TV Test Package
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TV Test Package

Compiled by

J. C. Hopkins
R. S. Thurston
J. T. Martin
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ABSTRACT
Several experimental packages were included on an NTS event to obtain qualitative information on spurious EM signals 16 to 20 msec after detonation. In addition a series of cryogenic experiments were performed to demonstrate the feasibility and simplicity of cooling underground instrument packages from a supply of liquid nitrogen.

INTRODUCTION
Several experimental packages were included on an NTS event to obtain qualitative information on spurious EM signals 16 to 20 msec after detonation. The experimental packages were:

1) Motorola Vidicon with TV camera,
2) Concord Vidicon camera with video amplifier,
3) Concord Vidicon camera without video amplifier,
4) photomultiplier tube, radioactive source, and pulse amplifier with gain of 500,
5) two battery operated pulsers, and
6) two thermistors.

The TV cameras viewed a test pattern with two thermometers, a hygrometer, and a pressure gauge. This experimental apparatus was used in conjunction with the CMF-9 cryogenic experiments described in Appendix A.

EXPERIMENTAL DETAILS
The experimental packages were housed in a copper box, electrically insulated from a surrounding steel box attached to the rack support cables. The center of the box was 110 ft above the device. The copper box was approximately 1 x 1 x 7 ft long. A 100-liter liquid-nitrogen dewar was housed in a steel cannister suspended below the steel box.

The electrical grounding scheme is shown in Fig. 1. The six signals were displayed on oscilloscopes and were recorded by high-speed drum cameras and slow-speed movie cameras. Two video signals were also recorded by video tape recorders.

The three TV signals and the photomultiplier-tube signal were sent through low-pass filters and emitter followers shown in Fig. 2. Figure 3 is a schematic diagram of the Model 333 pulse amplifier for the photomultiplier tube, an RCA 7764 with a 600-MΩ resistor string producing a current gain of $3 \times 10^3$ with a high voltage of 1200 V. A Sandia-Los Alamos Scientific Laboratory (P-4 type) 2-kHz chopper power supply was used for the high voltage. Figure 4 is a schematic diagram of the 2-kHz test pulser. Figure 5 is a schematic diagram of the P-1, Model 15 video amplifier.

The total cable length to the recording trailer was approximately 2000 ft.

The experimental apparatus without the copper box is shown in Figs. 6 and 7. In Fig. 6 the lower end is shown on the right, and the parts of the package are, from right to left: the NiCd batteries and switching network, isolation transformer, pulse amplifier, test-board lights, test-pattern board with various monitoring meters, and the photomultiplier tube and
pulse amplifier. Figure 7 is a close-up view of the TV cameras. The two bottom cameras were equipped with video amplifiers.

Figure 8 shows the details of the test-pattern board. A polaroid filter reduced reflection from the hygrometer-thermometer. Figure 9 shows the complete package suspended from an A-frame support prior to insertion. Figure 10 shows the package, on the rack cables, going down the hole.

RESULTS

Figure 11 is a dry-run video picture of the test board. The shot picture was identical to Fig. 11, with the exception that the pressure and temperature were different during the shot because of the cryogenic experiments.

Figures 12 and 13 are drum-camera traces of the signals during the shot. The package was turned on 2 min before shot time and remained on until it was destroyed. The amplitudes are shown in Fig. 12.

One pulser signal was transmitted by RG-215 cable. All other signals were transmitted through 3/8-in. Foam-flex cable.

Several observations should be noted:
1) The Foam-flex cable showed no pickup.
2) The RG-215 cable did show some pickup.
3) A large signal did appear on the PM line. This is interpreted as a signal picked up by the PM and associated circuitry before the amplifier. The peak amplitude at zero time was probably 50 mV or less.

Figure 14 shows a continuous picture of all signals from just before shot time until final destruction of the apparatus. The calibration on the thermistors line was 30 V/mm. The calibration on the AC signal line was 200 V/mm.

CONCLUSION

TV operation under conditions as described here is feasible. With reasonable precautions regarding grounding and RF shielding, no difficulty should be experienced with spurious EM signals. Some care, however, must be exercised in extrapolating this experience to new circumstances. Some devices appear to be much more powerful sources of RF noise than the one fired on this event. More work is necessary to shed light on this particular aspect. Guesses on the ratio of very noisy to relatively quiet shots may range from 1 to 5 up to 1 to 10.

