project increasing emphasis was placed on removal of radioactive iodine. Although quantities and the compounds of iodine to be expected in the gas were not predictable, tests with a probable form,  $I_2$ , were made using I-131 as a gamma tracer. Results were excellent. The removal factor for the combined scrubbers and charcoal beds was  $4 \times 10^5$ .

### OPERATION OF FACILITY

This period began on February 26, 1965. It can be divided roughly into three phases: 1) a standby period prior to cavity penetration (Feb. 26 to Mar. 3); 2) an operation period during which the greatest part of actual vent gas treatment took place (Mar. 4 to Mar. 13); 3) a continuing period of standby and occasional operation (Mar. 14 onward).

A summary of operational experience follows:

#### 1. Cleaning of air drilling returns

A crossover line was installed from the drill rig "bloop line" into the plant 10-inch process gas line. This system allowed the plant to provide protection against spreading of radioactive salt dust and release of radiogas encountered in the final stages of drilling. Drilling returns were diverted

to the plant for cleaning when radioactivity release limits were approached. This was done on penetration drilling into the cavity and later while drilling for cores below the cavity.

## 2. Vent gas treatment

The true operating phase began at cavity penetration, early on March

4. A pressure measurement shortly after penetration showed 0.8-inch Hg vacuum, so no immediate attempt was made to bleed off cavity gas.

Gas sample bottles and temperature measuring instruments were lowered into the cavity, and the plant gas chromatography unit analyzed a sample of this gas. This important findings were that the gas was primarily air, with CO<sub>2</sub> the primary additional constituent. Both H<sub>2</sub> and SO<sub>2</sub> were present, but in concentrations too low to be of concern in operations.

The first appreciable quantity of gas vented from the cavity occurred of March 6, following pressurization of the cavity to one-half atmosphere positive pressure with drilling compressors for purposes of cavity volume measurements. This gas was released through the crossover pipe installed for drilling returns, which allowed flows at approximately 1000 cfm. Cyclic flow pulses, with a period of about 30 to 60 seconds, were observed during bleeding off of the gas. These may have been caused by a reflux water leg, which also may have been responsible for closing the hole with a salt plug.

Activity release was very low. The maximum release rate of radioactive rare gas is estimated at less than 200 millicuries/minute. Approximately 30 curies of rare gas, mostly Kr<sup>85</sup>, were released in the initial bleed down of the 300,000 cubic feet of air added for cavity volume measurement. Due to dilution by the stack blower, 5 microcuries per cubic foot was the maximum concentration in effluent gas. I<sup>131</sup> was so slight as to be detectable only with difficulty.

The second and final major release of cavity gas was from the flushing operation. This was a procedure to reduce the concentration of radioactive gas to such a level that treatment of vent gases would no longer be required. Three cavity volumes of air were pumped into the cavity and bled off, reducing residual gas to 40 microcuries per cubic foot rare gas radioactivity.

Release rate was a maximum of 50 millicuries per minute early in the operation, and declined slightly. Total release was approximately 50 curies, primarily Kr<sup>85</sup>.

### 3. Downhole operations support

Regulated flows of nitrogen and air and slight suction were provided to the well on demand to assist in the use of well logging instruments and television cameras. Cavity pressures were decreased to just below atmospheric pressure to establish downdrafts during insertion and removal of drilling equipment and instruments.

Repeated use of plant equipment was made to test by pressurization and pressure decay measurement for communication between well and cavity. The dilution venturi suction was used to speed up final stages of gas pressure bleed down for the time saving benefit.

Suction of gas downward from the well head was used to reduce gas hazards on the rig floor when unsealed insertions or removals were necessary.

### CONCLUSIONS GAINED FROM OPERATIONAL EXPERIENCE

The experience gained from the design and operation of this unique vent gas treatment facility has initiated a number of research and development studies to overcome many of the process engineering problems uncovered.

We are actively studying methods of arresting detonation waves. Solution of this problem would eliminate necessity of air dilution, with a subsequent decrease in size of processing equipment capacity by an order of magnitude.

