WEATHER AND SURFACE RADIATION PREDICTION

U. S. Weather Bureau


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WEATHER AND SURFACE RADIATION PREDICTION

by

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U. S. Weather Bureau

June 1964
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The Weather and Surface Radiation Prediction Unit commenced preliminary weather observations at the SHOAL Site in August 1962. Sufficient data was collected to insure statistical significance. Commencing on D-30, a complete weather analysis and forecasting unit was in operation at the SHOAL Site. The weather facilities, observation schedules, detailed pre-shot weather and radiation forecasts, and their verification are discussed.
CHAPTER I
INTRODUCTION

1.1 OBJECTIVES

Proper evaluation and minimization of the potential radiation hazard, associated with the possible venting of radioactive materials from the SHOAL underground nuclear detonation, required the utilization of meteorological facilities for measuring and predicting atmospheric conditions. The complement of the Weather Observation and Prediction Unit varied from intermittent observations by 3 meteorological technicians, commencing in January 1963, to a complement of 13 (meteorologists, aids and technicians) from D-1 to the time of the actual event.

1.2 FUNCTIONS

A primary responsibility of the WBRS, Las Vegas, Nevada, was the maintenance of a meteorological service at the SHOAL Site with the capability of preparing and issuing forecasts of meteorological elements pertinent to test activities and estimates of possible radiation exposure resulting from venting. These forecasts were made available to the Test Manager and his Advisory Panel in formal briefings on October 25 and 26, and in informal briefings at the Weather Trailer Office in the CP Area during the period D-21 until shot-time. The unit was responsible for the interpretation of meteorological data and
for advising test personnel on matters influenced by the state of the atmosphere.

1.3 ORGANIZATION

The Weather Observation and Prediction Unit was under the operational control of the Test Manager. Responsibility for the weather service was delegated by the Scientific Advisor to the Weather Prediction Unit, with the Meteorologist-in-Charge, WERS, Las Vegas, Nevada, acting as chief of the unit. Technical personnel and supervision were provided by the U.S. Weather Bureau.

The Weather Observation and Prediction Unit worked in close cooperation with the Radiation Prediction Unit in order that the Safety Program would have the benefit of the most accurate, up-to-date and useful information possible.

The Weather Observation and Prediction Unit consisted of observation personnel that operated the upper air sounding stations and processed meteorological data, equipment maintenance personnel responsible for preventive and repair maintenance of all forms of equipment, and forecasting and briefing personnel responsible for the accurate and timely forecasts of pertinent meteorological parameters.
CHAPTER II

2.1 OBSERVATIONAL PROCEDURE

From the climatological data obtained from surface wind instruments, plus the upper air records from NAF, Fallon, Nevada and upper air data obtained by MARS personnel at intermittent intervals covering all seasons, it was determined that the most probable meteorological conditions that would occur during most seasons would be northwesterly winds at the GZ surface, gradually shifting to southwesterly winds above 8000 feet MSL. (See Figure 2.1 - 2.3). From these data a ground zero site as well as two off-site pibal stations was selected in the most probable downwind sector. Pibal Station \( \text{#1} \) was located at the intersection of the Scheelite Mine Road and the Shoal Site Access Road. Pibal Station \( \text{#2} \) was located one mile north of Highway 50 on the dirt road extension of the Scheelite Mine Road.

The two off-site Pibal Stations afforded excellent statistics on low level winds on the Fairview Valley and, with simultaneous data from the ground zero site, the ability to provide reliable short range forecasts of the wind field in the vicinity of the SHOAL Site and Fairview Valley was established.

In the event that a wind regime other than that described above were to exist on D-Day, two alternate pibal sites were
selected and samples of upper air data were collected inter-
mittently for climatological statistics. Pibal Station 
was located at the salt mill in Fourmile Flat. Pibal Station 
was located alongside U.S. Highway 50, 15 miles west-north-
west of the Scheelite Mine Road intersection.

