SLIFER Measurement for Explosive Yield

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SLIFER MEASUREMENT FOR EXPLOSIVE YIELD

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ABSTRACT

This report describes the SLIFER (Shorted Location Indicator by Frequency of Electrical Resonance) system used at Sandia Laboratories for determination of explosive yield of underground nuclear tests.

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SLIFER MEASUREMENT FOR EXPLOSIVE YIELD

I. General Description

The explosive yield of a nuclear device is one of the more important quantities to be measured in any underground device test. Several methods of determining yield are in common use. Probably the most important of these methods is that using radio-chemistry. Another useful method is by means of the teleseismic signal. A third and less well known technique is by means of the SLIFER.

SLIFER is an acronym from Shorted Location Indicator by Frequency of Electrical Resonance. The technique, which is simply a method of continuously measuring stress-wave velocity in a solid or liquid material, has been in use at the Nevada Test Site and at other test sites since the advent of underground nuclear testing. Numerous events have had SLIFER measurements applied in the emplacement bore hole or in a nearby satellite hole.

Recent developments by R. C. Bass of the Sandia Laboratories and D. D. Eilers of the Los Alamos Scientific Laboratory have improved the technique of yield measurement with an emplacement hole SLIFER. This yield measurement is almost completely independent of the type of geological material in which the detonation takes place and requires only accurate measurement of shock front position as a function of time following the detonation.

The relation between shock position and time takes the form:

\[
\frac{\text{Radius}}{(\text{Yield})^{1/3}} = a \left( \frac{\text{Time}}{(\text{Yield})^{1/3}} \right)^b
\]

Radius is in metres, yield is in kilotons, and time is in milliseconds with empirically determined values for \(a\) and \(b\) being approximately 6 and 0.47. The relation appears to be valid for all yields and to be essentially independent of geologic materials in the hydrodynamic regions immediately adjacent to detonations. Calculations for other geologic media support the "universal" nature of the relation.

The approximately 6th power dependence of the yield on the radius suggests that any constant error in shock position data can easily be found permitting accurate yield determination without exact knowledge of the location of the explosive center point. A data analysis scheme
which systematically varies the radius will give the error and hence the correct yield when the sequence of radius-time data points fits the universal curve, that is when the ratio of the standard deviation to the average yield value is a minimum.

Figure 1 is an artist’s conception of the SLIFER system as used for hydrodynamic yield measurements on underground nuclear tests.

The hardware used in SLIFER measurements is quite simple compared with other instrumentation systems in use at the Nevada Test Site. The system, as shown in the block diagram of Figure 2, consists of a shorted length of air or solid dielectric coaxial cable as a component in the tank circuit of an oscillator. The system utilizes the fact that a shorted coaxial cable less than one-fourth wavelength long at the resonant frequency is inductive. As the very strong stress wave proceeds outward from the detonation, the SLIFER cable is crushed. As the short proceeds along the cable, the inductance decreases and the frequency of the system increases. Frequency, the parameter being measured, plotted against time, can be converted to shock front position versus time.
The field installation is quite simple. The lower end of the SLIFER cable is attached to the
down-hole string at a location between 3-15 metres above the device center. While not required,
a measurement of this distance is usually made. The only real requirements are that the cable
be within the hydrodynamic shock region of the geological containment material and be in a com­
pletely stemmed volume. The stemming or backfill material can be a solid or liquid such as
sand, concrete, drilling mud, or water. The SLIFER oscillator and the cable both above and
below the oscillator are included in the cable bundle to the device. The active portion of the
SLIFER cable is sometimes attached 30 to 60 cm away from the cable bundle in order to assure
its being completely surrounded by stemming material. In most installations, two SLIFERS are
used for redundancy.

The SLIFER system is a simple, low cost, easily installed, accurate yield measuring tech­
nique. Schematics and mechanical drawings for the complete system are included as Appendix A
to this report.

