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FINAL REPORT

FOR

SOLID STATE SWITCH PANEL

26 NOVEMBER 1973

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ABSTRACT

An intensive study of various forms of transducers was conducted with application towards hermetically sealing the transducer pick off and all electronics. The results of the study indicated that the Hall effect devices and a LED/phototransistor combination were the most practical for this type of application. Therefore, hardware was developed utilizing a magnet/Hall effect transducer for single action switches and LED/phototransistor transducers for rotary multiposition or potentiometer applications. All electronics could be housed in a hermetically sealed compartment. A number of switches were built and models were hermetically sealed to prove the feasibility of this type of fabrication. One of each type of switch was subjected to temperature cycling, vibration, and EMI tests. The results of these tests are indicated in the following report.

TABLE OF CONTENTS

RESULTS

The results of this project are:

1. An operating switch panel conforming to the requirements of NAS-9-13144.

2. Test data taken during environmental tests performed on selected switch and rotary components. The tests performed were comparable to tests run on NASA flight hardware delivered on the skylab project. Satisfactory results were obtained on all tests.

3. Reliability data indicating MTBF for selected devices.

4. A project report covering the study phase of the project and containing test data, schematics, and outline drawings of the switch devices and the mounting panel.

CONCLUSIONS

The results of this project indicate that solid state switches and rotary components capable of meeting the requirements of manned space flight are feasable and well within the current state of the art. The environmental and reliability data indicate that a production unit would have the superior reliability associated with solid state equipment. The large selection of contact closure types will allow switches to be fitted to various requirements. A phase II production type unit would be packaged in a smaller and lighter housing. The feel of each switch and the front panel appearance would be improved in the phase II design.

RECOMMENDATION

The study indicated that the most efficient switch is one designed to switch a specified voltage and current. Using a high current switch to handle a low current is inefficient. Any production switches should be designed for a specific power level.

In production quantities a hybrid package containing all the electronics is recommended as a way to save size and increase reliability of the solid state switch devices.

Reduction of switch size would allow the toggle section of the switch to be brought flush to the panel surface and otherwise improve the appearance of the switches.

It is also recommended that a closer analysis of the front panel removability criteria be made with an effort to reduce the panel area used for fastening.

INTRODUCTION

The purpose of this report is to summarize the results of a study conducted to determine the optimum transducer type and output circuitry for a solid state switch configuration and to demonstrate with hardware, the feasibility of the resulting designs. Two basic types of switches are required, a single action switch (toggle, pushbutton) and a multiposition rotary switch and/or potentiometer. The switches will be designed to be hermetically sealed and removable as an integral unit from the front of the panel. Selected switches contain a Light Emitting Diode (LED) display indicating the status of the switch position and/or operable or failure mode.

The various types of transducers studied included the following:

- Light
- Capacitive
- Hall effect
- Magneto-resistor

Many factors were considered in selecting the appropriate transducer for the application and the necessary circuitry for the switch output. They were as follows:

- Type of excitation required
- Power required
- Cost
- Size
- Reliability
- Hermetic sealing capability
- Cross talk effects
- Packaging
- Switching characteristics

A matrix indicating these characteristics of the various transducers are shown in Table I.

TABLE I. TRANSDUCER MATRIX

	LIGHT	CAPACITANCE	HALL EFFECT	MAGNETO RESISTOR
POWER	.150 WATTS	.100 WATT	.050 WATT	.050 WATT
EXCITATION	DC 5-10V	AC 10 KHZ	DC 5-10V	DC 5-10W
COST	MODERATE	HIGH	LOW	MODERATE
CROSS TALK	NONE	PROBLEM AREA	NONE	NONE
HERMETIC SEAL	PROBLEM AREA GLASS TO METAL SEAL	PROBLEM AREA GLASS TO METAL SEAL	COMPATABLE	COMPATABLE
SIZE	MODERATE	LARGE	SMALL	MODERATE
COMPONENTS	TWO SILICON SEMI-CONDUCTORS AND GLASS SEAL	TWO SEALED METAL PLATES AND DRIVE CIRCUITRY	ONE INTEGRATED CIRCUIT AND MAGNET	ONE SEMI-CONDUCTOR AND DRIVE CIRCUITRY
SWITCHING CHARACTERISTICS	REQUIRES TRIGGER	REQUIRES TRIGGER	TRIGGER PART OF IC	TRIGGER REQUIRED

The results of the study indicated that the Hall effect transducer is the most effective for the single action switch and the LED/phototransistor is the optimum device for the multiposition rotary switch and potentiometer.

Dependent upon the function of the switch, four types of output circuits were selected to interface with peripheral equipment. The determining factor in the circuitry was the contact rating of the switch.

• High current	DC	(10 AMP)
• Medium current	DC	(400 MA)
• Low current	Analog	(50 MA)
• Low current	AC	(I AMP)

To insure reliable operation, redundant circuitry has been included wherever size and circuitry dictates practicability. The subject of man-hardware interface has not been discussed because standard mechanical switch actuating devices are used for inputs with normal actuating pressure loads and travel.

Envelope drawings and schematics are included in the appendices (Section 8) indicating the design approach configurations for the Phase I program. Production versions of these modules would require some modification for facility of fabrication and appearance. As a result of the study program, a panel was fabricated including 25 single pole or double pole toggle and pushbutton switches, two rotary 10 position switches and two potentiometers as indicated in Figure 1.

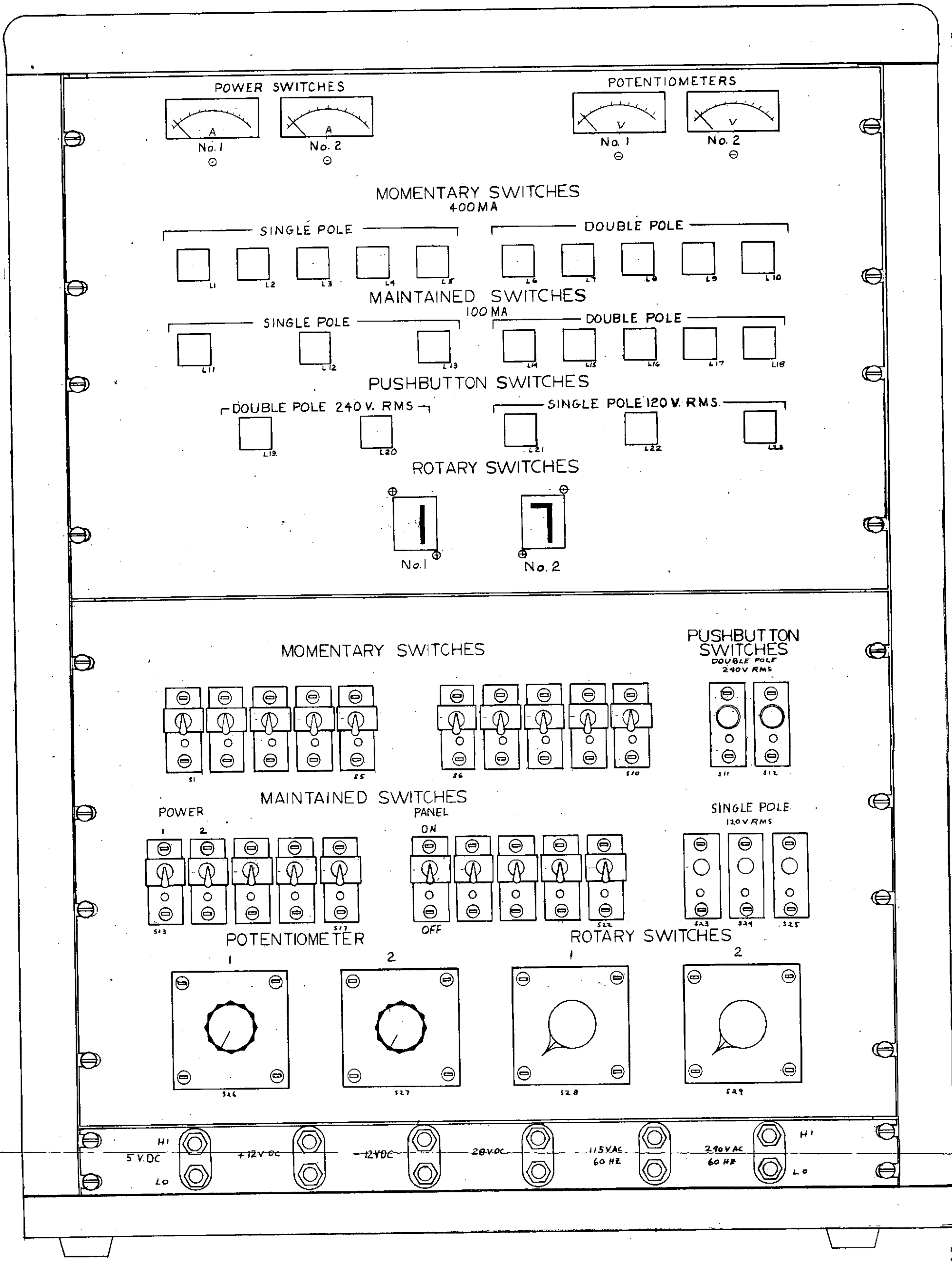


FIGURE 1 SOLID STATE SWITCH PANEL

TECHNICAL DESCRIPTION

The following four basic areas were studied in order to produce the required switch/potentiometer configurations for the switch panel:

- Transducers
- Mechanical Packaging
- Output (switch contact) circuitry
- Solid state potentiometer circuit configurations

TRANSDUCERS

Many types of transducers were evaluated to determine the optimum switch transfer. For each transducer the source and sensor of the switching medium is discussed along with the various configurations.

MAGNETIC CIRCUIT TRANSDUCER

A magnetic circuit transducer depends on changing magnetic flux for switching action. A mechanical switch change occurring external to the hermetic seal changes the reluctance of the magnetic circuit. This flux change is sensed inside the hermetic seal and interfaced with the logic section of the switch. Both alternating and direct flux devices have been reviewed.

DC Devices

The flux flows in only one direction in a direct flux circuit and is a function of the following relationship.

$$\Phi = \frac{MMF}{R}$$

A change in the flux is sensed and a typical simple switch is illustrated in Figure 2. With the switch open as in Figure 2 a high reluctance air gap exists in the magnetic circuit. If the missing slug is moved into the gap, the reluctance is diminished. This increases the flux and changes the characteristics of the flux sensing element. Two sources of mmf appear most appropriate for switch applications: permanent magnets or solenoid coils. Permanent magnets require the following characteristics to be effective.

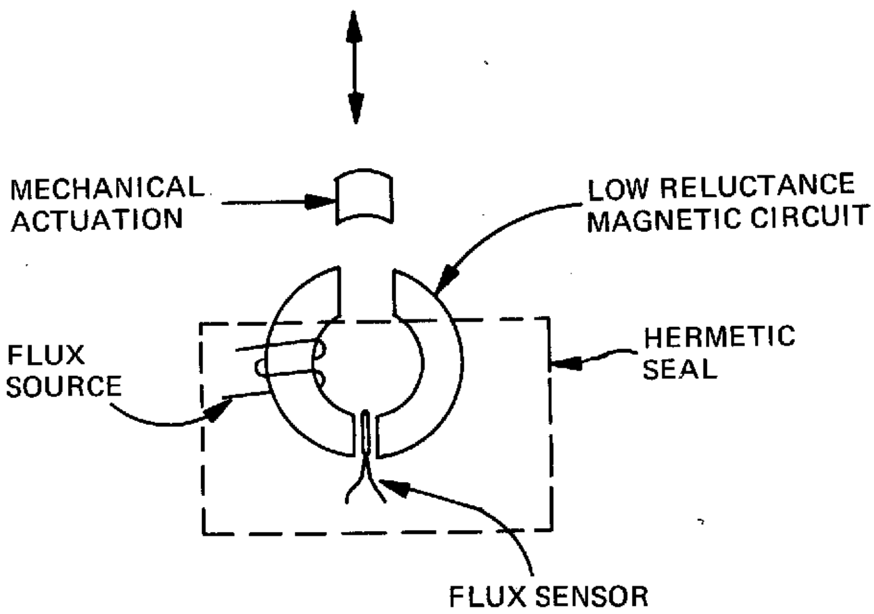

MECHANICAL ACTUATION
LOW RELUCTANCE MAGNETIC CIRCUIT
FLUX SOURCE
HERMETIC SEAL
FLUX SENSOR

FIGURE 2

- Small size
- High induction
- High demagnetization force

Of the present commercially available magnetic materials, the following best suit these characteristics:

- Ceramic permanent magnets
- ALNICO SERIES*
- Gecor*

The life characteristic of these materials (time of retention of useful magnetic properties) has been estimated at approximately 15 years.