Prior to D-30, intermittent sampling of upper air data 
was conducted to determine the topographic effects on the 
lower level winds and to statistically compare the wind field 
above the surrounding topography with simultaneous upper wind 
observations taken at NAAF, Fallon in order to determine at 
what levels the wind fields were nearly identical. The data 
collected implied that the seven year record of wind statistics 
at 8000 feet MSL and above would apply to the SHOAL Site. The 
levels below 8000 feet MSL were definitely affected by the 
local topography. The proper location of downwind off-site 
pibal stations greatly alleviated the low level forecasting 
problem.

Commencing on D-30, simultaneous hourly upper wind observ-
ations from 0600-1300 PDT were taken at GZ and one off-site 
pibal station. This schedule was expanded to include both off-
site pibal stations commencing on D-21.

On D-14, and continuing through D-Day, the GZ observations 
were made from the M-33 radar located below CP alongside the
the CP Access Road.

On D-7, and continuing through D-Day, upper air pressure, temperature, and humidity observations were taken at 0730 PDT and 1000 PDT to augment the hourly upper air wind field data.

On D-1, and continuing through D-1, smoke pot observations were conducted at 1200 PDT at GZ to determine low level trajectories under northwest surface wind conditions. On D-Day these observations were conducted from the radar site at 0730, 0830, 0915, and 1115 PDT using tetrons (constant level balloons).

One surface wind speed and direction instrument and recorder was installed on the Communications Microwave Tower on the peak, approximately two miles southwest of ground zero. This instrument was so located to obtain as nearly as possible the true surface wind free of terrain effects. The other surface wind speed and direction instrument and recorder was installed approximately 500 feet west-northwest of ground zero.

In early October the two wind instruments were telemetered to the Weather Bureau Trailer at the CP Site in order to have the wind data immediately available to the forecaster.

Radio and telephones were used to disseminate weather information on-site. Off-site upper-air data were transmitted by radio communications. Tabulated weather data covering the event were distributed to principal participants immediately
after the event. Post-shot trajectories were computed and disseminated to USPHS and AFTAC until H+24 hours.

2.2 ANALYSIS PROCEDURE

Prior to D-30, local surface and upper air data were used to compile statistics on the general monthly wind and temperature pattern at the SHOAL Site. Commencing on D-30, facsimile charts were the major source of information required for general forecasting. These were supplemented twice daily by more detailed analysed surface and upper air charts from teletype data, and daily time cross-sections of the upper air wind, pressure, temperature, and humidity patterns from SHOAL Site observations were utilized as aids to detailed local forecasting.

Commencing on D-7, surface weather charts, the wind fields at 2000 feet above the surface, and the wind field at 10,000 feet MSL were analysed every six-hours.

2.3 WEATHER BRIEFINGS

The weather briefing was formally presented to the Advisory Panel by the Briefing Meteorologist. Briefing charts and forecasts used in the presentation were prepared by the Briefing Meteorologist assisted by the Project Officer. The final decision on the forecast and the briefing charts was the responsibility of the meteorologist giving the formal briefing. Briefing materials were graphical displays (Figures 2.4 and 2.5) of the:
10,000-foot prognostic streamlines for H-hour, with forecast trajectories to 48 hours for the 2nd standard level above the surface and to 24 hours for 10,000 feet MSL; clouds and weather for the period H-4 to H+8; and winds aloft and surface wind forecasts for ground zero bracketing shot time. Also included were the event forecast temperature sounding and wind profile to 14,000 feet MSL.

A daily forecasting service was maintained at the SHOAL Weather Trailer. Event briefings were prepared separately. One briefing was held in Fallon at an AEC conference room at 1300 PDT the day prior to the event; the second follow-on briefing for the Advisory Panel was held in the Test Manager's Trailer at H-2 hours. The final shot-time wind forecast in 1,000-foot increments up to 10,000-foot MSL was completed one hour prior to briefing time and given to the forecaster from the Radiation Prediction Unit.