II. Down-Hole Hardware

SLIFER Oscillator

The SLIFER oscillator, shown schematically in Figure 3 and in the photograph of Figure 4,
is of the Colpitts type. The components are mounted on a 3.8 cm wide by 8.9 cm long printed
Figure 3. SLIFER Oscillator Schematic

Figure 4. Printed Circuit Card and Canister
circuit card which is mounted in a 5.0 cm diameter by 10.0 cm long aluminum canister with a type HN cable plug (male) on the uphole end, and a type N cable plug on the down-hole end.

The inductance of the SLIFER cable can be calculated by means of the following equation.

\[ L_1 = \frac{Z_0}{2\pi f_1} \tan \left( \frac{2\pi f_1}{V_c} \right) \]

Where:

- \( L_1 \) = resonant cable inductance for \( f_1 \) (henrys)
- \( Z_0 \) = characteristic impedance of cable (ohms)
- \( f_1 \) = full length of cable (metres)
- \( V_c \) = propagation velocity of cable (metres/s)
- \( f_1 \) = low frequency (full length of cable) (Hz)

After a value of resonant cable inductance has been determined for a given cable length and low frequency, the internal oscillator inductance \( L_{i1} \) is obtained from

\[ L_{i1} = \frac{L_1}{\left( \frac{f_o}{f_1} \right)^2 - 1} \]

Where:

- \( f_o \) = highest frequency in the frequency range of operation (resonant cable shorted at the oscillator) (Hz).

When the total inductance is known, the total capacitance required to obtain the desired frequency can be calculated using the following equation:

\[ C_T = \left( \frac{1}{2\pi f_1} \right)^2 \]

Where \( L_T = L_1 \) + tank circuit inductance. The small capacitor labeled "cal" in Figure 3 may be inserted to "tweak" the oscillator to the desired frequency.

Nominal frequencies used are 800 kHz with a full length of SLIFER cable, to 1200 kHz with the oscillator shorted at the SLIFER input. These frequencies were chosen to be compatible with the 900 ± 300 kHz discriminators available for data playback.
The SLIFER oscillator with its waterproofing neoprene rubber boots and cable end seal is shown on Drawing No. P90344, Appendix A. Normally, strain relief (Kellum) grips are installed on each side of the oscillator assembly. The Kellum grips are then fastened to turnbuckles which are attached to a supporting member located near the oscillator. A Kellum grip may also be used at the shorted end of the SLIFER to provide a tie-off point at the bottom. To provide additional mechanical protection during the downhole and backfill operation, an additional protector assembly, as shown on Drawing No. P73592, Appendix A, may be installed over the entire oscillator assembly.

Tests were conducted by Sandia on two transistor SLIFER oscillators (without SLIFER cables) to determine the effects of temperature vs. frequency. Results indicate a decrease in frequency of less than 2 percent from 0°F (-18°C) to 150°F (65°C).

SLIFER Cable

Various types of cables have been used as SLIFER cables on underground tests. All are approximately 1.25 cm diameter coaxial cables with 50 ohm impedance. Sandia and Los Alamos Laboratories have used the following types of cables:

1. Telcon (air dielectric)
2. Helical membrane (air dielectric)
3. Styroflex (air dielectric)
4. Heliax (air dielectric)
5. RG-213 (solid dielectric)
6. RG-214 (solid dielectric)

The first cable used by Sandia was made by Telcon, a British firm. This type of cable eventually became unavailable and a switch was made to Phelps Dodge helical membrane cable which has similar electrical and mechanical characteristics as Telcon. When helical membrane became a special order cable, a change was made to Phelps Dodge styroflex cable. This is a standard styroflex cable except the thin sheet of polystyrene normally installed between the poly­styrene tape helix and the outer conductor is eliminated. This is done to enhance the shorting capability of the cable under shock stress.

Heliax cable, manufactured by Andrews Cable Company, was used in several deep water-filled holes where it was felt that the air dielectric cables normally used would not withstand the higher hydrostatic pressure encountered.