Solenoid coils require electrical power in order to operate. However, these devices utilize materials which are more readily available than magnets and do not require any special handling techniques as is sometimes the case with magnets. Of the flux sensing elements available the following exhibit the most suitable properties for switch application:

- Pick up coil
- Hall effect device
- Magnetic resistor

- Pick Up Coil - The simplest of the three devices is a pick up coil which is a coil of wire of many turns wound around the magnetic core. This coil does not require a gap in the magnetic circuit which greatly increases the reluctance and, therefore, reduces the magnetic strength required. Many magnetic materials can be used for this application. The greatest disadvantage of using a pick up coil in a direct flux circuit is the fact that a coil can only sense a change in flux. Therefore, an output voltage would only be available from the coil during switching transition. After the coil has reached a different steady state valve as a result of the new switch position no voltage is present at the coil. The logic necessary to sense these

---

*Trade name of a General Electric Co. product transient pulses is relatively simple, however, the problem exists in the initial start up procedure. The use of this device is limited to momentary switch applications where the switch mode of operation is in the normally off condition.

- Hall Effect Device - The Hall effect element is a semiconductor device that generates a voltage as a function of control current and magnetic field. As illustrated in Figure 3 control current is passed through one axis of the semiconductor. The Hall voltage will appear perpendicular to the control current at the edges of the semiconductor chip. This voltage will be a function of the magnetic flux passing through the chip perpendicular to both control current and the output voltage. In the switch application, this voltage is used to control the switch output. The advantages of the Hall effect device are:

  - Small size
  - Detection of steady state flux levels
  - Life and reliability similar to silicon semiconductors

  Because the Hall effect device has a relatively low output voltage (in the order of 50mv) an amplification stage is necessary as an interface between the transducer and the switch output circuitry. The control current required for the Hall effect device is approximately 5 → 50 MA. The Hall effect device is made very thin (.006 inches typical) in order to retain a high flux density across the Hall device in the on condition.

  A device available from Honeywell Microswitch incorporates a Hall effect device and an amplifier and trigger circuit in one integrated chip. This device operates on low levels of flux and provides as an output two current sinks. In addition to being small and sensitive this magnetic switch requires very little power to operate (30 mw max. at 5 volts). This power level is equivalent or lower than most flux sensing devices made of discrete parts.

  The device has been designed to operate over the standard Military temperature range (-55°C -- +125°C) and is available off the shelf from Micro-Switch. The device is sensitive enough that no specific flux path need be incorporated in the hermetic seal. The switch will sense

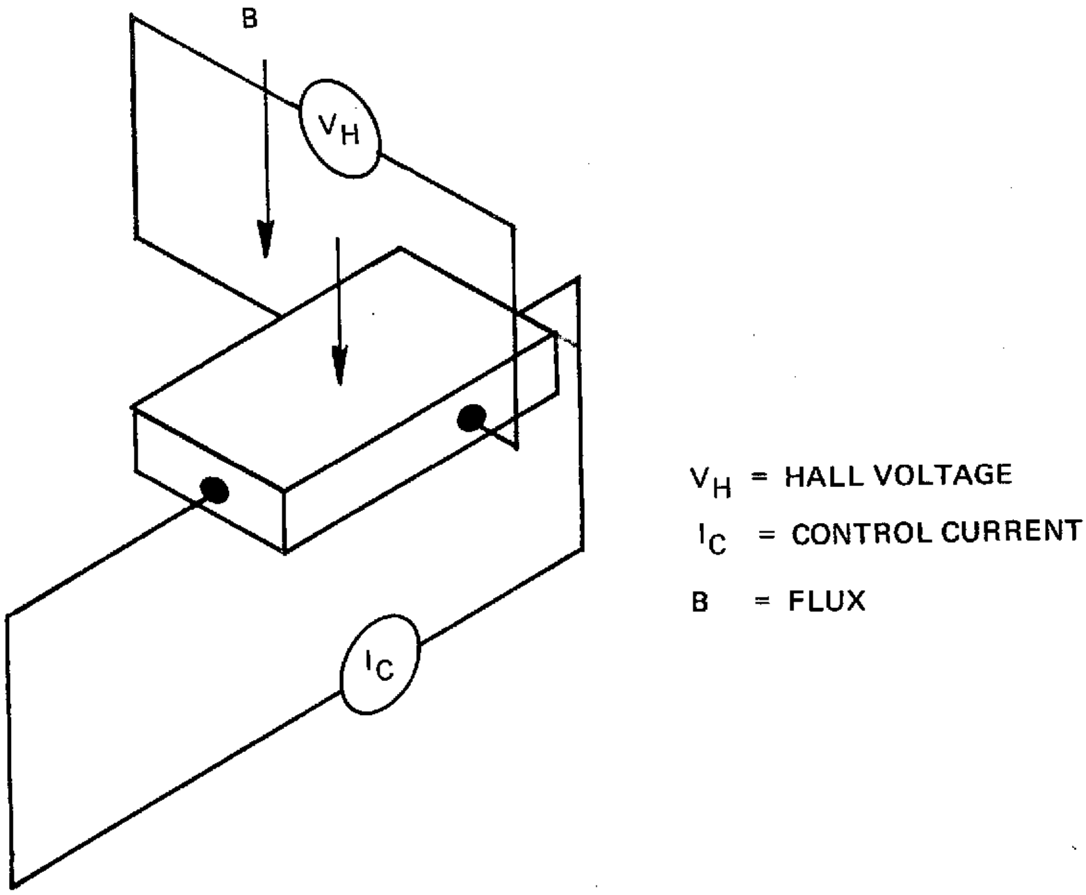


FIGURE 3

the presence of a small magnet at distance of .090 in. with any non-magnetic material between the magnet and the sensor. This feature will greatly simplify the process of hermetically sealing the final package.

- Magneto Resistor - Magneto resistors are solid state passive devices that change their resistance in the presence of a magnetic field. The devices are thin crystals of Indium Antimonide with electrical connections at both ends (Reference Figure 4a). The crystal is a semiconductor with a grid-like conducting material running perpendicular to the direction of the current flow. With no flux passing through the device current flows perpendicular to the conducting bands implanted in the semiconductor. Under these conditions the device exhibits its lowest resistance. If flux is allowed to pass through the device, the current is forced to travel a greater distance between conducting bands (Reference Figure 4b). The longer current path increases the resistance between the ends of the device. Typical ratios between maximum and minimum resistance are on the order of 13 to 18 for sensitive devices. The application of the magneto resistor is similar to the Hall effect devices in that they are mounted in the gap in the magnetic circuit. Magneto resistors have the following advantages:

- Small size
- Low power
- Life and reliability similar to silicon semiconductors

Power consumption of magneto resistors is a function of the input current and resistance and is, therefore, in the order of mw.

Alternating Magnetic Flux Devices

Alternating magnetic flux can also be used to convey mechanical switch status through a hermetic seal. Switches of this type operate using transformer coupling. This method would require the use of AC signals inside the hermetic seal. Because AC signals must be generated to produce the alternating flux and later rectified to interface with the logic and switch sections, this method will consume more power and be more complex than direct flux circuits.

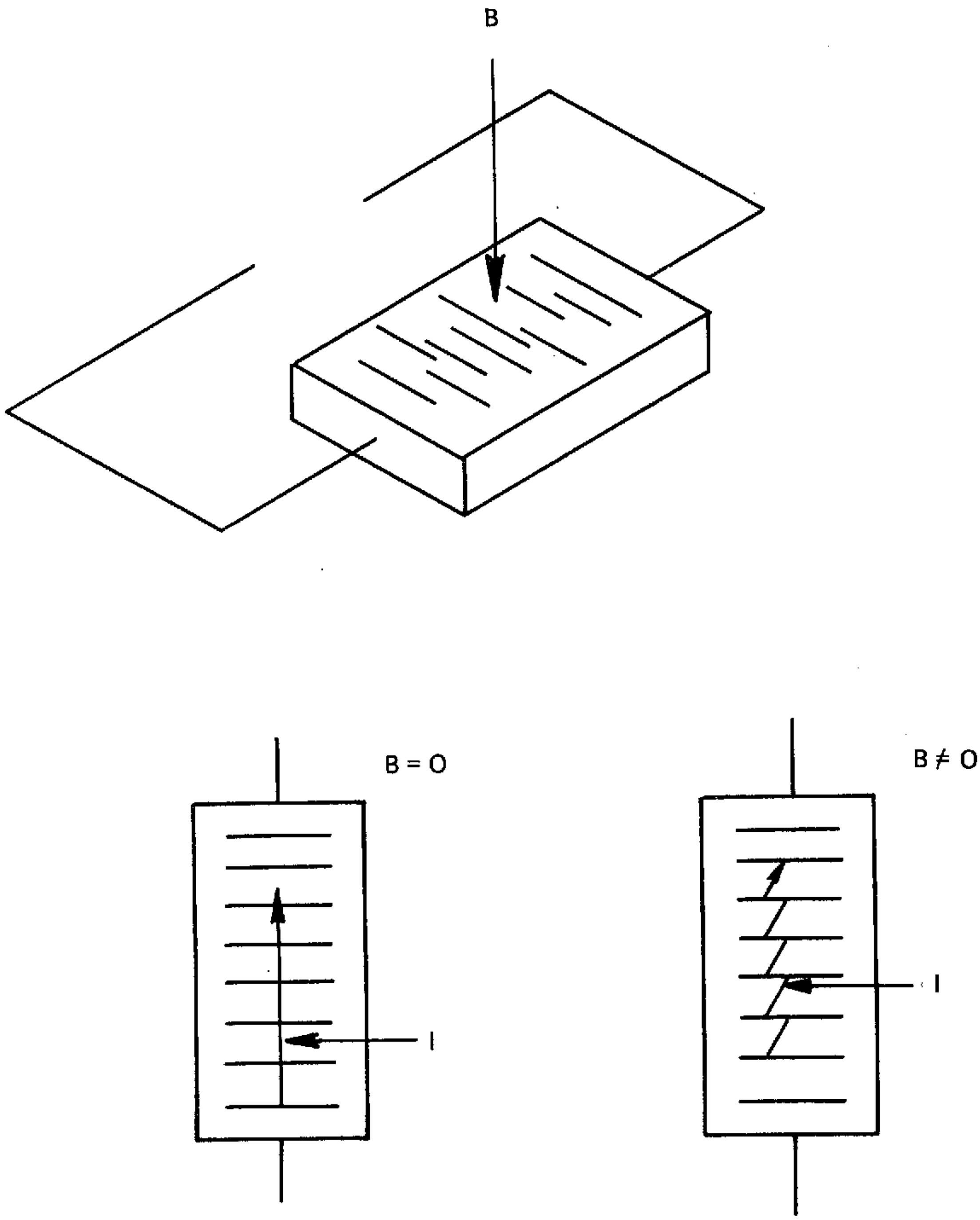
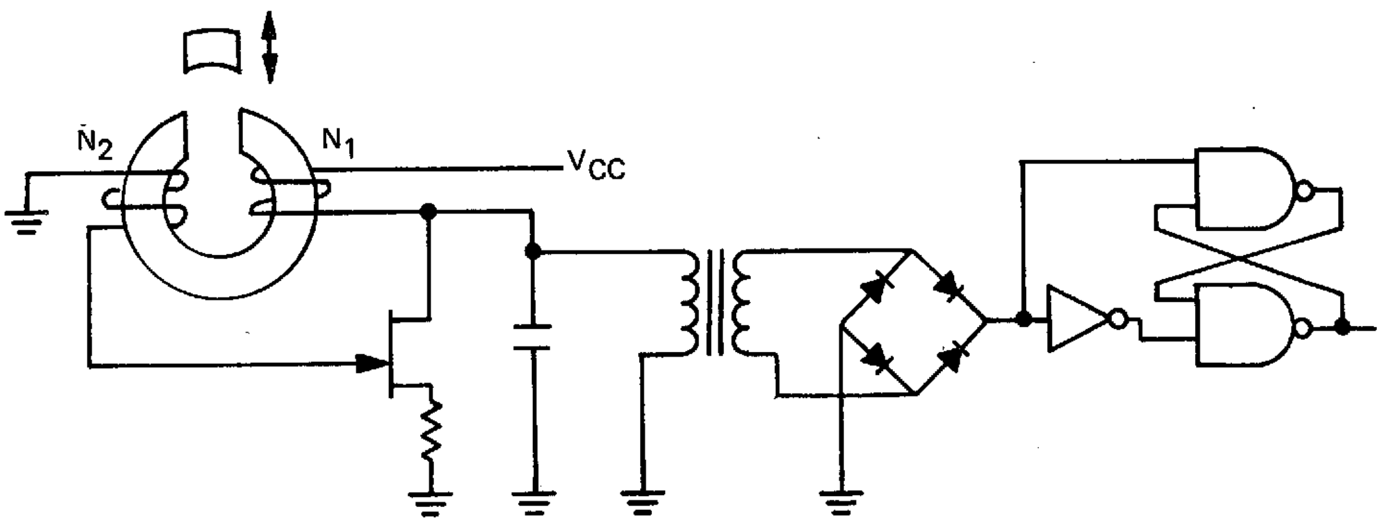


FIGURE 4

The only source of alternating flux convenient for use in this application is a coil of wire around the magnetic flux path. The optimum frequency at which the flux should oscillate will be a function of core losses in the magnetic circuit, the size of the oscillator, and the amount of radiated energy acceptable.