ACKNOWLEDGMENTS

The work described in this report was performed by the following individuals:

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<tr>
<th>Code</th>
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<tr>
<td>P-10</td>
<td>D. M. Drake</td>
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<td>P-1</td>
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<td>P-3</td>
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<td>W-8</td>
<td>W. K. Brown</td>
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<td>J-12</td>
<td>J. A. Farrell</td>
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<td>J. D. Rogers</td>
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Fig. 1. Schematic diagram of TV package.
Fig. 2. Schematic diagram of low-pass filter and emitter follower.
Fig. 3. Schematic diagram of puloc amplifier.
Fig. 4. Schematic diagram of 2-kHz pulser.
Fig. 5. Schematic diagram of video amplifier.
Fig. 6. Entire package without the copper box.

Fig. 7. Close-up view of TV cameras.
Fig. 8. TV test-pattern board.

Fig. 9. Entire TV package with the cryogenic apparatus below.
Fig. 10. TV package at insertion into the hole.

Fig. 11. TV picture of test board (dry run).
Fig. 12. Drum-camera traces at zero time ($T_0$).
Fig. 13. Drum-camera traces at zero time ($T_0$).
Fig. 14. Traces for entire time range.
Fig. 14 (continued)
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1. OBJECTIVES

The primary objective of a series of cryogenic experiments performed in conjunction with an NTS shot was to demonstrate the feasibility and simplicity of cooling underground instrument packages at the Nevada Test Site from a supply of liquid nitrogen. The instrument package contained three TV cameras dissipating a total of 60 W, nickel-cadmium batteries, and associated electronic equipment. The secondary objective was to investigate the ability of the instrument package to exchange heat with backfill and the ability of gN₂ to flow through the backfill to the surface.

2. TEMPERATURE RATING OF ELECTRONIC EQUIPMENT

According to Gordon Smith, J-12, the manual on TV equipment indicates a Vidicon camera can operate between -25 and +55° C (-13 to +130° F), and an Image Orthocon camera can operate between -30 and +55° C (-22 to +130° F).

The Eveready Battery Manual states:

"Eveready sealed nickel-cadmium cells experience a relatively small loss of capacity at operating temperatures ranging from -20° C to +45° C. Within this range the characteristic stable discharge voltage is maintained. Ranges of temperature applicable to operation of the cells are:

Charge: 0° C + 45° C (+32° F to +113° F)
Discharge: -20° C + 45° C (-4° F to 113° F)
Storage: -40° C to +60° C (-40° F to +140° F)

The batteries may be discharged at a maximum temperature of 160° F (71° C). This does not apply to charging or storage as high temperatures in both instances are detrimental to the battery."

3. DESCRIPTION OF NTS COOLING SYSTEM

Figure A-1 shows the lower half of the instrument and the upper half of the cryogenic packages. Parts of three TV cameras are shown near the top of Fig. A-1. One is mounted above a Micarta board and two are mounted below it. The cut in the cryogenic container allowed access to the dewar fill port and solenoid valves shown wrapped with Mylar and tape to minimize dust problems. One solenoid valve was on a dewar exhaust line leading to the instrument package; the other was on a line exhausting into the container. The container in turn exhausted into the backfill through three stubs packed with steel wool. One of them is shown in Fig. A-1 to the right of the solenoid valves. The coolant from the dewar flowed through an insulated flex line into a connecting pipe for the instrument package. (The connecting pipe is on the left within the cryogenic container in Fig. A-1.) Shown above the connecting pipe is Tygon tubing, through which gN₂ flows until it exhausts through a tee under the TV cameras. The tee, as shown in Fig. A-1, was taped to the edge of the Micarta board so gN₂ could be directed at the cameras on either side of the board. Gas in the instrument package was exhausted into the cryogenic container through a Pall sintered stainless steel 10-15 micron filter, shown to the right of the connecting pipe and above a solenoid valve in Fig. A-1.

Gaseous nitrogen for cooling the instrument package was generated by boiling LN₂ in a 100-liter dewar through the use of two submerged 115-V, 450-W die heaters, connected in parallel, and voltage controlled by a Variac. These heaters were calibrated...
in \( \text{LN}_2 \) with short power leads. The calibration curve for single and dual heater operation is shown in Fig. A-2.