All of the air dielectric cables appear to short effectively at pressures of a few tenths of a kilobar or more. The air dielectric cables have the disadvantages of being difficult to handle and can be easily damaged during the downhole and backfill operation. Hydrostatic pressure tests conducted at Sandia revealed that one-half inch styroflex cable has a shorting threshold of approximately 2700 psi (1.86 x 10^7 pascals), and heliax 4200 psi (2.89 x 10^7 pascals).
RG-213 and RG-214 solid dielectric cables are more rugged and easier to handle; however, the crush threshold is about 10 kilobars.

The approximate maximum lengths (one-fourth wavelength) for each type of SLIFER cable presently used are given in Table I. Lengths normally used are from 20 to 60 metres.

| Table I
<table>
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<th>SLIFER Cable Data</th>
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<td></td>
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<tr>
<td>Helical Membrane</td>
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<tr>
<td>Heliax</td>
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<tr>
<td>1/2 inch Styroflex</td>
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<tr>
<td>RG-213, RG-214, RF-1</td>
</tr>
</tbody>
</table>

Transmission Line

The cable for both signal and power from the oscillator to the recording facility could be any of the aforementioned types. However, rigid containment requirements dictate the use of a gas blocked cable from the oscillator to the surface. RF-1 and RF-14 cables, manufactured for the Energy Research and Development Administration, are presently used. Electrically, RF-1 is similar to RG-213 or RG-214, and RF-14 is similar to Phelps Dodge 1/2-inch foamflex. Both cables are gas blocked to prohibit leakage of radioactive gases to the atmosphere.

Specifications for RF-1 cable require the cable to withstand a pressure of 3100 psi (2.137 x 10^7 pascals) at a temperature of not less than 121°C for 48 hours.

Outer Shield

On the shorted end of the SLIFER cable, a three-metre-long outer shield is installed to minimize the effects of electromagnetic pulse (EMP) noise generated at zero time. The shield aids the system recovery after zero time preventing a prolonged loss of data. This shield is earth grounded to the downhole structure but is electrically isolated from the SLIFER cable.
III. Recording Facility

General

The SLIFER recording facility is usually housed in a trailer or an air transportable shelter. It requires an external 25 kW, 60 Hz, three-phase, 208-volt generator for power during the event. Prior to the event, the facility is normally powered from a commercial source. Generator fuel service as well as generator mechanics are required in case of mechanical problems. Support personnel are required to lay cables and assist with the downhole operation. In the event the recording facility must be located near surface zero, shock mitigation may be required to assure sur of equipment. Radio and/or telephone communications with the control center are also requ The facility is usually operated by two electronic technicians.

Equipment

Most of the equipment required in the recording trailer is commercially available. However, the SLIFER chassis itself is unique to the measurement. The Sandia SLIFER chassis is a power supply and amplifier system for five SLIFERs. The unit is shown in Figure 5.

The schematic for the SLIFER chassis is shown on Drawing No. CKN87742, Appendix A. Several features incorporated in the chassis are no longer used with the present SLIFER system, i.e., a mixer system which mixes the incoming frequency with an internal crystal controlled frequency to obtain a lower difference frequency, and a remotely operated relay in the SLIFER oscillator which shorts out the SLIFER cable at the oscillator to obtain the high frequency. Also, the chassis included a means by which the zero fiducial signal may inhibit the SLIFER oscillator signal for a short time. The main function of the chassis as now used is to provide 56 mA of constant current for the SLIFER oscillator and amplify the incoming signal to approximately one volt rms for the magnetic tape recorder.

The printed circuit cards labeled card B, A' and C' are used with the 800 to 1200 kHz SLIFER oscillator. There is only one card B per chassis. It's main purpose is to provide a regulated -24 volts for circuits on the A' cards, one for each SLIFER. The A' cards provide a constant current of 56 mA at about 14 volts for the SLIFER oscillator.

Another piece of equipment sometimes used but not commercially available is the automatic program timer. This unit requires a test site timing closure signal, e.g., -5 minutes, then counts down and provides internal relay closures for starting tape recorders of other functions required in the unmanned recording facility. In case the countdown signal is interrupted and the event is put in a "Hold" status, a "hold" signal (closure) is required to stop the program timer until the countdown is resumed when the "hold" signal is released. Also, a "reset" signal is required to reset the program timer to its original starting time in the event the countdown sequence is started over. The recording facility can also be operated remotely without use of the program timer if a sufficient number of test site signals (closures) at the required times are available.
Figure 5. SLIFER Chassis
A listing of all equipment follows. (At least two, assuming one spare, of each critical item are listed.)