The greatest disadvantage to this type of design is the possible energy radiated to other switches and circuitry behind the switch. This radiation can be minimized to some extent by placing a magnetic shielding around the switch and EMI filters on the electrical lines, however, this would complicate both the packaging and the manufacture of the final switch.

All the sensors which sense direct flux also sense alternating flux. Of the three types discussed (pick up coil, Hall effect, magneto resistor), the pick up coil is the most adaptable to alternating flux. A transformer type switch using coils might operate as follows:



In the configuration above, coil N_1 is not strongly coupled with coil N_2. Coil N_2 is a feedback circuit for the oscillator. With the slug removed from the magnetic path the feedback is insufficient to maintain oscillation. This results is a zero voltage output at the full wave rectifier. If the missing part of the core is placed into the magnetic circuit, coil N_1 is coupled to coil N_2 providing feedback to the circuit. This causes the circuit to break into oscillations and provides a DC voltage at the full wave rectifier switching the latching logic.

The selection of the material to form the magnetic core, is based on a number of factors.

- Magnetic properties
- Ease of machining
- Compatibility with switch housing material
- Ability to form hermetic seal.

A material of high relative permeability and low magnetic retentivity is most desirable. This would insure the greatest change in flux for a given magnet. Two materials appear best suited to this requirement.

1. Cold rolled armco Magnetic input iron.
2. Cold rolled electro-magnetic iron.

When properly heat treated these materials are easily machined and can be soldered or brazed in the normal fashion.

One other consideration must be made if alternating flux is to be used. Core losses must be kept to a minimum which will require either a laminated core or a ferrite core. Both of these cores would be difficult to hermetically seal and will complicate the machining and manufacture of the transducer unit.

Transducer Evaluation

In the following section each of the sensors and sources are evaluated, thereby, allowing the best possible combination to be determined. A summary at the end of this section compares all the combinations.

Coil Source With Coil Sensor

This approach is not acceptable because of the inability of the coil sensor to detect a steady state flux. A memory device of some type would be required to hold the switch in either the on or off state after a change in the flux level. Such a transducer would be further complicated by the circuitry required to guarantee proper start up. When power is first applied to the switch, circuitry must be provided to set the memory in either the on or off position depending on the position of the moveable core section.

Another disadvantage of this method is the coil source which dissipates electrical power to provide a steady state flux. Permanent magnets use no power to accomplish the same thing.

Coil Source With Hall Effect Sensor

A transducer of this type is feasible. It has two major disadvantages which make it less acceptable than other methods to be described.

1. Power must be supplied to both the coil and the Hall effect device for proper operation. This current would be on the order of 30 ma which is much higher than other types of transducers.

2. The Hall effect device puts out a low voltage (40 - 400 mv) when magnetic flux passes through it. This voltage level would have to be amplified in order to drive logic. The addition of an amplifier would consume more power and space in the final design and is therefore not desirable.

Coil Source With Magneto Resistor Sensor

A transducer of this type offers many advantages. The magneto resistor requires no control current as does the Hall effect device so the total power consumption will be smaller than the Hall effect. With a flux change of 10 kilogauss the magneto resister changes its resistance by a factor of 7 from its 0 kilogauss level. This change is enough to actuate logic without amplification. At worst a single transistor will interface between the transducer and the logic section.

The only drawback to this combination is the coil source which will draw current to generate the flux.

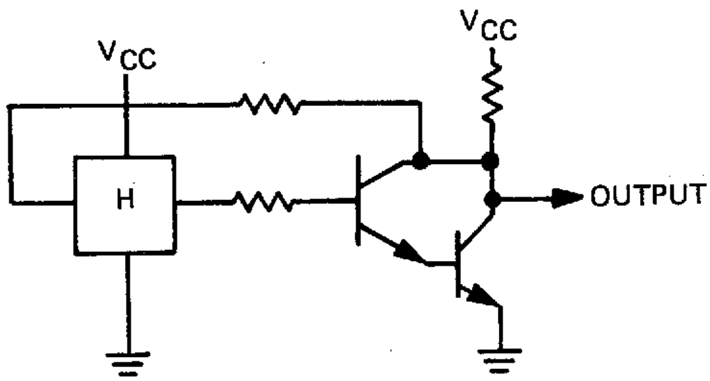
Permanent Magnet With Coil Pick Up

This method is unacceptable for reasons mentioned under coil source coil pick up.

Permanent Magnet With Hall Effect Device

This arrangement has the same drawbacks as the one using Hall effect with coil source. The only advantage is the fact that no current would be required to generate the flux.

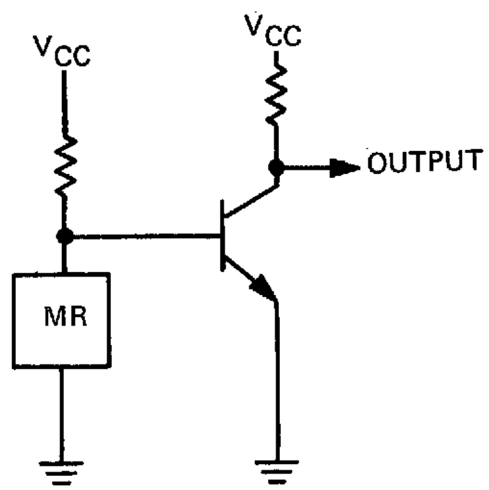
The complete transducer circuit is indicated as follows:



Permanent Magnet With Magneto Resistor

This combination is acceptable because the flux is generated without the use of power and the Magneto resistor requires few additional components and uses little power.

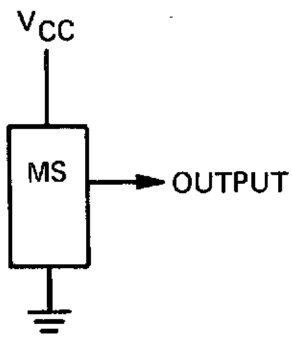
The complete transducer is as follows:



Permanent Magnet With Micro-Switch Sensor (Hall Effect/Amplifier/Trigger)

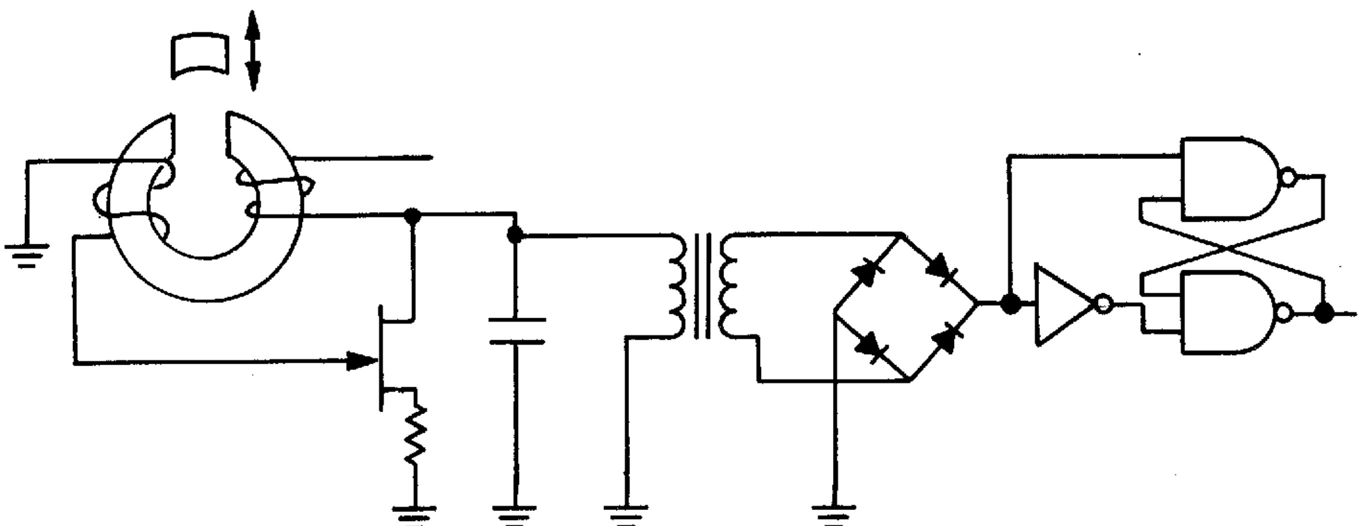
Because this device is very sensitive and comes packaged with a trigger and amplifier on the same chip it appears to be by far the most advantageous transducer. It is sensitive enough that no pole pieces would have to pass through the hermetic seal barrier. This would greatly simplify the sealing process. Furthermore, the device comes in a small package allowing the overall switch size to remain small.

The complete circuit is shown below:



Coil Source With Coil Sensor (ac)

A transducer operating with these components would require the following circuitry:



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The variable inductive coupling between the output and the input controls the feedback to the oscillator. Thus, by changing the feedback, the oscillator can be driven out of oscillation. By rectifying the output and using this signal to control the logic section, switch operation can be made.

The following problems complicate this approach to the transducer problem.

1. The oscillation inherent in this type of switch will be difficult to shield from the outside world. Use of large RF filters would be difficult due to the small package size required.

2. The difficulty in hermetically sealing a low loss AC type core (laminated or ferrite) would necessitate use of a DC type core. This would force the oscillator to work at a higher power level to offset core losses.

3. Part count for this type of transducer would be high making a small package size difficult.

Coil Source With Hall Effect Sensor (ac)

This type of transducer would have all the drawbacks mentioned under coil source and coil sensor plus the following:

The Hall effect device must be placed in the path of magnetic flux requiring a gap in the core of the oscillator decreasing the coupling. The output from a Hall effect device would be a very small voltage (40 - 10 mv).

The Hall effect device requires a control current for operation which is an added power requirement not necessary with a coil pick up. This type of transducer is not acceptable because of the poor AC flux characteristics of the Hall effect device. A coil pickup is far superior in every respect for this application.

Coil Source With Magneto Resistor Pick Up

This transducer is unacceptable for the same reasons mentioned under coil source Hall effect device pick up.

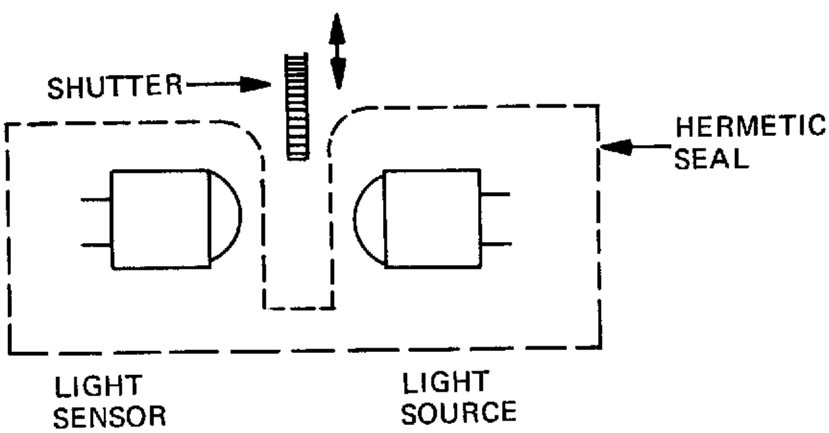
<u>Conclusions</u>

Of all the magnetic transducers discussed in this section, the most acceptable is the Honeywell magnetic switch used in combination with a permanent magnet. It is the best selection for the following reasons.

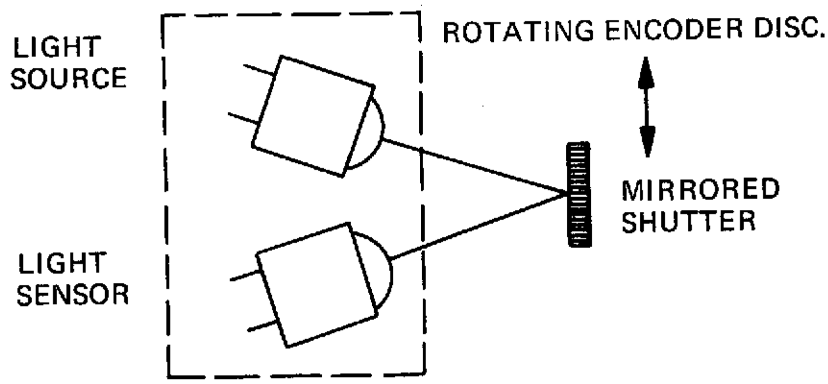
- Low power
- Smallest size of any magnetic transducer
- Lowest component count.

LIGHT TRANSDUCERS

Transducers of this type will direct a beam of light from a light source through a shutter arrangement to a light sensor. Both light sensor and source will be contained inside a hermetic seal. The shutter arrangement will be external to the hermetic seal. By either allowing the light beam to strike the sensor or interrupting the light beam with the shutter, switch control of the light sensor can be obtained.