After the pre-shot briefing, the Briefing Meteorologist monitored the latest incoming wind and weather data and interpreted additional data as necessary both before and after detonation. With venting a possibility at shot and after, the services of the Briefing Meteorologist were available to commence tracking activities and trajectories associated with any nuclear cloud resulting from such venting.
CHAPTER III
RESULTS

3.1 WEATHER CHRONOLOGY

During the period September 26 through October 23, extremely persistent weather conditions prevailed, characterized by abnormally warm and dry weather throughout the United States. During this period winds at the SHOAL Site were southeasterly from the surface up to approximately 10,000 feet MSL, an unacceptable direction since the winds were directed towards Fallon. On October 24th, a rapidly developing low pressure area moved into the Gulf of Alaska and was headed toward the Washington-Canadian Border. An active cold front passed the coastline in Washington the afternoon of October 25th, bringing torrential rain and high winds as far south as the North California Coast. The speed of this cold front was determined by successive hourly plots and, by 1100 PDT, October 25, it was determined that the front would pass through the SHOAL Site late on the 25th or early morning the 26th (See Figure 3.1). At this time it was also noted that the southern portion of the cold front, after passing the coastal mountain barrier, was producing progressively less amounts of precipitation. Based on the above, a forecast was issued for near perfect conditions to prevail at H-Hour the morning of the 26th.

The surface front passed through the SHOAL Site at 0215 PDT, October 26, indicated by a sudden wind shift at the surface from
south to northwest. Overcast skies prevailed until 0430 PDT, then rapid clearing occurred. By 0700 PDT, surface winds were steady northwest 9-12 MPH, with clear skies. Winds aloft indicated approximately a 60 degree wind shear aloft becoming southwest 20-25 knots at 10,000 feet. A temperature sounding at 0700 PDT indicated the front aloft to be at approximately 7500 feet MSL. Using normal slope for a frontal surface this indicated the front was at the surface (3000 feet MSL) approximately 50-75 miles southeast of the SHOAL Site. This was verified upon analyzing the 1200Z (0500 PDT) surface weather chart. (See Figure 3.3).

Figures 3.1 through 3.4 show the continuity of the surface weather charts. Figure 3.5 is a streamline analysis of the 10,000-foot wind at H+1 hours indicating a moderate southwesterly wind field above the SHOAL Site.

Table 3.1 below indicated the measured mean layer winds observed on 24-26 October with the potential fallout arcs measured in degrees true from GZ and the angular width of the potential fallout area.

3.2 WIND FORECAST VERIFICATION

One method of obtaining a measure of forecasting skill is to compare the forecast made by the Briefing Meteorologist with a "persistence forecast" made by the wind sounding prior to the
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TABLE 3.1

YEAR LAYER WITH SUMMARIZED 24 OCTOBER 1969
briefing with both projected to the actual event time and compared with shot time winds.

The briefing wind forecasts and persistence wind forecasts are compared to the actual shot time winds in Table 3.2, and error evaluations are made for each level in speed and direction.
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**Table 3.2: Wind Verification Data**

**NOTE:** Values are in whole degrees.

**Event Time:** 1000 PPI
**Event Date:** October 25, 1963
**Beginning Date:** 0600 PPI

For 1000 PPI - October 26, 1963

For 1000 PPI - October 26, 1963

Predicting Error: 0300 PPI

Report Run: 0600 PPI
3.3 RADIATION CHRONOLOGY

The SHOAL experiment was designed to completely contain underground all radioactive materials produced by the detonation. Based on previous experience, the 1200-foot burial depth of the device was sufficient to prevent a blowout through the overburden. Closure of the horizontal tunnel was anticipated both because of the vertical buttonhook emplacement of the device and the presence of a fault in the tunnel which was expected to cause collapse at that point. To prevent gases leaking through the tunnel and up the vertical shaft to the surface, a series of sand stems was used in the tunnel and in the lower portion of the shaft. The combination of these factors minimized the probability that venting would occur through the tunnel. Cracks, however, would be formed as a result of the detonation which might intersect existing faults in the immediate vicinity, this producing a possible means of escape for radioactivity. This mechanism was considered most probable for the maximum credible release. The material release would be inert gases - all particulates being removed before reaching the surface. The initial release would probably not take place immediately but would require several hours because of the long and indirect path to the surface. If venting of this nature occurred it was expected to continue for many hours. A modified form of Sutton's continuous point source diffusion equation was
used to predict total exposures due to the vented radioactive gases.