From the measured performance of the charcoal scrubbers, we believe much of the radioiodine released was present as organic compounds possibly  $\text{CH}_3\text{I}$ . We have completed studies on improving the performance of charcoal adsorption beds for the removal of  $\text{CH}_3\text{I}$ . We are now studying new analytical techniques which will allow us to determine the chemical state of iodine in future field experiments.

Basic studies of the chemical nature of an underground nuclear explosion are underway. We plan to use computer calculation techniques and laboratory scale experiments, as well as actual field experiments involving underground nuclear detonations.

With the results obtained from these basic studies, we expect to be able to make better predictions of inlet feed streams and to design more compact, higher performance vent gas treatment plants in the future.



Fig. 1. Aerial view of vent gas treatment plant.

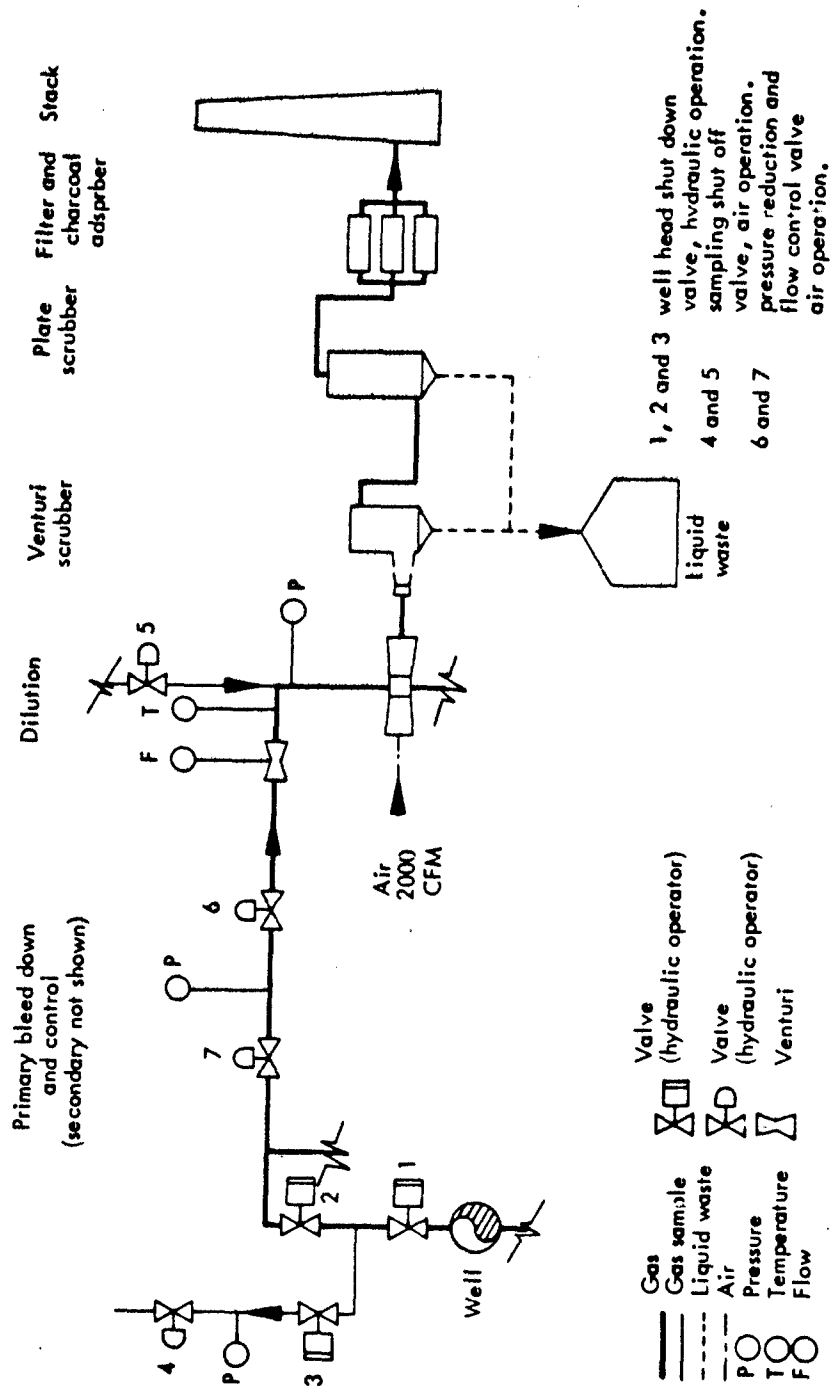


Fig. 2. Project Dribble bleed-down process flow and control schematic.