The shutter type of transducer would require that the hermetic seal wrap around the movable shutter. This means a transparent hermetic seal would have to be made at each side of the shutter. To avoid this complicated seal, an alternate configuration with a reflective surface can be used. In this method light is directed through a transparent hermetic seal towards a reflective surface. Upon striking the surface the light beam is directed back toward the light sensor through the same transparent seal through which it originally passed. In this way only one transparent seal is required and both source and sensor can be placed in the same place. Switching is obtained by either reflecting or not reflecting the light beam back to the sensor. No moving parts are required within the hermetic seal.



Light Sources

A beam of light can be obtained from the following sources:

- Incandescent lamp
- Light emitting diode
- Electro luminescent lamp

The following characteristics would be desirable in a light source:

- Small size
- High brightness
- Low power
- Long life

It would also be desirable to have the light eminate from a single point source. As the light must be gathered into a beam to pass to the detector a single point source would simplify this requirement.

- Incandescent lamps - A light source of this type satisfies the size and brightness requirements with no difficulty. Light intensities as high as 2,400 foot LAMBERTS can be obtained in package sizes as small as Figure 5. The drawbacks of this source are its power consumption and its limited life. There would be no way to conveniently replace the lamp because of the hermetic seal. This factor alone makes use of incandescent lamps PROHIBITIVE.

- Light emitting diode - Light emitting diodes satisfy most of the requirements. They are small, have a very long life time, moderate power consumption with moderate brightness. A further advantage of the LED source is its narrow frequency band of light output.

Many types of photo diodes and photo transistors are optimized for use at a single frequency. This means that the proper combination of LED and photo diode will make more efficient use of the light than a combination of photo transistor and any other light source.

LED's come in a variety of package sizes. The device pictured in Figure 6 would be most suited to the requirements of this application. This device was designed to be used with a particular photo transistor in high speed card and tape readers. The characteristics of this device are listed in Table II.

- Electro-Luminescent Lamps - This type of lamp would not be suitable for this application. Electro-luminescent lamps have very low brightness (20 fL) and are better suited to surface illumination.

Light Sensors

Light emitting diodes are the best choice for light sources so only sensors which interface with LED's will be considered. The following devices are specifically designed to interface with LED's.

- Photo - Diodes

- Photo - transistors

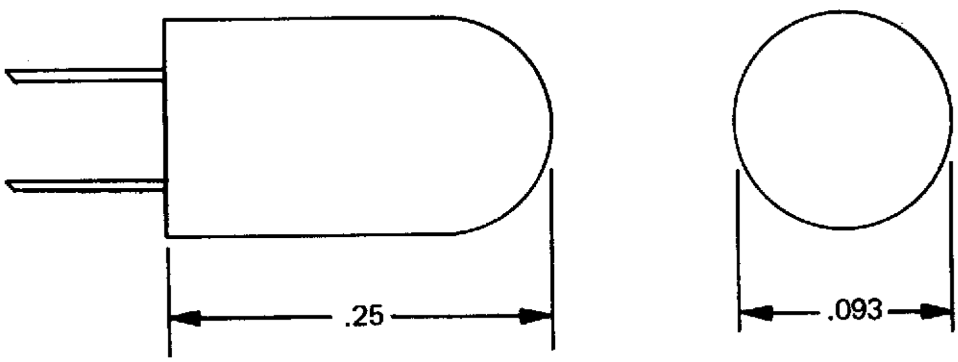


FIGURE 5

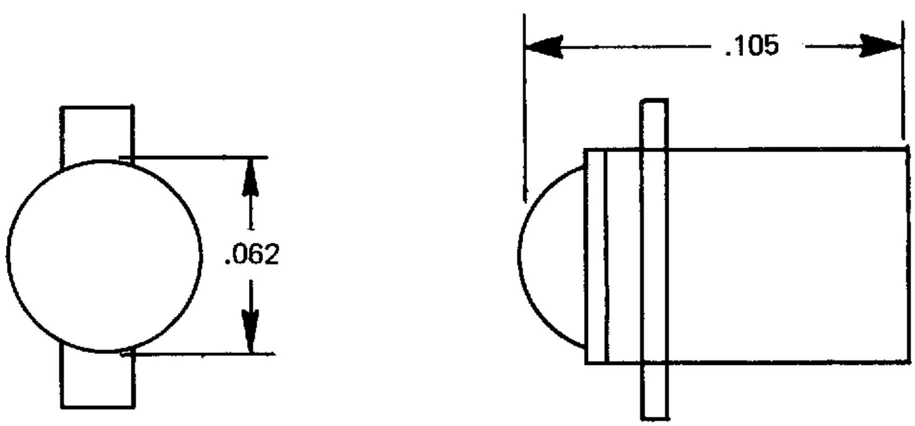


FIGURE 6

TABLE II. LIGHT EMITTING CHARACTERISTICS

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Typ	Max	Unit
Reverse Leakage Current (V_R = 3.0 V, R_L = 1.0 Megohm)	-	I_R	-	50	-	nA
Reverse Breakdown Voltage (I_R = 100 µA)	-	BV_R	3.0	-	-	Volts
Forward Voltage (I_F = 50 mA)	2	V_F	-	1.2	1.5	Volts
Total Capacitance (V_R = 0 V, f = 1.0 MHz)	-	C_T	-	150	-	pF

OPTICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

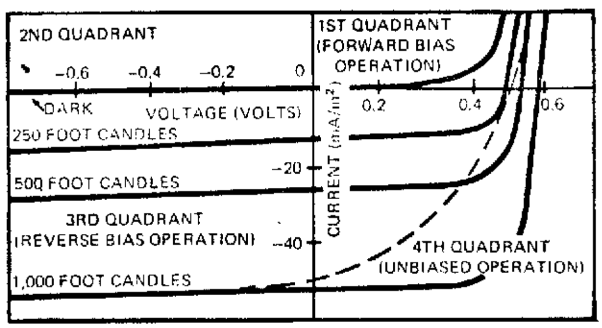
Characteristic	Fig. No.	Symbol	Min	Typ	Max	Unit
Total Power Output (Note 1) (I_F = 50 mA)	3,4	P_o	50	150	-	µW
Radiant Intensity (Note 2) (I_F = 50 mA)		I_o	-	0.66	-	mW/steradian
Peak Emission Wavelength	1	λP	-	9000	-	Å
Spectral Line Half Width	1	Δλ	-	400	-	Å

The characteristics desirable for this application are:

- Small size
- Compatible with LED light sources
- High light sensitivity
- Low power consumption

- Photo Diodes - Photo diodes are P on N or N on P silicon function devices that generate a photo current in response to a beam of light focused on the sensitive junction.

Being composed of silicon, these devices are small, rugged and reliable. The photo-diode is the basic photo sensitive device in all of the photo transistor varieties, so in one form or another it will be used in any kind of light transducer. The current voltage curves for a typical photo diode are shown below.

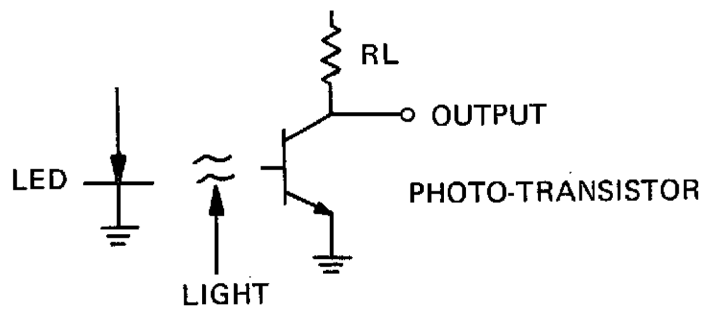


The voltage and current levels are sufficient to drive the logic section without further amplification. However, if a photo transistor were used, lower light intensities would be able to drive the same logic section. This would mean lower power consumption in the LED.

- Photo-transistors - The photo-transistor uses a photo diode to generate base current for a normal transistor. This, in effect, amplifies the current sensitivity of the device by the β of the transistor. There is no difference in package sizes between the photo diode and photo transistor, both can be obtained in packages as small as Figure 6.

Photo FETS take advantage of the photo voltaic effect of photo diodes. This is the change in output voltage as a function of light intensity of an open circuited photo diode. The increase of current gain available using a photo FET is of the same order of magnitude as that of a photo-transistor.

Configurations - The simplest configuration of a light transducer would look as follows:



In this configuration the light from the LED provides base current for the photo transistor turning it on. The shutter can be placed in the path of the light beam turning off the transistor.

The LED must be provided with from 20 to 50 ma of current depending on the distance between the diode and the transistor, the load RL on the transistor, and any attenuating devices between the diode and the transistor (glass, light pipes, etc.).

The configuration of the reflective type transducer would be identical to that pictured above except for the shutter which would become a mirrored surface.

Conclusions

Of the light type transducers the light emitting diode in conjunction with the photo-transducer is the only method which will adequately meet the requirements of this application.

Table III below lists the characteristics of this type of transducer.

TABLE III. LIGHT TRANSDUCER CHARACTERISTICS

POWER	.150 WATTS
COMPONENT COUNT	3
CROSS TALK	NONE
EXCITATION	DC-5-10V
HERMETIC SEAL	PROBLEM AREA GLASS TO METAL SEAL

CAPACITANCE TRANSDUCERS

A transducer of this type would operate by sensing the change of a capacitor and operating a trigger circuit from this change. Because all electrical components must be contained inside a hermetic seal the only portion of a capacitor which could be used to change the capacitance would be the dielectric. The plates of the capacitor being current carrying devices must lie within the hermetic seal and are therefore inaccessable for mechanical change.

This factor makes it very difficult to implement this type of transducer. Both plates must be sealed behind at least .050 thick sheets of glass while the dielectric contained within the environmentally sealed section is moved in or out of the plate gap.

A further complicating factor is the dielectric itself. It would be desirable to have the capacitor make a very large change in capacitance. This would mean using a material with a high dielectric constant. Most materials with this characteristic are unacceptable for use in a space cabin environment.

A variable capacitance transducer is therefore unacceptable for use in this application.

CIRCUITRY

SINGLE ACTION SWITCH

The basic circuitry of the switch consists of a magnet and Hall effect transducer, amplifier and output solid state relay switch as shown in schematic SW201 (Appendix I). The Hall effect device is an integrated hybrid chip containing the Hall effect pick off, an amplifier and a Schmitt trigger. The output of the Schmitt trigger drives a transistor amplifier which supplies current to the coil of the solid state relay switch. The output of the solid state relay directly supplies the load. The solid state relay coil is in series with the transistor driver and a light emitting diode. The light emitting diode provides an indication that the switch is in the ON condition and that approximately 80 percent of the circuitry is operating normally. The only difference between the single pole and double pole switch is the addition of a solid state relay, the coil of which is in series with the original solid state relay coil, and an increased supply voltage to provide additional drive power.

TEN POSITION ROTARY SWITCH

The circuitry of the ten position rotary switch is shown in Schematic RD001 (Appendix I). Four LED - phototransistor transducers provide the initial BCD triggering to obtain 10 discrete switch position outputs. The output of the phototransistors provides triggers to exclusive or gates which inserts the proper logic format into a BCD to one of ten decoders. The output of the decoder supplies through transistor amplifiers the current to drive the appropriate coil of solid state relay matrix. The output of the solid state relay directly supplies the load.

POTENTIOMETER

The input to the potentiometer consists of 7 LED - phototransistor transducers providing a resolution of 128 bits. The output of the phototransistors provides logic states to exclusive or gates, the outputs of which supply the necessary binary data to the digital to analog decoder. The decoder utilizes a ladder network with an operational amplifier output. The output is a 0 to 10 volt analog voltage capable of supplying a 1000 ohm or greater load. A visible LED on both the rotary switch and potentiometer indicate that all internal LEDs are energized.

OUTPUT SWITCH CIRCUITRY

The output characteristics of the switches are tabulated in Table IV. Physically all chips are the same size so that any possible combination of switch outputs is available. An important consideration with all types of switches is that the input to output isolation impedance is in excess of 10^{11} ohms.

SWITCH CONFIGURATION

The following types of mechanical packages must be produced to comply with the contract.

- Toggle switch (maintained)
- Toggle switch (momentary)
- Push button
- Potentiometer
- Rotary switch

TABLE IV. SWITCH CHARACTERISTICS

SWITCH TYPE	100 MA DC	140V AC	28V AC	400 MA DC
LOAD VOLTAGE	±50V MAX PEAK	140 VAC RMS	280 VAC RMS	60 VDC

INPUT (CONTROL) SPECIFICATIONS

CONTROL VOLTAGE RANGE	3.8-10 VDC	3.8-10 VDC	3.8-10 VDC	3.8-10 VDC
MAX INPUT CURRENT @ 5V	22 MA DC	15 MA DC	15 MA DC	15 MA DC
TURN OFF VOLTAGE (MAX)	0.4 VDC	0.8 VDC	0.8 VDC	0.4 VDC
DIELECTRIC STRENGTH INPUT TO OUTPUT	1000 VAC (PP)	2500 VAC (RMS)	2500 VAC (RMS)	1500 VAC (PP)
ISOLATION INPUT TO OUTPUT	10" Ω MIN	10" Ω MIN	10" Ω MIN	10" Ω MIN

OUTPUT (LOAD) SPECIFICATIONS

OUTPUT CURRENT RATING	±100 MA PEAK	1.0 AMP	1.0 AMP	400 MA
OUTPUT VOLTAGE	±50 MAX PEAK	140 VAC RMS	280 VAC RMS	60 VDC
OFFSET VOLTAGE	±5.0 MV MAX	-	-	-
CONTACT "ON" RESISTANCE (OHMS)	5.0 MAX	-	-	-
CONTACT "OFF" RESISTANCE (OHMS)	10^9 MIN	2×10^5 MIN	2×10^5 MIN	10^7 MIN
MAX DRIVE FREQUENCY (Hz)	100K	500	500	30K
MAX SURGE RATING	0.1 JOULE	10 AMP	10 AMP	-
CONTACT VOLTAGE DROP AT RATED CURRENT (MAX)	250 MV	1.5V RMS	1.5V RMS	1.5VDC

Each type must have the electronics hermetically sealed. The packages for each type therefore have two sections, a hermetically sealed section and an environmentally sealed section. The hermetically sealed section contains the drive electronics. The mechanical actuation is contained in the environmentally sealed section.