2 - 1.5 MHz tape recorders
2 - Oscilloscopes with cameras
   (HP-180 w/1805A and 1821A)
2 - Digital freq. and time interval counters/dig.
   volt meters HP5326B
2 - Sandia SLIFER chassis, shop made
2 - Pulse generators, HP214A
2 - Engine generators, 25 kW
1 - Trailer or shelter, portable, with utilities
2 - Time code generator
2 - WWV receivers
4 - Radios for local communication
2 - Countdown receivers
2 - Hi potters, HP4329A
1 - Time mark generator (Cal scopes) HP226A
2 - Variable oscillators, HP3312A
2 - Time delay generators, Rutherford
3 - Counter (HP5345A)
2 - Program timer, shop made

The oscilloscopes with cameras are used to check out the transmission link and for other trouble shooting. The digital frequency meter/digital volt meters are used to adjust the SLIFER oscillator frequencies, and for general trouble shooting. The pulse generators are used in conjunction with the oscilloscopes and cameras to check the SLIFER transmission link. The generators are for electrical power. The time code generators provide a time base for the tape recorded data. The WWV receivers are used to adjust the time code generators to world time. The countdown receivers are used for communications to the test director. The hi potters are used to test all of the coaxial cables and their insulation. The time mark generators are used to calibrate the time base on the oscilloscopes and are used in data reduction. The variable oscillator is used to set up the tape machines, and as a general-purpose test device. The time delay generators and counters are used in field playback of SLIFER data.

Monitors

In order for the test director to know the status of the recording system prior to the detonation, a monitor system is often used. This system assures the test director that the trailer has power and the tape recorder is operating. Relay closures are provided by the equipment when operating properly.
Fiducial Signal

A zero time fiducial signal is recorded along with the SLIFER signal. This signal may be transmitted by hard wire or by radio. It usually consists of a very short electrical pulse from the device firing system.

IV. Calibration, Data Reduction, and Analysis

The oscillator is calibrated by means of a SLIFER cable of the same type and length to be used during the event. Small holes are drilled in the cable at three-meter intervals which permit shorting of the outer conductor to the inner conductor. The oscillator to be used during the event is connected to the cable and a plot of frequency versus shorted length is made (Figure 6). These data points are then compared with a computer generated theoretical frequency versus shorted length curve for the type of cable being used to verify validity of the calibration.

The magnetic tapes containing the SLIFER data are normally returned to the data reduction facility at Sandia Laboratories. The recorded data are played back through a 900±300 kHz discriminator, a frequency-to-voltage converter. The discriminated output is digitized and plotted. From this plot, zero time, to which all times are related, is determined from the first zero time EMP disturbance noted on the plot. A computer program is then used to convert the digitized frequency versus time data to distance versus time data. These data are then used in an iterative computer process to determine yield by means of the universal shock position versus time equation given in Section I.

Figure 6. Plot of Frequency vs. Shorted Length
References


APPENDIX A

SLIFER SYSTEM SCHEMATICS AND MECHANICAL DRAWINGS

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<thead>
<tr>
<th>Drawing No.</th>
<th>Issue</th>
<th>Description</th>
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NOTES

1. Minimum sheet, minimum per 2000000000
2. Holes per temporary type 2 plug
3. Limits of acceptable dimensions are defined in drawing.

---

SLIFER,
SUB-CHASSIS

29-30
NOTES

1. ALUMINUM SHEET, 2024-T4 PER QQ-A-250/4. .062 THK.
2. ANODIZE PER SAE162999, CLEAR.
3. LIMITS OF ACCEPTABLE WORKMATERIAL ARE DEFINED IN 990000.