The ability of a 100-liter dewar to withstand an external pressure of 37 psig was verified in a test at the Sandia Test Laboratory in Albuquerque. This was done against the possibility that the backfill would not vent \( \text{gN}_2 \) out of the hole. After the pressurization test the dewar was filled with \( \text{LN}_2 \) and boiloff was found to be the normal 3% per day. Drawings of the cryogenic container are numbered 34Y1143-D-1, 2.

### 4. SURFACE TESTS AT LOS ALAMOS

On 3 January 1968 tests were performed on cooling the instrument package within a plywood box instead of a metallic container. The gaseous nitrogen was piped from the dewar to the lower right-hand corner of the plywood box by a thick-walled rubber hose. The nitrogen was piped within the box by a length of 3/8-in.-O.D. by 1/4-in.-I.D. Tygon tubing, which was taped to the right wall of the box. The gaseous nitrogen was discharged below the two TV cameras on the right side of the box. The nitrogen left the box through a 1-in. hole in its bottom left-hand corner.

The box was equipped with a thermistor on its right side at about the middle altitude of the battery packs, a thermistor on the left base side of the Micarta board supporting a TV camera, and a dial thermometer on the TV target panel. Four dial thermometers were added to these sensors. A thermometer with a 6-in. stem was inserted 1 in. above the lens of the right-hand TV camera. Thermometers with 4-in. stems were mounted through the right and left walls below the Model 15 amplifier drivers and on the base side of the Micarta board on which the pulisers were mounted. A 6-in. stem thermometer to measure outlet gas temperature was mounted from the left side below the battery pack.

Temperatures recorded during the test are shown in Fig. A-3. Thermistor readings are indicated by solid lines. Thermometers mounted from the right are designated by dashed lines, and thermometers mounted from the left are designated by dot-dashed lines. The room where the test was conducted was about 65°F. Zero time in Fig. A-3 corresponds to 1:40 p.m. The highest temperatures were registered on the No. 10 camera thermistor. Temperatures at conditions that approached equilibrium are shown in Table A-1. The computed inlet gas temperatures were based on a heat balance involving the rate of vaporization of liquid nitrogen, the heat load in the box, and the outlet temperature.

### TABLE A-1

<table>
<thead>
<tr>
<th>Near-Equilibrium Temperatures, Surface Test</th>
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<tr>
<td>Power dissipation in ( \text{LN}_2 )</td>
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<tr>
<td>LN2 flow rate</td>
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<tr>
<td>Thermometer above TV lens</td>
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<tr>
<td>Camera thermistor</td>
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<tr>
<td>Right amplifier thermometer</td>
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<tr>
<td>Left amplifier thermometer</td>
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<tr>
<td>Battery thermistor</td>
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<tr>
<td>Thermometer under batteries</td>
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<tr>
<td>Computed inlet gas temperature</td>
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During normal boiloff due to heat leak into a 50-liter dewar, J. R. Bartlit, CMF-9, found that temperatures at the end of a 6-ft vacuum-jacketed transfer line tended to level off near -50°F.

### 5. HOLE PARAMETERS

A cross section of the hole in which the underground NTS test took place is shown in Fig. A-4. The hole has a 4-ft I.D. The primary fill was 3/8-in.-max-dia of Bentonite. The uppermost layer of Bentonite was 24 ft thick. Based on the assumption that the average void factor was 40%, the void volume was computed to be 4,000 ft³. The atmospheric pressure at the instrument package was 18 mmHg (0.35 psi) higher than at the surface. The temperature in the vicinity of the instrument package was 75°F.

### 6. NTS PROCEDURE

A 100-liter dewar half-filled with LN2, containing two resistance heaters, and with two solenoid valves and a 10-psi pressure relief valve in place was shipped within the cryogenic container from Los Alamos to NTS. The dewar still contained LN2 when it arrived at NTS. The pressure relief valve vented into the cryogenic container. After the cryogenic container was attached to the instrument package, it was field tested above ground. These tests showed that with the TV cameras on the TV camera thermistor dropped from 84°F with a time
constant* of 1.9 hr when 12.1 lb/hr of \( \text{LN}_2 \) were boiled off, and then rose from 67° F with a time constant of 2.4 hr when the boiloff rate was reduced to 4.6 lb/hr.