There are two basic types of package. One contains all the single action switch configuration and the other houses the rotary switch and potentiometer.

SINGLE ACTION SWITCH

The single action switch is packaged in a rectangular case of the same approximate dimensions as the present hermetically sealed single pole double throw mechanical switch made by Texas Instruments for the LEM and Apollo missions.

Of all approaches tried, Hall effect devices and magneto resistors were the most acceptable. The Hall effect device, because of the higher sensitivity of the Micro-switch device, results in no pole pieces extending through the hermetic seal and, therefore, is the optimum selection.

Figure 7 depicts the layout of the single action switch using this Hall effect device.

POTENTIOMETER AND ROTARY SWITCH

A potentiometer with a resolution of 3.6 degrees is provided. The potentiometer is not a variable resistor but a variable voltage supply which should serve all the functions normally performed by a potentiometer. Rotation of the pot shaft varys the digital input to a D to A converter (DAC) producing a variable voltage. The pot is, in effect, a 7 bit encoder connected to a DAC.

The encoder portion of the potentiometer is a mirrored disk outside of the hermetic seal. Inside the hermetic seal a series of photo diodes and light emitting diodes operating through a transparent seal senses the position of the mirrored disk. This digital information is connected to a DAC to provide the output.

The rotary switch is of the same configuration as the potentiometer. An encoder disk is mirrored into 10 sections. A series of photo diodes and light emitting diodes senses the position of the encoder disk and operates 10 individual switches. Any of the switch outputs shown in Table IV can be provided in the rotary switch.

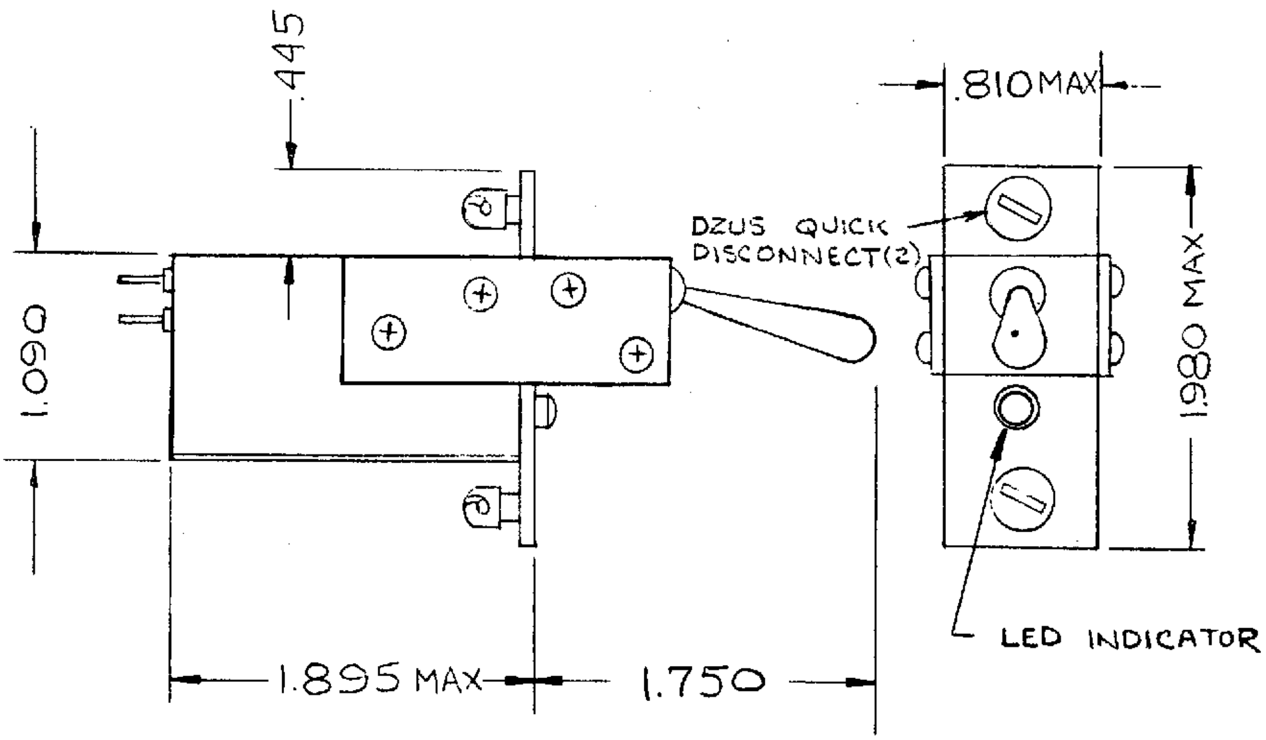


FIGURE 7. SOLID STATE TOGGLE SWITCH OUTLINE DRAWING
(Sheet 1 of 2)

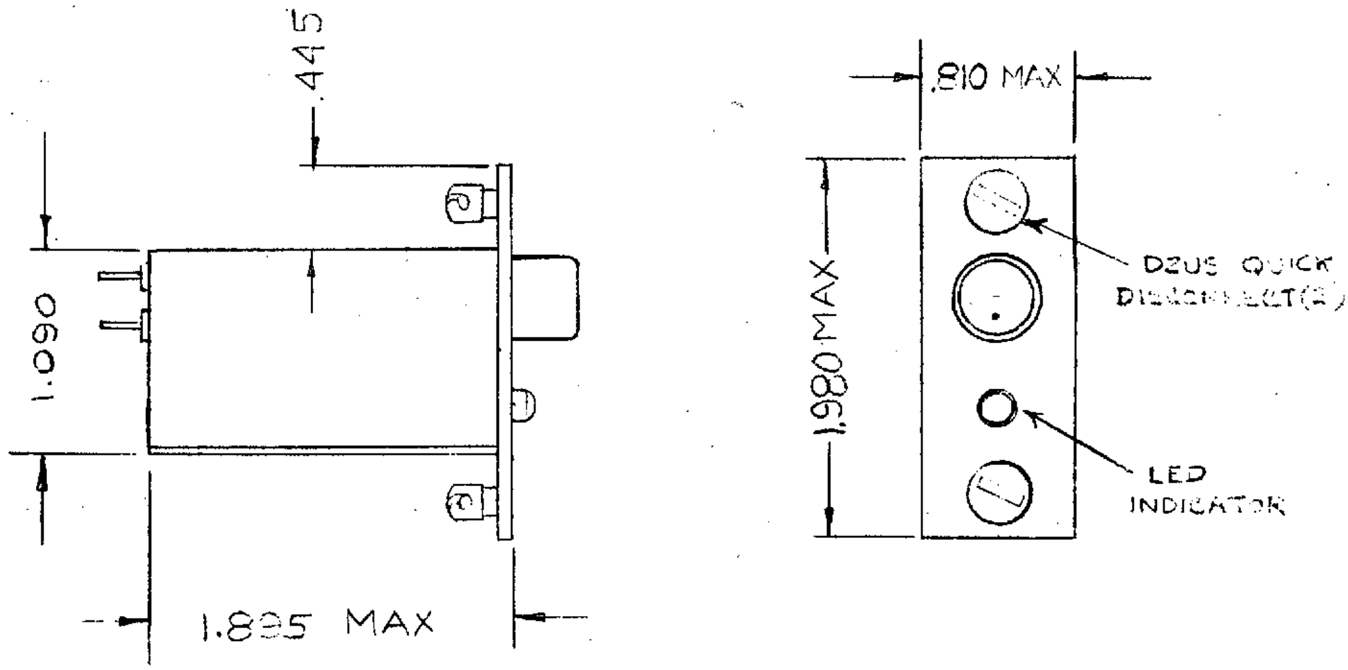


FIGURE 7. SOLID STATE TOGGLE SWITCH OUTLINE DRAWING
(Sheet 2 of 2)

The potentiometer and rotary switch are both packaged in a cylindrical housing approximately 2.5 inches in diameter and 1.5 inches in depth. Figure 8 depicts the layout for the solid state pot and rotary switch. A glass seal separates the hermetic section from the encoder wheel. The encoder wheel is environmentally sealed at the shaft with an O- ring. Light from the LEDs passes through the glass seal, is reflected by the silvered encoder disk and after again passing through the glass seal turns on the phototransistor. Seven LED phototransistors are arranged to align with a Gray code disc providing seven bits of non-redundant binary information. This information is converted into a variable voltage in the D to A section located on the two PC boards in the sealed area.

HERMETIC SEAL

A sample of each package style is hermetically sealed. The hermetically sealed portions of these packages constructed as gas tight enclosures completely sealed by fusion of glass to metal or bonding of metal to metal. Special sapphire glass discs already hermetically sealed to a metal ring are brazed into the brass casing to provide the chamber hermetic seal. After the electronics are inserted into the chamber and leads attached to the soldered glass/metal interconnect the back cover is soldered into place. Prior to sealing, the enclosure is cleaned and dried. The enclosure is purged of all air and backfilled with one atmosphere of gas consisting of 95 percent nitrogen/5 percent helium. A primary consideration in the selection of enclosure materials is the ease of welding, brazing or soldering the bonding methods typically employed for metal to metal hermetic seals. Final material selection provides for brass casings for ease of brazing and soldering.

Environmental Seals

Environmental sealing is accomplished primarily by gasketing. Silicone O-rings and gaskets are utilized at closure points to prevent dirt or moisture infiltration and other contaminants.

PANEL CONFIGURATION

The sold state switch panel contains the following types and quantities of switches.

Toggle maintained	SPST	5
Toggle maintained	DPST	5

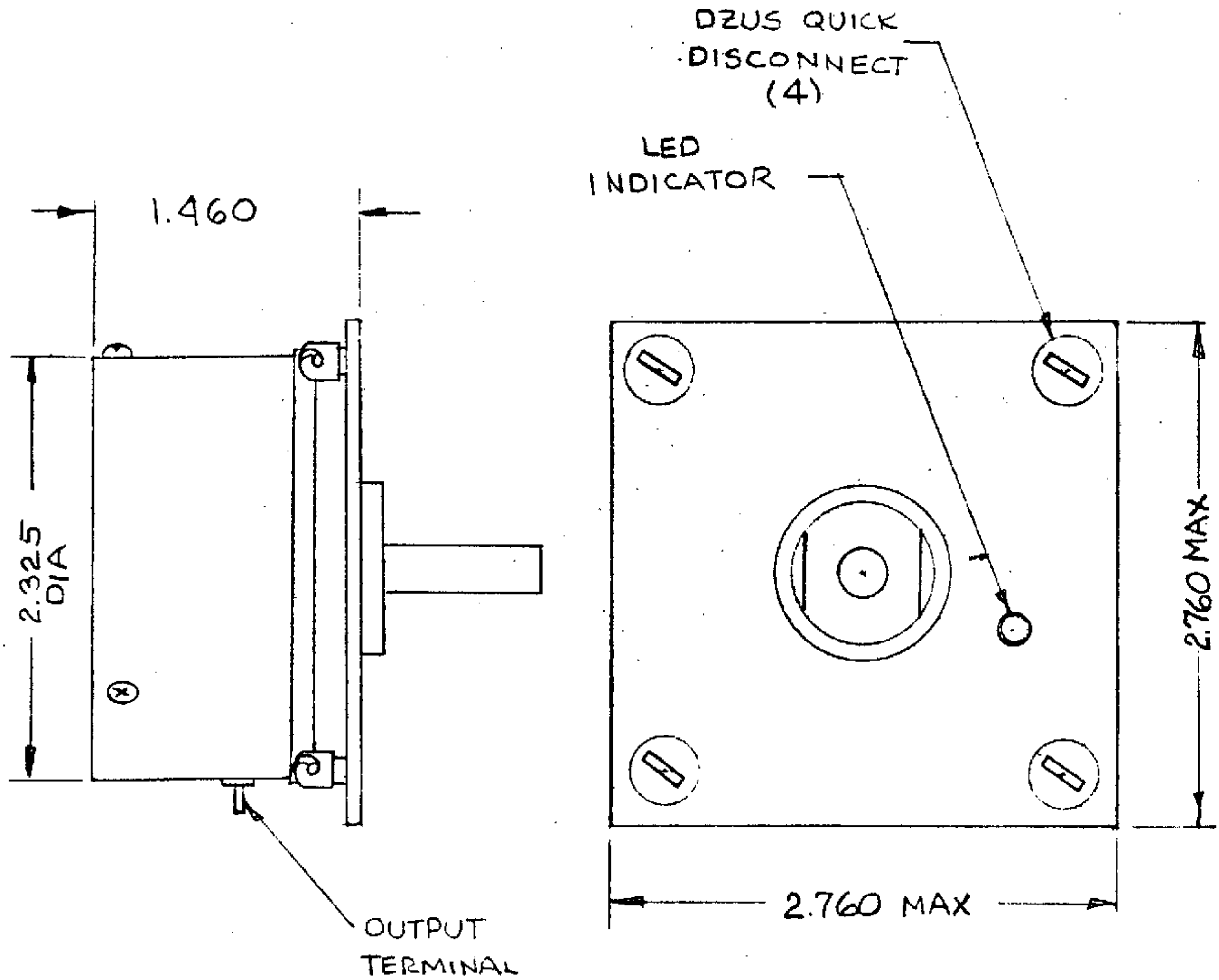


FIGURE 8. SOLID STATE POTENTIOMETER (Sheet 1 of 2)