Consideration was also given to the consequences of immediate venting with the fraction of total activity out per unit time being similar to the Gnome event. This was considered to be an extremely unlikely occurrence. The estimated peak dose rates due to cloud passage would undoubtedly be conservative because of the differences in stemming.

It was assumed that 0.4% of the radionuclides Xe and Kr produced by the detonation would be released to the atmosphere over a 24-hour period beginning at H+6 hours and ending at H+30 hours. The hazard associated with these radionuclides is in the form of an external gamma dose and therefore total exposures due to the passing cloud of gases as a function of distance from ground zero was computed. Since the 24-hour release would occur during both a nighttime and a daytime atmosphere, a separate set of meteorological parameters was used to determine the exposure for each period and then totaled. This amounts to assuming that the mean wind directions would remain constant during the entire 24-hour period. It was further assumed that the meander of the plume would be confined to a very narrow 10° sector. These assumptions tend to make the estimate very conservative. Each Xenon and Krypton nuclide was examined separately and the total
exposure at all distances produced by each nuclide was compared with the maximum permissible exposure as furnished by the Operational Safety Division, NVOO. The predicted total exposure to $^{135}\text{Xe}$ produced the greatest hazard but it was approximately two orders of magnitude below the maximum permissible ($1.7 \times 10^{-2}$ cur·min/m$^3$) at a distance of five miles downwind, the radius of the exclusion area. This estimate is shown on Figure 3.7.

Peak dose rates due to cloud passage for the unlikely case of immediate venting are shown in Figure 3.8. A 3000-foot cloud layer, 30° of shear in the fallout hodograph and a mean layer wind speed of 10 mph was assumed. A hot line bearing of 135° was predicted. The nearest populated site downwind on this bearing is the town of Cabbs at a distance of 35 miles. At this distance it was estimated that the peak dose rate due to cloud passage would be 20 mr/hr.

The pre-shot vertical temperature structure is shown in Figure 3.9. This diagram indicates an inversion at approximately 2000 feet above the GZ surface, however, a 3000-foot cloud layer was used in the prediction computations. This is because the SHOAL Site terrain drops off a few miles downwind to a valley, the elevation of which is approximately 1000 feet lower than the SHOAL GZ, making the use of a 3000-foot cloud layer reasonable.
3.4 RADIATION VERIFICATION

No radioactive materials were released to the atmosphere as a result of detonating the SHOAL device. This was verified both by ground and aerial monitors.
CHAPTER IV
POST-SHOT ACTIVITIES

As pointed out in Section 3.4, no radioactive materials were released to the atmosphere as an immediate result of detonating the SHOAL device. Thus it seems logical to assume that leakage of radioactive gases through small cracks in the overburden, possibly produced by the detonation, might occur at some later time or that pockets of gases might be encountered during the drill-back operation.

For this reason it was necessary to provide meteorological support until December 14, 1963 at which time the project manager decided there was no longer a requirement.

The extent of the meteorological support provided was a function of the drill-back progress. Initially four wind soundings were taken each day at 0400, 1000, 1600, and 2200 PST. Although no formal weather forecasts were presented, intermittent monitoring of the weather was maintained and forecasts were provided on request. Facsimile weather transmissions, teletype data for winds aloft analysis, and the local wind tower information were utilized. A constant level balloon (tetroon) was kept ready at all times in case radioactive gases should be released to the atmosphere. This tetroon would be useful in determining the radioactivity trajectory.
When the drill-back had progressed sufficiently the weather station was manned continuously.

Temperature soundings were taken at 0400 and 1600 PST and radar winds were taken at 0400, 0700, 1000, 1600, 1900, and 0000 PST. Estimates of radioactive gas concentrations as a function of distance from the source and the trajectory of the radioactivity were provided upon request.

Upon completion of weather support requirements at the SHOAL site, plans were made to make ready and return all Weather Bureau equipment to the Nevada Test Site.
Figure 2.1

Cumulative Frequency (%)
B. FREQUENCY GRAPHS SUMMER SEASON (May-September).