TECHNICAL AND SAFETY PROGRAM REPORTS SCHEDULED FOR ISSUANCE  
BY AGENCIES PARTICIPATING IN PROJECT DRIBBLE

SAFETY REPORTS

| <u>Agency</u> | <u>Report No.</u> | <u>Subject or Title</u>                                                                                         |
|---------------|-------------------|-----------------------------------------------------------------------------------------------------------------|
| USWB          | VUF-1020          | Weather and Surface Radiation Prediction Activities                                                             |
| USPHS         | VUF-1021          | Final Report of Off-site Surveillance                                                                           |
| USEM          | VUF-1022          | Pre and Post-Shot Safety Inspection of Oil and Gas Facilities Near Project Dribble                              |
| USGS          | VUF-1023          | Analysis of Geohydrology of Tatum Salt Dome                                                                     |
| USGS          | VUF-1024          | Analysis of Aquifer Response                                                                                    |
| REECO         | VUF-1025          | On-Site Health and Safety Report                                                                                |
| RFB, Inc.     | VUF-1026          | Analysis of Dribble Data on Ground Motion and Containment - Safety Program                                      |
| H-NSC         | VUF-1027          | Ground-Water Safety                                                                                             |
| FAA           | VUF-1028          | Federal Aviation Agency Airspace Advisory                                                                       |
| H&N           | VUF-1029          | Summary of Pre and Post-Shot Structural Survey Reports                                                          |
| JAB           | VUF-1030          | Structural Response of Residential-Type Test Structures in Close Proximity to an Underground Nuclear Detonation |
| JAB           | VUF-1031          | Structural Response of Tall Industrial and Residential Structures to an Underground Nuclear Detonation.         |

NOTE: The Seismic Safety data will be included in the USC&GS Technical Report VUF-3014

TECHNICAL REPORTS

| <u>Agency</u> | <u>Report No.</u> | <u>Subject or Title</u>                                                |
|---------------|-------------------|------------------------------------------------------------------------|
| SL            | VUF-3012          | Free-Field Particle Motions from a Nuclear Explosion in Salt - Part I  |
| SRI           | VUF-3013          | Free-Field Particle Motions from a Nuclear Explosion in Salt - Part II |
| USC&GS        | VUF-3014          | Earth Vibration from a Nuclear Explosion in a Salt Dome                |
| UED           | VUF-3015          | Compressional Velocity and Distance Measurements in a Salt Dome        |

|      |            |                                                                                                          |
|------|------------|----------------------------------------------------------------------------------------------------------|
| IRL  | VUF-3016   | Vent-Gas Treatment Plant                                                                                 |
| IRL  | PNE-3002 * | Response of Test Structures to Ground Motion from an Underground Nuclear Explosion                       |
| SRI  | VUF-3017   | Feasibility of Cavity Pressure and Temperature Measurements for a Decoupled Nuclear Explosion            |
| IRL  | VUF-3018   | Background Engineering Data and Summary of Instrumentation for a Nuclear Test in Salt                    |
| WES  | VUF-3019   | Laboratory Design and Analyses and Field Control of Grouting Mixtures Employed at a Nuclear Test in Salt |
| IRL  | VUF-3020   | Geology and Physical and Chemical Properties of the Site for a Nuclear Explosion in Salt                 |
| EG&G | VUF-3021   | Timing and Firing                                                                                        |