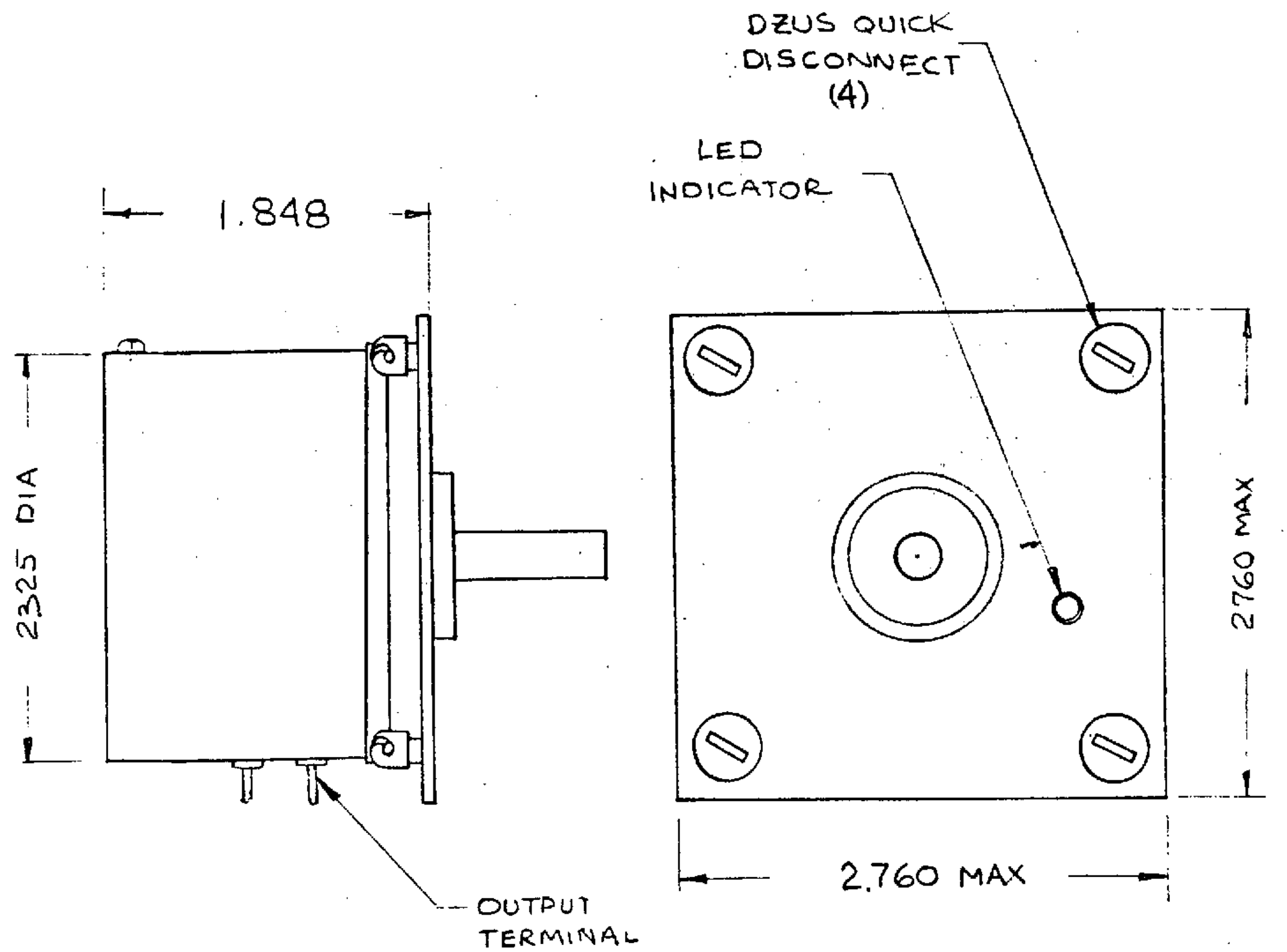


FIGURE 8. SOLID STATE 10 POSITION SWITCH (Sheet 2 of 2)

Toggle momentary	SPST	5
Toggle momentary	DPST	5
Pushbutton	SPST	3
Pushbutton	DPST	2
Rotary	10 position	2
Potentiometer		2

These switches are mounted on a 19-inch wide rack. Two of these switches control high powered 10 amp switches mounted directly on the test panel. The test panel also contains the rated loads for all the switches and potentiometers and provides an indication as to which switches are being operated. The switches are grouped relative to contact rating and identified accordingly on the test panel.

SUMMARY

For the small number of switches produced, several techniques were utilized which would not necessarily remain in the production unit. The same housing was used for both pushbutton and toggle switches which necessitated the use of an add-on toggle assembly. In production units, the toggle assembly would become an integral part of the switch body thereby enhancing the usual outline of the toggle switch.

In production quantities, all switch and rotary components would be hybridized to miniaturize the electronics. This would diminish the package size and simplify hermetic sealing.

POWER CONSUMPTION

Excluding the switch contact ratings, the following power is required in the quiescent (non-operating) state and the operating mode for each type of switch.

Switch	Voltage (volts)	Power Quiescent (mw)	Power Operating (mw)
Pushbutton/toggle SPST	5 & 12	20	320 mw
Pushbutton/toggle DPST	5 & 28	20	720 mw
10 Position Rotary	5 & 12	500 mw	500 mw
Potentiometer	5 & ±12	450 mw	450 mw

total panel power quiescent 2.4 watts

Operating 14.7 watts

PANEL OPERATION

POWER APPLICATION

Place all switches in the off (down) position. Apply the power to the proper pins on the input jack panel located at the bottom of the switch panel. The positive side of the -12 volt input connects to the black input jack and the negative connects to the red jack. The 28 power supply shall be capable of suppling 25 amps in order to test the power switches.

The AC voltages (120 VAC, 240 VAC) are only used to provide contact voltage ratings on the 5 pushbutton AC switches. The AC need not be connected for proper check out of all DC switches and rotary components.

OPERATION

The switch labeled panel controls power to the entire panel. Power is connected to this switch whenever power is present on the jack panel. When it is switched to the ON position, power is applied to all other switches.

With power connected to the panel and the panel switch on, all switches will operate. Switching any toggle momentary or maintained to the ON (up) position or operating any pushbutton will cause the appropriate load light to illuminate. For the two power switches there are no load lights. Closure indication for these switches is given by two current meters located at the top of the panels.

The rotary devices are also actuated by the panel switch. The outputs of the potentiometers are indicated by two volt meters located at the top of the panel. The rotary switches are connected to decimal displays which indicate the position of the switch.

LOAD CONNECTOR PIN OUT.

PIN	LOAD	PIN	LOAD	
1	S10	35		
2	S9	36		
3	S8	37		
4	S7	38		
5	S6	39		
6	S5	40		
7	S4	41		
8	S3	42		
9	S2	43		
10	S1	44		
11	S22	45		
12	S21	46		
13	S20	47		
14	S19	48		
15	S18	49		
16	S17	50	POWER SWITCH 2	S14
17	S16	51	POWER SWITCH 1	S13
18	S15	52	ROTARY SWITCH 2	0
19	S23	53		9
20	S22	54		8
21	S21	55		7
22	S20	56		6
23	S19	57		5
24	POTENTIOMETER # 1	58		4
25	POTENTIOMETER # 2	59		3
26	ROTARY SWITCH 1 POSITION 1	60		2
27	ROTARY SWITCH 1 POSITION 2	61		1
28	ROTARY SWITCH 1 POSITION 3	62	ROTARY SWITCH 1 POSITION	0
29	ROTARY SWITCH 1 POSITION 4	63	ROTARY SWITCH 1 POSITION	9
30	ROTARY SWITCH 1 POSITION 5	64	ROTARY SWITCH 1 POSITION	8
31	ROTARY SWITCH 1 POSITION 6			
32	ROTARY SWITCH 1 POSITION 7			
33				
34				

TESTS

FUNCTIONAL TESTS

All switches were tested at standard ambient conditions to insure proper operation at rated voltage and 10 percent under and over voltages. Power at nonoperating (quiesent) and operation conditions were measured for the entire panel with the following results:

Panel Quiesent Power	2.4 Watts
Panel Operating Power	14.7 Watts

The panel operated satisfactorily when submitted to the various functional tests.

ENVIRONMENTAL TESTS

One type of each switch: toggle, pushbutton, rotary and potentiometer were submitted to the following environmental tests.

TEMPERATURE

2 Hour Soak at 0°C

Functionally tested

2-Hour Soak at 70°C

Functionally tested

RESULTS

SPST, DPST, and Rotary Switch operated satisfactorily. Potentiometer intermittent at high temperature as a result of low current through LED's. Increasing current through LED's provides stability over temperature range, however, higher power dissipation results.

RANDOM VIBRATION

Procedure

A random vibration equal to the total G level utilized on the LEM and Skylab was impressed on the switches. Period of application is 2 minutes.

1150-2000 Hz 20-2000 Hz .02 $^{gr}/Hz$

Switches Tested

Pushbutton

Toggle

Rotary Switch

RESULTS

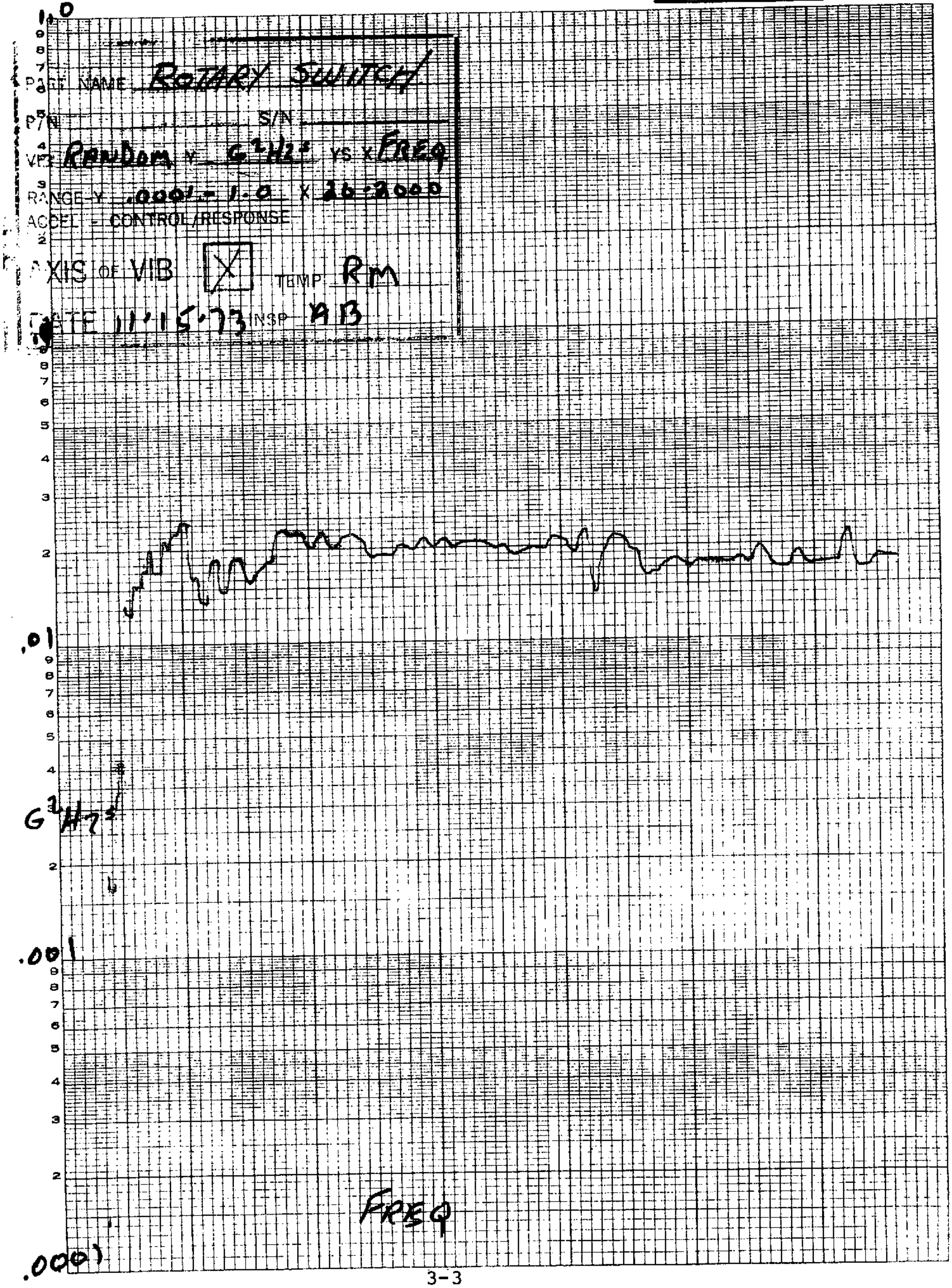
All switches functioned throughout the random vibration. The pushbutton normally open remained in the normally open state, the toggle maintained in a closed switch position remained in that state without interruption and the rotary switch set at position 5 remained closed in that position with all other positions normally open. The graphs on the following pages visually depict the vibration levels applied in the during the test.