Figure 2.2

SURFACE WIND FREQUENCIES GROUND ZERO

Figure 2.3

UPPER WIND FREQUENCIES GROUND ZERO

-20-
BRIEFING FORECAST for 1330 25 October 1963
time date
VALID from 0600 PST 26 October to 1800 PST 26 October
time date
Latest Available Data 1200 Z 25 October 1963
time date

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WIND LADDER

VALID 26 October 1963

WIND TIME SECTIONAL Time: 06-18 PST

CLOUDS & WEATHER
VALID: 06-18 PST
26 Oct. 1963
Figure 2.5
0500 PDT
26 October 1963
Surface Analysis

Figure 3.3
26 October 1963
Surface Analysis

Figure 7.4
Figure 3.5
Figure 3.6  Graph of Predicted Total Exposure to Xe$^{135}$
Figure 3.7  Graph of Predicted Peak Dose Rates Due to Cloud Passage
Figure 3.8 Actual Pre-Shot Temperature Profile.
## AEC Reports

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* This is a Technical Report to be issued as PHK-3001 which will receive TID-4500 category UC-35 Distribution "Nuclear Explosions-peaceful Applications"

** Project Shoal results are combined with other events, therefore, this report will not be printed or distributed by DTIE

*** Report dated March 1964 has been published and distributed by USC&GS

**** Report dated December 9, 1963, DATDC Report 92, has been published and distributed by UED
### LIST OF ABBREVIATIONS FOR TECHNICAL AGENCIES

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<tr>
<td>BR Ltd.</td>
<td>Barringer Research Limited, Rexdale, Ontario, Canada</td>
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<tr>
<td>EG&amp;G</td>
<td>Edgerton, Germeshausen &amp; Grier, Inc. Boston, Massachusetts; Las Vegas, Nevada; Santa Barbara, California</td>
</tr>
<tr>
<td>FAA</td>
<td>Federal Aviation Agency, Los Angeles, California</td>
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<tr>
<td>GEO-TECH</td>
<td>Geo Technical Corporation, Garland, Texas</td>
</tr>
<tr>
<td>GIMRADA</td>
<td>U.S. Army Geodesy, Intelligence and Mapping Research and Development Agency, Fort Belvoir, Virginia</td>
</tr>
<tr>
<td>H-NSC</td>
<td>Hasleton-Nuclear Science Corporation, Palo Alto, California</td>
</tr>
<tr>
<td>H&amp;N, Inc.</td>
<td>Holmes &amp; Narver, Inc. Los Angeles, California; Las Vegas, Nevada</td>
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<tr>
<td>ISOTOPES</td>
<td>Isotopes, Inc. Westwood, New Jersey</td>
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<tr>
<td>ITEK</td>
<td>ITEK Corporation, Palo Alto, California</td>
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<tr>
<td>LPI</td>
<td>Lucius Pitkin, Inc. New York, New York</td>
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<tr>
<td>NBM</td>
<td>Nevada Bureau of Mines, University of Nevada, Reno, Nevada</td>
</tr>
<tr>
<td>NRDL</td>
<td>U.S. Naval Radiological Defense Laboratory, San Francisco, California</td>
</tr>
<tr>
<td>REECo</td>
<td>Reynolds Electrical &amp; Engineering Co., Inc. Las Vegas, Nevada</td>
</tr>
<tr>
<td>SC</td>
<td>Sandia Corporation, Albuquerque, New Mexico</td>
</tr>
<tr>
<td>SRI</td>
<td>Stanford Research Institute, Menlo Park, California</td>
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</table>
RFB, Inc.  
R. F. Beers, Inc.  
Alexandria, Va.

STL  
Space Technology Laboratories, Inc.  
Redondo Beach Park, California

TI  
Texas Instruments, Inc.  
Dallas, Texas

USBM  
U. S. Bureau of Mines  
Washington, 25, D. C.

USBM-PRC  
U. S. Bureau of Mines  
Bartlesville Petroleum Research Center  
Bartlesville, Oklahoma

USC&GS  
U. S. Coast and Geodetic Survey  
Las Vegas, Nevada

USGS  
U. S. Geologic Survey  
Denver, Colorado

USPHS  
U. S. Public Health Service  
Las Vegas, Nevada

USWB  
U. S. Weather Bureau  
Las Vegas, Nevada