The only temperature sensors available for the field tests were the thermistors and the dial thermometer on the TV target panel. The rate at which heat was dissipated in \( \text{LN}_2 \) was determined from an ammeter reading and Fig. A-2. The rate of boiloff of \( \text{LN}_2 \) was, in turn, determined from the heater wattage and the 13-psia line in Fig. A-5. A log was kept of \( \text{LN}_2 \) consumption to determine the amount remaining in the dewar. Figure A-6 presents a graphical illustration of this log.

7. DOWN HOLE TESTS

The dewar was filled to capacity and the operation of the system checked prior to its lowering into the test hole. All joints on the container were sealed with Silastic. When down hole the system was again checked by demonstrating its ability to cool the instrument package.

7A. HEAT-EXCHANGE EXPERIMENTS

An experiment in operating the instrument package without \( \text{N}_2 \) cooling was performed by W. K. Brown, P-3. He found that the temperature of the camera thermistor rose from 69 to 89° F in 2 hr. The time constant of the temperature rise for the uncooled operation was 3.6 hr. Two hours after the experiment ended the temperature of the camera thermistor dropped to 78.5° F, 4 hr later it was 73.5° F. After the initial drop, the time constant for cooling from the backfill was 7.2 hr.

Since it was undesirable to risk additional operating time on the TV cameras, an experiment similar to the surface test was canceled. As a substitute the instrument package was cooled by nitrogen with the TV cameras off. This substitute experiment was to estimate the rate of \( \text{LN}_2 \) boiloff which would yield the same time constant observed by W. K. Brown during the uncooled operation of the package. A boiloff rate of 12 lb/hr produced a time constant of 1.4 hr. A boiloff of 6 lb/hr yielded a time constant of 6.6 hr. An interpolation from these results to a time constant of 3.6 hr indicates that a boiloff of 9 lb/hr would maintain the package near 75° F. This corresponds to operating the \( \text{LN}_2 \) heater at 250 W, which agrees with the surface test data in Table A-I. It should be noted that a smaller boiloff rate could maintain the package at a higher but acceptable operating temperature.

7B. HOLE PRESSURIZATION EXPERIMENT

The ability of \( \text{LN}_2 \) to flow through the backfill to the surface was investigated by boiling off \( \text{LN}_2 \), exhausting it into the cryogenic container, and subsequently into the backfill. This resulted in boiling off 76 lb of \( \text{LN}_2 \) within 4 hr prior to a routine electronic test on January 30. When the electronics were turned on at 2:00 p.m., 5:15 p.m., and 7:30 a.m. the following morning, a pressure gauge in the instrument package was monitored by a TV camera. The readings are shown in Table A-II. Since the atmospheric pressure at the location of the cryogenic container is 18 mmHg higher than at the surface, where the reference side of the differential pressure gauge was sealed, this quantity was subtracted from the measured pressure to determine the pressure available to induce flow to the surface.

Since the pressure in the hole is proportional to the mass of nitrogen it contains, the pressure decay rate, \( \dot{p} \), is also proportional to the rate at which nitrogen is flowing away from the instrument.
Thus, 
\[ \dot{p} = C \dot{\theta}, \]  
(A-1)

where \( C \) is the proportionality constant. In laminar flow the rate at which nitrogen is flowing is proportional to the pressure available to induce flow, \( p \). Thus, 
\[ p = R \dot{\theta}, \]  
(A-2)

where \( R \) is the resistance coefficient. From Eqs. A-1 and A-2, the pressure available to induce flow during the pressure decay at the instrument package is
\[ p = p_0 e^{-t(C/R)}, \]  
(A-3)

where \( p_0 \) is the pressure at the beginning of the decay. The data in Table A-II are within 12% of Eq. A-3 for a time constant \((R/C)\) of 7.3 hr. Therefore, laminar flow is a reasonable assumption for estimating rates of pressure decay and gas diffusion through the backfill.

If it is assumed that steady conditions existed after boiling off \( \dot{N}_2 \) for 4 hr, the pressure of 212 mmHg corresponded to a \( N_2 \) flow rate of 18.6 lb/hr.