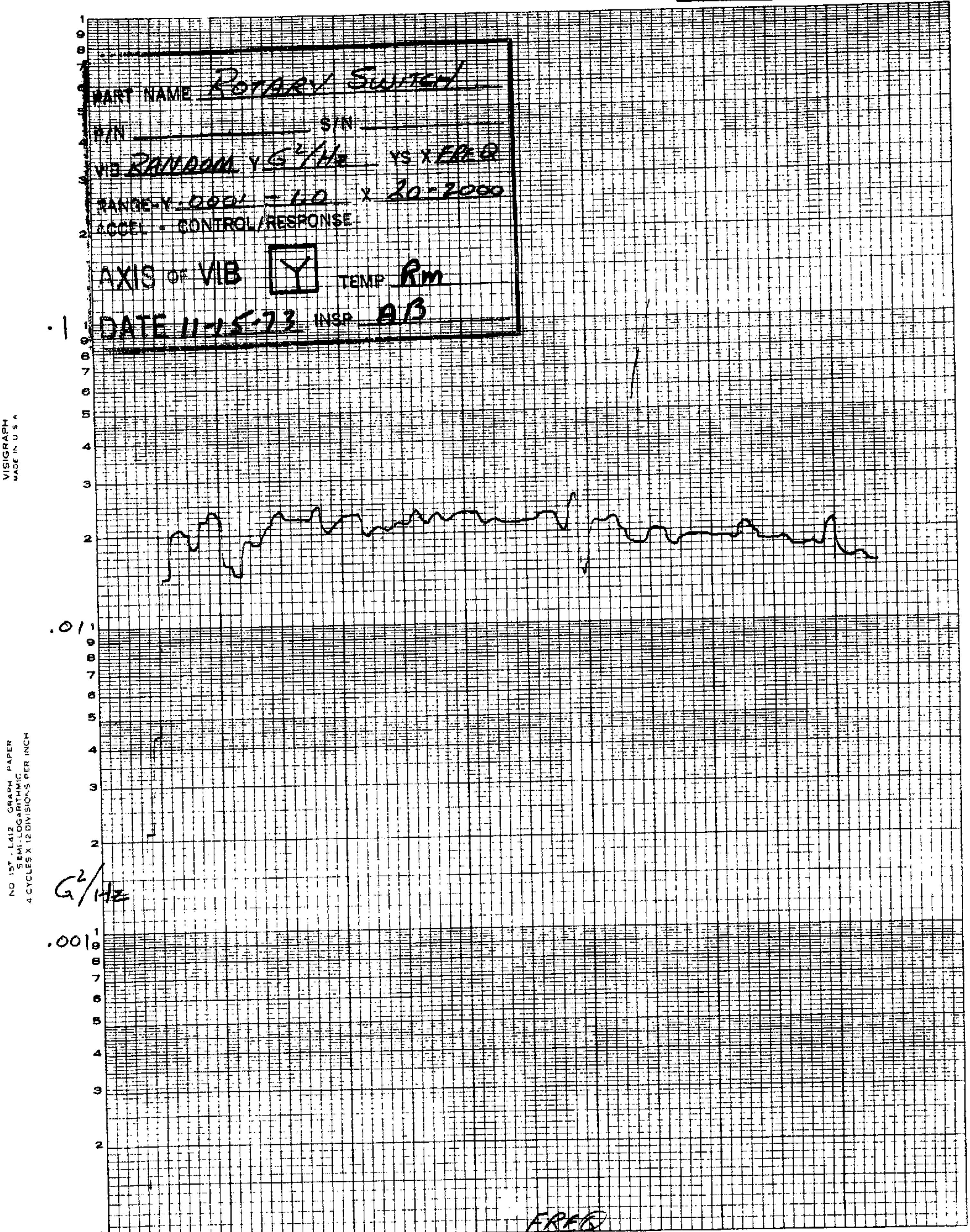
EMI TESTS

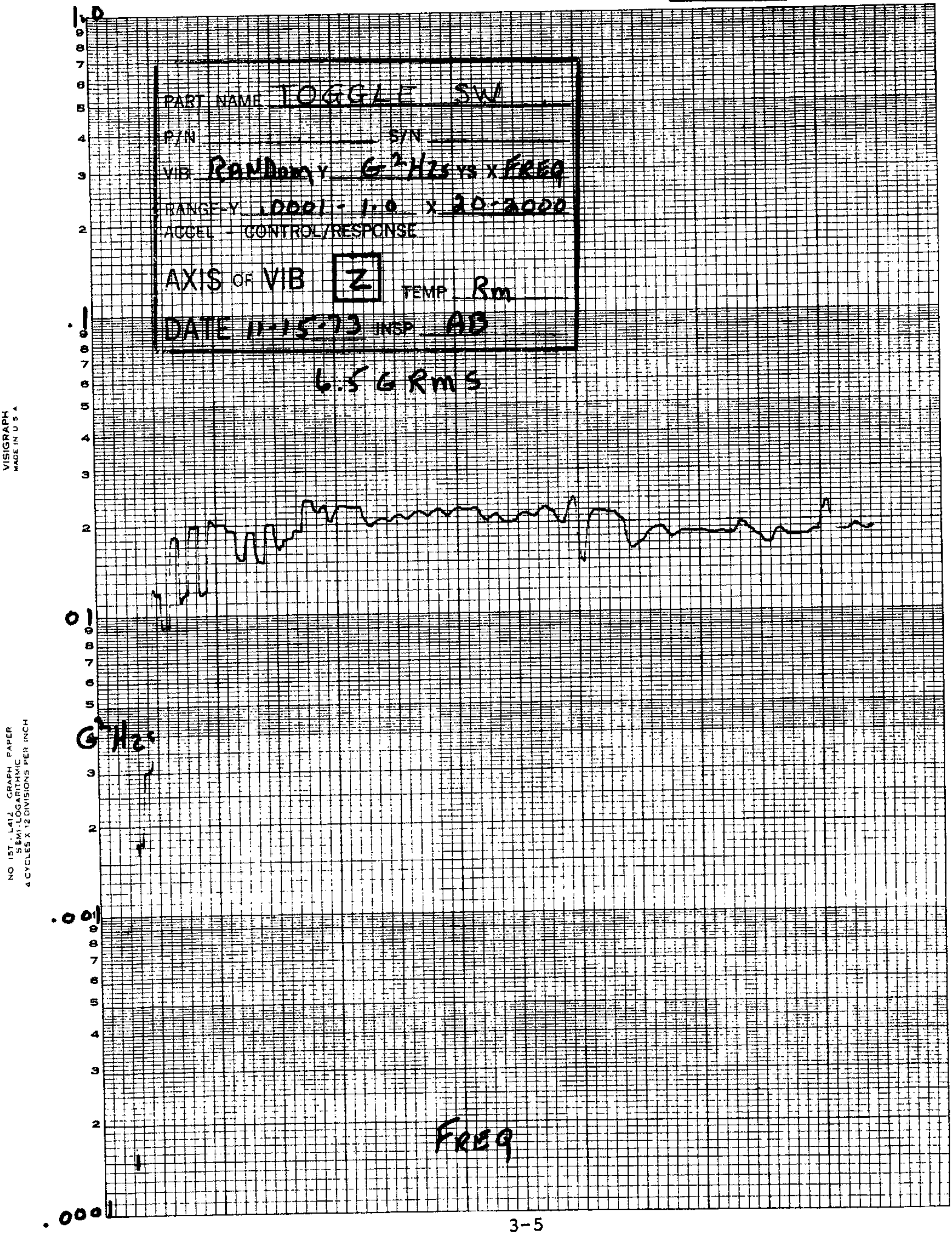
EMI tests were conducted on the double pole, single pole and the potentiometer in accordance with MIL-STD-461. The tests performed were CE01, CE03 and CS06. CE01 and CE03 were preformed on every lead of the device under test. CS06 was preformed on all power leads with the spike equal to 50% of the nominal line voltage.