2.750±.040

1.080±.005

1.000±.005

.550±.005

.340±.005

.850±.040

.970±.040

.060±.005

.240±.005

.600±.005

.720±.005

.140

2 HOLES

.148

.166

4 HOLES
NOTES

1. ALUMINUM ALLOY CHANNEL, 6063-T6, DIE NO. 238B,
3 x 1/2 x 1/8 INCHES. MAY BE OBTAINED FROM GUCCOMI
METAL AND SUPPLY CO., 1224 BELLAMAR AV., R.M.,
ALBUQUERQUE, N.M.

2. ANODIZE PICA 5504103, TYPE 1, CLEAR.

3. LIMITS OF ACCEPTABLE WORKMANSHIP ARE DEFINED IN 9900000.

[Diagram of dimensions and tolerances for a channel with holes and dimensions marked.
Markings include: 1.500±.020, .281±.010, .938±.005, 4-40 UNC-2B, .126 DIA, .375 DIA, .134, .380, .906±.005, .453±.005, .547±.020, .750±.020.]
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### Design Agency

**Title:** Heat Sink

**Design Agency Approvals:**

**Sheet Index:**

**Classification Category:**

**M79 Agency Approvals:**

**Dwg. Classification Level:**

**Part Classification:**

**S/C:** 092950

**Dwg. Number:**

**Unclassified:**

**Scale:** 2:1

**Sheet 1 of 1**
NOTES

1. UNLESS OTHERWISE SPECIFIED, RESISTANCE VALUES ARE IN OHMS.

2. ▼ INDICATES CIRCUIT RETURN.

3. CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED.

4. ° INDICATES SCREWDRIVER CONTROL.
NOTES
1. UNLESS OTHERWISE SPECIFIED, RESISTANCE VALUES ARE IN OHMS.
2. △ INDICATES CIRCUIT RETURN.
3. ◆ INDICATES SCREWDRIVER CONTROL.
4. CAPACITANCE VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED.

Mixer output
-24V

C3 100
-38V

Mixer Card A

Schematic Diagram
NOTES

1. SOLDER PER QQ1200-02, METHOD OPTIONAL.
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<td>8</td>
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<td>10</td>
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<td>13</td>
<td>SLIDER END SEAL</td>
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<tr>
<td>14</td>
<td>CABLE SEAL, TYPE H/P CONNECTOR RLG, 3/8 DIA</td>
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</tr>
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<td>15</td>
<td>CABLE SEAL, TYPE N CONNECTOR</td>
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<td>16</td>
<td>EXIT CAP, TYPE KH</td>
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<td>OSCILLATOR CAN</td>
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<td>18</td>
<td>SCREW MA-9 SHORTING CAP</td>
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<td>19</td>
<td>ADAPTOR, OUTER CONDUCTOR TYPE MA-9C</td>
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<td>22</td>
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**SOLDERING ELECTRICAL CONNECTIONS**

**GENERAL REQUIREMENTS**

**SLIDER OSCILLATOR CAN**

**PROJECT FAULTLESS**
NOTES:

1. GENERAL REQUIREMENTS ARE DEFINED IN 9900000-03.

2. MATERIAL: NEOPRENE RUBBER PER 4150190-01.
DI02187

<table>
<thead>
<tr>
<th>DESIGN AGENCY</th>
<th>PART NO.</th>
<th>ISSUE</th>
<th>DESCRIPTION</th>
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<td>D. LIST 9123</td>
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- 2.875±.030
- .344±.005 DIA
- 1.250±.030 DIA
- .188±.010 CHAMFER

CABLE SEAL
TYPE "HN" CONNECTOR

CLASSIFIED

SCALE 1/4
NOTES:

1. GENERAL REQUIREMENTS ARE DEFINED IN 9900000-03.

2. MATERIAL: NEOPRENE RUBBER PER 4150190-01.
DI02187

P70366-000 A

BASICALLY IDENTICAL TO
E.G. AND G. DWG. NO. 31035
F. MARTINEZ 7652-2
D. LIST 9123

.188 +/- .010 CHAMFER

.563 +/- .005 DIA.