\* This report number was assigned by SAN

In addition to the reports listed above as scheduled for issuance by the Project DRIBBLE test organization, a number of papers covering interpretation of the SALMON data are to be submitted to the American Geophysical Union for publication. As of February 1, 1965, the list of these papers consists of the following:

| <u>Title</u>                                                                        | <u>Author(s)</u>                              | <u>Agency(s)</u>       |
|-------------------------------------------------------------------------------------|-----------------------------------------------|------------------------|
| Shock Wave Calculations of Salmon                                                   | L. A. Rogers                                  | IRL                    |
| Nuclear Decoupling, Full and Partial                                                | D. W. Patterson                               | IRL                    |
| Calculation of P-Wave Amplitudes for Salmon                                         | D. L. Springer and<br>W. D. Hurdlow           | IRL                    |
| Travel Times and Amplitudes of Salmon Explosion                                     | J. N. Jordan<br>W. V. Mickey<br>W. Helterbran | USC&GS<br>AFTAC<br>UED |
| Detection, Analysis and Interpretation of Teleseismic Signals from the Salmon Event | A. Archambeau and<br>E. A. Flinn              | SDC                    |
| Epicenter Locations of Salmon Event                                                 | E. Herrin and<br>J. Taggart                   | SMU<br>USC&GS          |
| The Post-Explosion Environment Resulting from the Salmon Event                      | D. E. Rawson and<br>S. M. Hansen              | IRL                    |
| Measurements of the Crustal Structure in Mississippi                                | D. H. Warren<br>J. H. Healy<br>W. H. Jackson  | USGS                   |

All but the last paper in the above list will be read at the annual meeting of the American Geophysical Union in April 1965.

LIST OF ABBREVIATIONS FOR TECHNICAL AGENCIES

|          |                                                                                                                |           |                                                              |
|----------|----------------------------------------------------------------------------------------------------------------|-----------|--------------------------------------------------------------|
| BR LTD   | Barringer Research Limited<br>Rexdale, Ontario, Canada                                                         | RFB, INC. | R. F. Beers, Inc.<br>Alexandria, Virginia                    |
| ERDL     | Engineering Research<br>Development Laboratory<br>Fort Belvoir, Virginia                                       | SDC       | Seismic Data Center<br>Alexandria, Virginia                  |
| FAA      | Federal Aviation Agency<br>Los Angeles, California                                                             | EG&G      | Edgerton, Germeshausen &<br>Grier, Inc.<br>Las Vegas, Nevada |
| GIMRADA  | U. S. Army Geodesy, Intelli-<br>gence and Mapping Research<br>and Development Agency<br>Fort Belvoir, Virginia | SL        | Sandia Laboratory<br>Albuquerque, New Mexico                 |
| H-NSC    | Hazleton-Nuclear Science<br>Corporation<br>Palo Alto, California                                               | SMU       | Southern Methodist University<br>Dallas, Texas               |
| H&N, INC | Holmes & Narver, Inc.<br>Los Angeles, California<br>Las Vegas, Nevada                                          | SRI       | Stanford Research Institute<br>Menlo Park, California        |
| II       | Isotopes, Inc.<br>Westwood, New Jersey                                                                         | TI        | Texas Instruments, Inc.<br>Dallas, Texas                     |
| ITEK     | Itek Corporation<br>Palo Alto, California                                                                      | UA        | United Aircraft<br>El Segundo, California                    |
| JAB      | John A. Blume & Associates<br>Research Division<br>San Francisco, California                                   | UED       | United Electro Dynamics, Inc.<br>Pasadena, California        |
| LRL      | Lawrence Radiation Laboratory<br>Livermore, California                                                         | USM       | U. S. Bureau of Mines<br>Washington, 25, D. C.               |
| NRDL     | U. S. Naval Radiological<br>Defense Laboratory<br>San Francisco, California                                    | USC&GS    | U. S. Coast and Geodetic<br>Survey<br>Las Vegas, Nevada      |
| REECO    | Reynolds Electrical &<br>Engineering Co., Inc.<br>Las Vegas, Nevada                                            | USGS      | U. S. Geologic Survey<br>Denver, Colorado                    |
|          |                                                                                                                | USPHS     | U. S. Public Health Service<br>Las Vegas, Nevada             |
|          |                                                                                                                | USWB      | U. S. Weather Bureau<br>Las Vegas, Nevada                    |

# PROJECT DRIBBLE

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