Accordingly, the steady-state pressure developed by boiling \( \dot{N}_2 \) in similar holes of different depths can be estimated from
\[ p = 25.7 \left( \frac{L}{1000} \right) + \left( \frac{212}{18.6} \right) \left( \frac{L}{690} \right) \dot{\theta} \]
or
\[ p = \left( \frac{L}{1000} \right) (25.7 + 16.5 \dot{\theta}), \]  
(A-4)

where
- \( p \) = pressure above that on surface, mmHg.
- \( L \) = depth of cryogenic container, ft.
- \( \dot{\theta} \) = rate at which \( \dot{N}_2 \) is boiled, lb/hr.

The first term inside the parentheses represents the increase in atmospheric pressure with hole depth.

8. GUIDELINES FOR FUTURE APPLICATIONS

a) In order to maintain an instrument package near 75°F, 4 W of \( \dot{N}_2 \) refrigeration (frigawatts) are required to cool 1 W of thermal load (thermowatts). This is equivalent to boiling 0.087 liters/hr (0.155 lb/hr) of \( \dot{N}_2 \) to cool a thermowatt. Higher temperature operation will result in a lower rate of consumption of \( \dot{N}_2 \).

b) The typical boiloff due to heat-leak of a standard 100-liter dewar is 3% per day, or 0.22 lb/hr. The typical boiloff of a standard 50-liter dewar is 6% per day, or 0.22 lb/hr.

c) The temperature of \( N_2 \) exhausted into an instrument package is approximately -50°F during normal boiloff, and -100°F when \( \dot{N}_2 \) is boiled to cool a thermal load.

d) The time constant for cooling the instrument package by the backfill is 7.2 hr. The package can be expected to return to the backfill temperature overnight.

e) The steady-state pressure at the instrument package when nitrogen is boiled can be estimated from Eq. A-4.

f) The time constant for the rate of pressure decay when the cryogenic container was at a depth of 690 ft was 7.3 hr. For different depths in similar holes the time constant would be proportional to the depth.

g) A standard 100-liter-\( \dot{N}_2 \) dewar can withstand an external pressure of at least 37 psi.

h) The heaters for boiling \( \dot{N}_2 \) should be calibrated to produce a curve similar to Fig. A-2. This calibration curve can be used with Fig. A-5 to account for \( \dot{N}_2 \) consumption.

i) It is advisable to keep a log of \( \dot{N}_2 \) consumption. This requires either a conscientious operator with a time piece and a logbook or an automatic recording of heater current.

j) The control system need only be a simple, manually operated Variac for the heaters and on-off switches for the solenoid valves. A pressure relief valve on the dewar is mandatory.
Fig. A-1. Instrument and cryogenic packages.
Fig. A-2. Eeater output in watts versus current.
Fig. A-3. Nitrogen cooling of box containing three TV cameras.
Fig. A-4. Cross section of hole for underground test of $\text{HN}_2$ cooling system.
Fig. A-5. Boiloff versus heater watts.
Fig. A-6. Log of \( \text{LN}_2 \) remaining in dewar.
OFFICE MEMORANDUM

TO: John C. Hopkins

SUBJECT: J-12 Program for AXE

SYMBOL: F-3OR East

DATE: December 15, 1967

We propose to include several simple experiments on AXE. The prime objective is to obtain qualitative information on spurious EM signals over a period of 16 to 20 msec after detonation.

In order of priority the experimental packages are:
1. Vidicon TV camera viewing test pattern,
2. PM tube with suitable base (observing radioactive source and scintillator),
3. PM tube base only,
4. Pulser,
5. One or more magnetometers.

Problems of one form or another will undoubtedly prevent the inclusion of several of these projects on AXE. None are ready now.

This apparatus will be housed in a copper box, electrically insulated from a surrounding steel box attached to the rack support cables. Ten cables are available for signals and power; 3 RG 219 and 7-3/8" Foam-flex. The RG 219 will have sheathed armor. The inner copper box will be tied electrically to the skin of the F-3 recording trailer. Care will be taken to prevent ground loops. No use will be made of a systems ground.

The oscilloscope displayed signals will be recorded photographically in the F-3 recording station. The vidicon signals will also be recorded with a magnetic tape recorder.

Present Status:
1. Experimental Packages: some hardware on hand. None tested or assembled for this experiment.
2. Power requirements: some battery from package, some 47, some HV. Requirements not yet firm.
3. Recording Station: oscilloscope and camera well in hand. TV magnetic tape recorder ordered, but has not arrived.

Future:
We hope to have a complete experimental package, without the surrounding copper box by 5 January 1968.

* This event was not fired.