1.5002 .039 DIA.
NOTES:

1. GENERAL REQUIREMENTS ARE DEFINED IN 9900000-03.
2. MATERIAL: NEOPRENE RUBBER PER 415090-01.
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<td>D. LIST 9123</td>
<td>3/20/69</td>
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<td>N/A</td>
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<td>B</td>
<td>1.843 ±.005 DIM was 1.643 ±.005 GJEYS 7652-2</td>
<td>D. LIST 9123 3-19-69</td>
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<td>N/A</td>
<td>N/A</td>
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<tr>
<td></td>
<td></td>
<td>C</td>
<td>.685 DIM was .625</td>
<td>D. LIST 9123 G JEYS 7652-2 3-24-69</td>
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**Diagram:***
- Diameter: 3.75 ±.030
- Diameter: 1.250 ±.030
- Chamfer: .188 ±.030

**Title:** CABLE SEAL TYPE “HN” CONNECTOR RF1.50DIA
**Designation:** UNCLASSIFIED

**Notes:**
- 2123 0-17-69 DRI
- 14213 P70367 UNCLASSIFIED

---

55-56
NOTES
1. GENERAL REQUIREMENTS ARE DEFINED IN 9900000-03.
2. MATERIAL: NEOPRENE RUBBER PER 4150190-01.
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---

.188 ± .010 CHAMFER

.062 ± .010

---

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SLIFER END SEAL

SCALE 1/1

57-58
NOTES

1. MATERIAL: ALUMINUM 6061-T6 \(2.000 \pm .020\) DIA STOCK.

2. ANODIZE, CLEAR.
\[ 0.150 \pm 0.010 \]

\[ 0.385 \pm 0.010 \]

\[ \text{DIA} \]

\[ 0.188 \pm 0.010 \quad \text{4 PL} \]

\[ 0.375 \pm 0.015 \]

\[ 0.562 \pm 0.010 \]

\[ \text{TION A-A} \]
NOTES
1. MATERIAL: BRASS, .250 DIA
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<tr>
<td>A</td>
<td>J. GONZALEZ</td>
<td>7652-2</td>
<td>9/13</td>
<td>A</td>
<td>4/1</td>
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- UNCLASSIFIED
- ADAPTOR CENTER CONDUCTOR
- TYPE HJ4-50

**Sheet 1 of 1**
NOTES

1. MATERIAL: ALUMINUM ALLOY, 7075-T6, 1.750 x .750 PLATE.
NOTES

1. MATERIAL: ALUMINUM ALLOY 7075-T6, 2.000 x .500 PLATE.
NOTES

1. MATERIAL: BRASS, .750 DIA.

- 2.000±.060
- .312±.015
- .430±.030
- .100±.015
- .830±.005
- .625±.015
- .750±.030
- .070±.030 THREAD RELIEF
- .030±.015 x 45°±1° CHAMFER 2 PL
- 11/16 - 24 UNEF
**ADAPTOR OUTER CONDUCTOR**  
**TYPE HJ4-50**

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<th>TITLE</th>
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</thead>
<tbody>
<tr>
<td>ORG</td>
<td>DATE</td>
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**PART CLASSIFICATION**  
**UNCLASSIFIED**

**UNCLASSIFIED BERKLEY CLASSIFICATION LEVEL**

**SCALE** 2:1  
**SHEET 1 OF 1**
NOTES

1. MATERIAL: BRASS, .625 DIA.

---

DIAGRAM WITH DIMENSIONS:
- .030 R MAX
- .515 ± .005
- .030 ± .015 x 45° ± 1° CHAM
- 1.250 ± .030
- .025 ± .010
- .164
- .170
NOTES
1. GENERAL REQUIREMENTS ARE DEFINED IN 9900000-04.
2. MATERIAL: BRASS BAR, 1/4 HARD.
SLIFER CABLE SHORT

UNCLASSIFIED

DI20345

DEMON AQCNCT KVIMONS
pAkm^mmm). ISfUl OUCMPtI ON MEHUM9 BV OATf
ZMA INO*

-171 .005 DIA. THRU
- .000

ADAGENCY APPROVALS

SLIFER CABLE SHORT

UNCLASSIFIED

DRAWN

9/25 10/13: R20

SHEET INDEX

PART CLASSIFICATION
UNCLASSIFIED

DRAWING CLASSIFICATION LEVEL
UNCLASSIFIED

SCALE 2/1

SHEET 1 OF 1

71-72
NOTES

1. MATERIAL: ALUMINUM ALLOY, 6061-T6, 2.000 ± .020 DIA x .250 WALL.

.030±.015 x 45°±1° CHAMFER BOTH ENDS

.188±.010 2 PL

4.250±.010

.136 THRU X .141 CSK 82°±1° TO .245±.010 DIA 4 HOLES AS SHOWN WITHIN .010 BOTH ENDS
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<td>I. MEDINA @ 7652-2</td>
<td>D. List</td>
<td>7/11/70</td>
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<td>D. List</td>
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**OSCILLATOR CAN**

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<td>1/1</td>
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<td></td>
</tr>
</tbody>
</table>

---

\( x = 0.005 \)
NOTES

1. MATERIAL: LAMINATED PLASTIC (SALT, GLASS FABRIC BOARD HEAVY COPPER CLAD, 1/16 IN. THICK (C-177), PER MIL-F-13930 400 THREE-SPACER.

2. HSHE PRINTED WIRING BOARD PER PRINTED, TYPE 1 PLATING, GASS 3/16 IN. THICK.

3. HOLES TO F. LOCATE So A MINIMUM OF .050 IS MAINTAINED BETWEEN ELE. OF HOLE AND END OF CONDUCTOR.

4. ALL HOLES TO Q .010 THR THIN.

5. PRINTED CIRCUIT CONNECTION PER Schematic.

6. CRITERIA CAPACITOR TO BE SELECTED AND INSTALLED ON FLEX.

7. NOTE: POSITION OF TAB BEFORE INSTALLING CASS.

8. NOT BE OBTAINED FROM:
   A. J. H. MILLER 3117 NORTH ST, LOS ANGELES 5, CAL.
   B. THERMOTRON PRECISION INC., 4111 E. 14TH ST, L.A., CAL.
   C. IMPACT PRINTED WIRING, MELBOURNE, N.J.
   D. FRYE ELECTRIC CO. NORTH SIDES, MASS.
   E. RADIO CORP. OF AMERICA CAMDEN, N.J.
   F. INTERNATIONAL RECTIFIER CORP., EL SEGUNDO, CAL.
   G. MOTOROLA SEMICONDUCTOR FAB. PHOENIX, ARIZ.

9. Wire Diameter AFT AFTER PLATING.

10. INSTALLING CAPACITOR SHOULD BE PLACED BETWEEN BOARD AND MOUNTING OF TRANSMISSION.
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<td>1</td>
<td>RESISTOR, 200 ohm</td>
<td>25</td>
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<tr>
<td>1</td>
<td>RESISTOR, 100 ohm</td>
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<td>RESISTOR, 5 Ohm</td>
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<td>RESISTOR, 10k</td>
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<td>CAPACITOR, 0.1uf, DISC CERAMIC, 20V</td>
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</tr>
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<td>CAPACITOR, 1000 pf</td>
<td>6 C4</td>
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<td>CAPACITOR, 1500 pf, 15V, MYLAR</td>
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**Diagram:**
- A4, L2, C5, L3, R6
- Q1, Q2

**Dimensions:**
- 49/32 x 23/32 x 9/32
- 75-70
NOTES

1. UNLESS OTHERWISE SPECIFIED, RESISTANCE VALUES ARE IN OHMS.
2. UNLESS OTHERWISE SPECIFIED, CAPACITANCE VALUES ARE IN MICROFARADS.
3. CAPACITOR TO BE INSTALLED IN FIELD.
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**DESIGN AGENCY APPROVALS**

**TITLE**

**MASTER, PRINTED CIRCUIT**

**CLASSIFICATION LEVEL**

**UNCLASSIFIED**

**SHEET NUMBER**

CMN83412
NOTES.

1. MATERIAL: LAMINATE PLASTIC SHEET, GLASS BAKED EPOXY RESIN, ONE SIDE CLAD, TL-SF-4160-421-C-26, PER MIL-P-29458.
   1.25" THICKNESS.
2. HOLE DRILLS USING SMOKE PER MIL-20210, TYPE 1 PLATING, C-415.
3. HOLE DIMENSIONS AND MINIMUM OF 0.001" IS MANDATORY.
4. ALL HOLES TO BE PLATED THRU.
5. SOLDER POINTED CIRCUIT CONNECTION PER S 2180-33.
6. SUITABLE CAPACITANCE TO BE SELECTED ARE INSTALLED IN FIELD.
   (Note: Position of the supply pin located relay.

7. NOT TO BE OBTAINED FROM:
   A. J. M. MILLER 3450 E. BAUER RD., LOS ANGELES, CA.
   B. TELEPHONE PRECISION INC., 105 W. 6TH ST., NEW YORK, NY.
   C. RICHARD'S ELECTRIC CORP., 106 S. MARKET ST., LAUGHLIN, NV.
   D. SUPPLY ELECTRIC CORP., 1050 W. 10TH ST., LOS ANGELES, CA.
   E. RADIO CORP. OF AMERICA, CAMDEN, N.J.
   F. INTERNATIONAL RECTIFIER CORP., EL SEGUNDO, CA.
   G. MOTOROLA SEMICONDUCTOR PROD., PHOENIX, ARIZ.
8. HOLE DIAMETERS APPLY AFTERPLATING.
9. INSULATING DISC SHOULD BE PLACED BETWEEN BOARD AND UNDERSIDE OF TRANSISTORS.
NOTES

1. UNLESS OTHERWISE SPECIFIED, RESISTANCE VALUES ARE IN OHMS.
2. UNLESS OTHERWISE SPECIFIED, CAPACITANCE VALUES ARE IN MicroFARADS.

CAPACITOR TO BE INSTALLED IN FIELD.

PRINTED BOARD  N83420 CMA
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<td>11-20-64</td>
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<tr>
<td>2</td>
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<td>C2 AC3 WERE 7500UV MYLAR</td>
<td>6-1-65</td>
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NOTES

MARK PER 9919100. CLASS C-1. .250 INCHES HIGH, SERIAL MARKING 1, 2, 3, 4, 5 --- FOR MATCHING PARTS AT ASSEMBLY.
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**Notes:**
- UNCLASSIFIED
- Sheet 1 of 2
- Item 2
- Item 1 Locate
NOTES

1. MAT'L: ALUM. ALLOY.
2. ALL FILLETS 1/8 OR 3.560 UNLESS OTHERWISE SPECIFIED.
### NOTES

1. Material: Laminated plastic sheet, black and white print, scale 1:100.
2. Hole sizes indicated in mm, type 1 failure, Class 3.
3. Hole size and type indicated by letters.
4. Holes to be drilled and tapped by .25 in. drill and 3/8-16 tap.
5. Holes to be located and marked by 3rd party.
6. Holes to be checked by 3rd party.
7. Holes to be located by 3rd party.
8. Holes to be marked by 3rd party.
9. Holes to be checked by 3rd party.
10. Holes to be located by 3rd party.
11. Holes to be marked by 3rd party.
12. Holes to be checked by 3rd party.
13. Holes to be located by 3rd party.
14. Holes to be marked by 3rd party.
15. Holes to be checked by 3rd party.
16. Holes to be located by 3rd party.
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29. Holes to be marked by 3rd party.
30. Holes to be checked by 3rd party.
31. Holes to be located by 3rd party.
32. Holes to be marked by 3rd party.
33. Holes to be checked by 3rd party.
NOTES

1. Resistance values are in ohms unless otherwise specified.
2. Capacitance values are in microfarads unless otherwise specified.
3. □ indicated circuit return.
4. ● indicated screw driver adjustment.