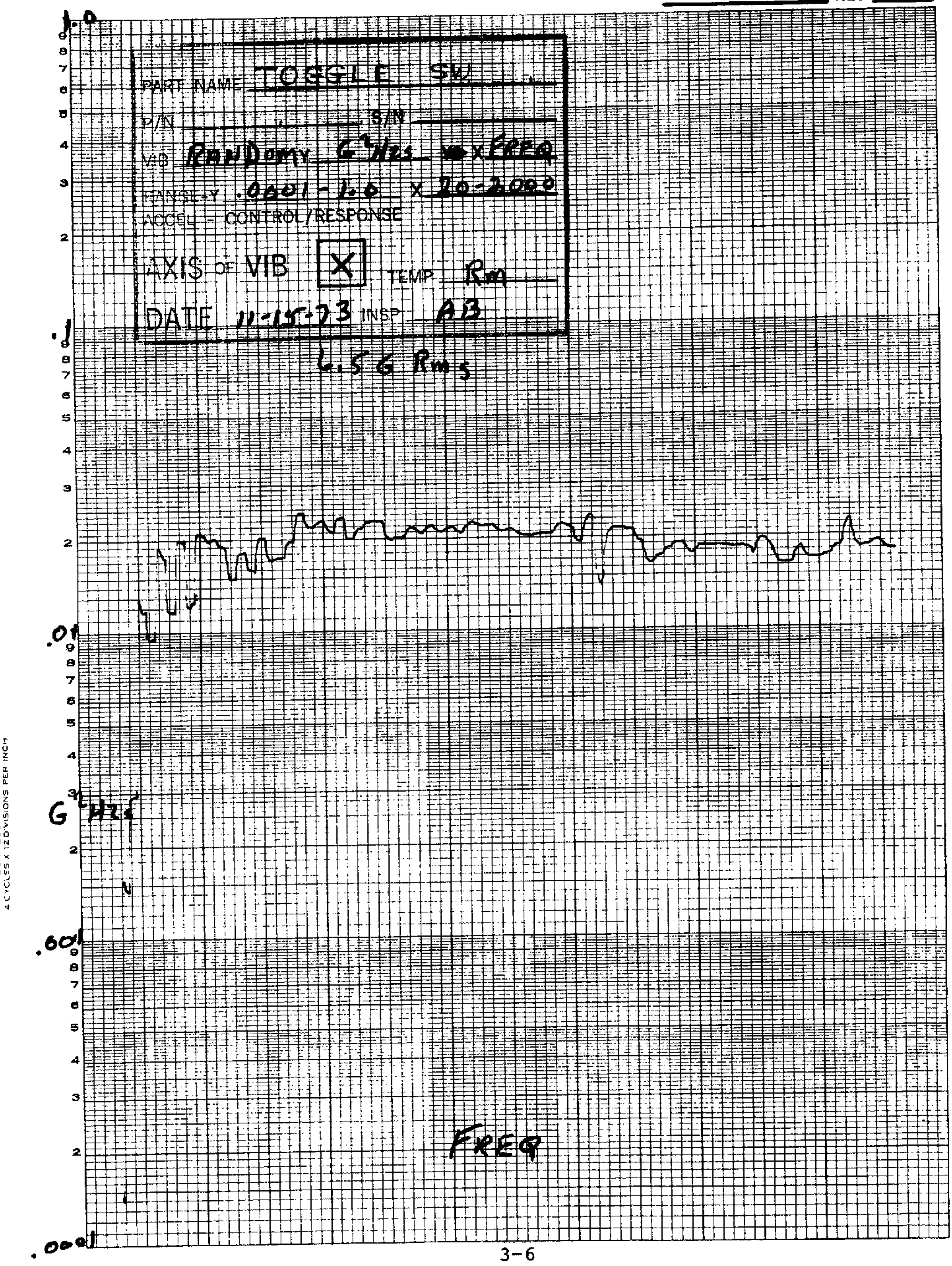
RESULTS

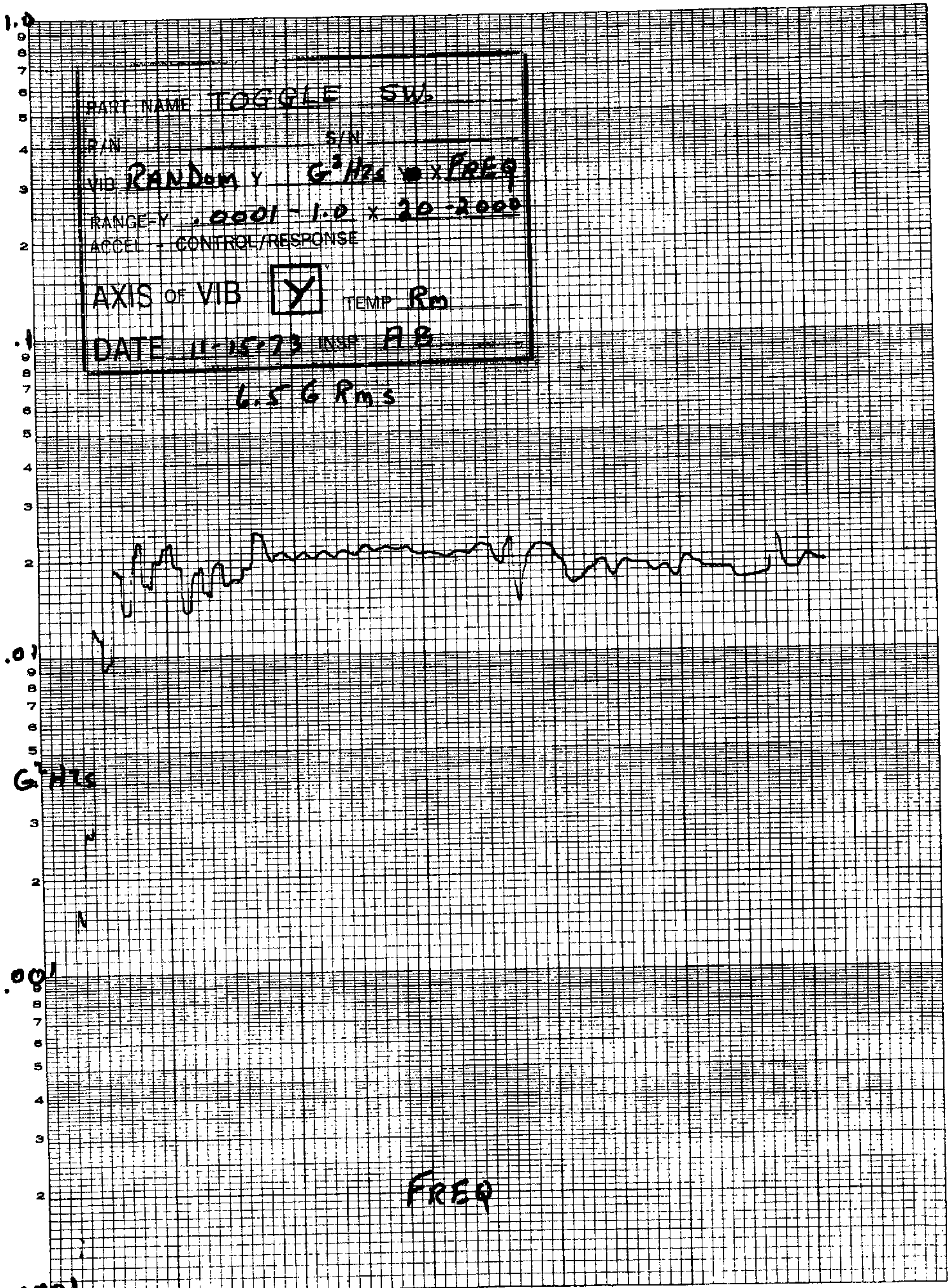
The results of the CE01 & CE03 tests are contained in the attached data. Emissions for all devices were within the max specification limit. All devices operated successfully during the CS06 tests.

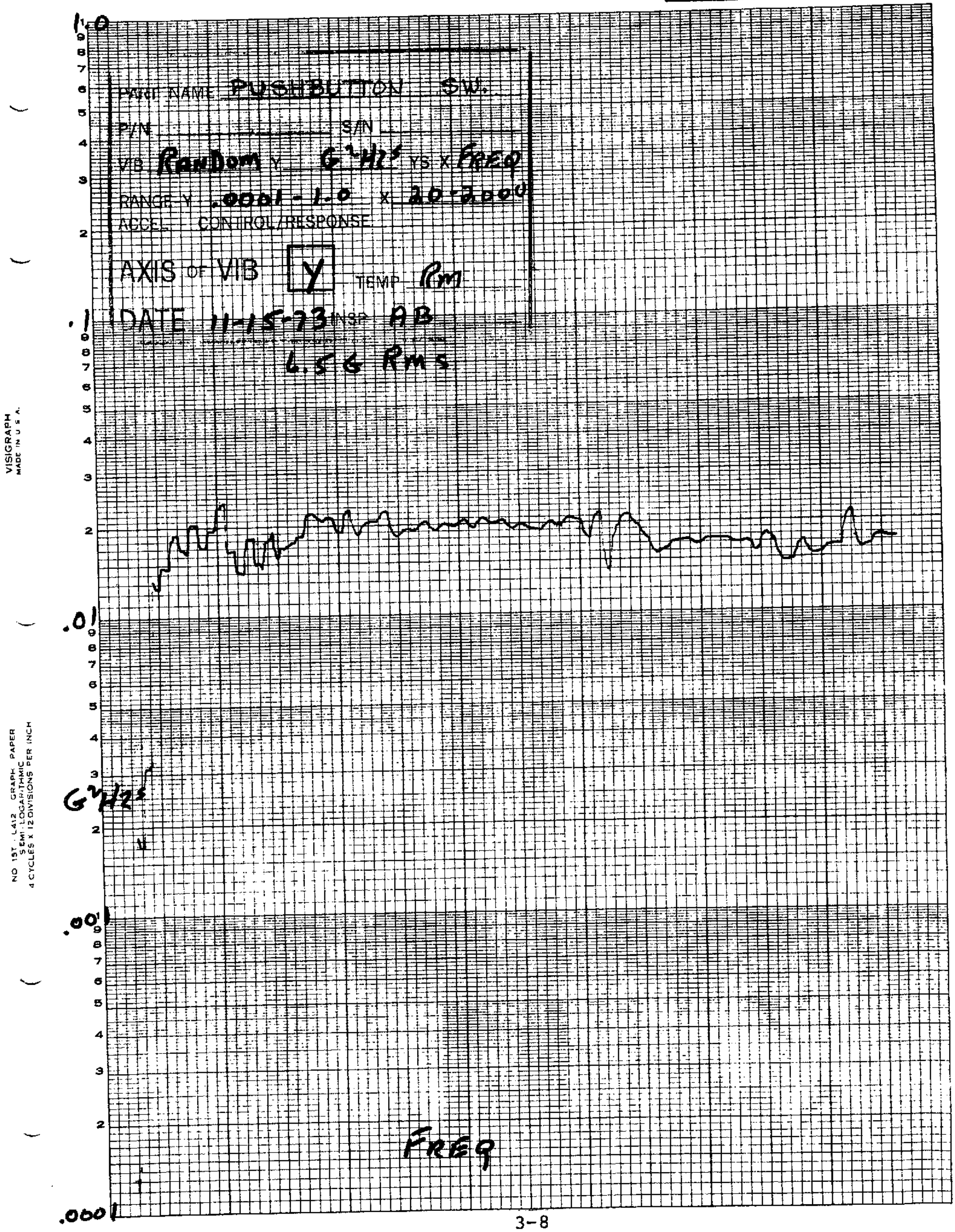

PART NAME ROTARY SWITCH
P/N
S/N
VIB RANDOM Y G²HZ² VS X FREQ
RANGE Y .0001 - 1.0 X 20-2000
ACCEL - CONTROL/RESPONSE
AXIS OF VIB X
TEMP RM
DATE 11-15-73
INSP AB
1.0
.01
.001
.0001
G²HZ²
FREQ


PART NAME Rotary Switch
P/N
S/N
VIB Random Y G²/Hz VS X Freq
RANGE-Y .0001 - 1.0 X 20-2000
ACCEL - CONTROL/RESPONSE
AXIS OF VIB Y
TEMP Rm
DATE 11-15-73
INSP AB
.1
.01
.001
G²/Hz
FREQ
VISIGRAPH MADE IN U.S.A.
NO. 15T. L412 GRAPH PAPER SEMI-LOGARITHMIC 4 CYCLES X 12 DIVISIONS PER INCH

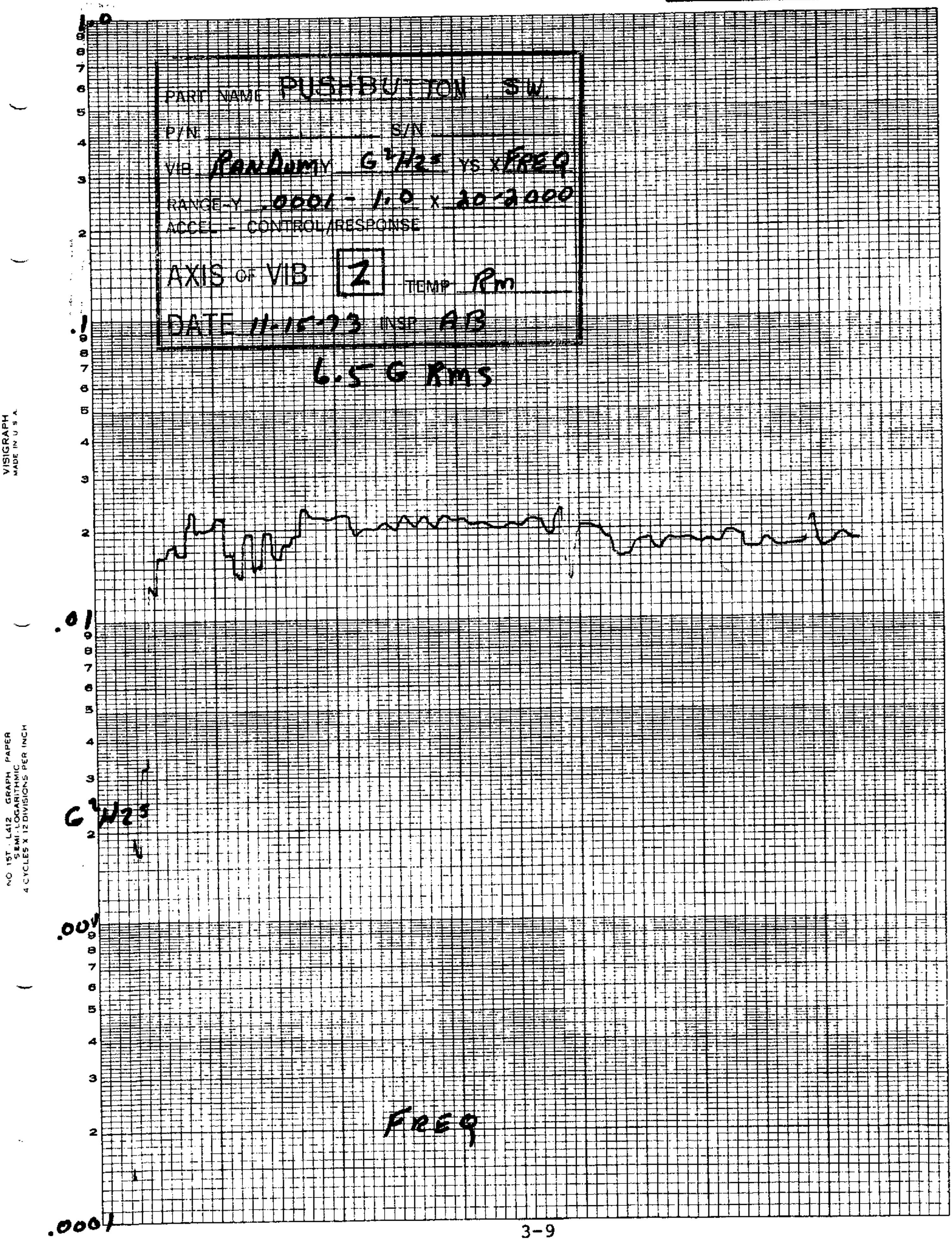

PART NAME TOGGLE SW
P/N
S/N
VIB RANDOM Y G²/HZ VS X FREQ
RANGE-Y .0001 - 1.0 X 20-2000
ACCEL - CONTROL/RESPONSE
AXIS OF VIB Z TEMP Rm
DATE 11-15-73 INSP AB
6.5 G RMS
1.0
.1
.01
.001
.0001
G²/Hz
FREQ
VISIGRAPH MADE IN U S A
NO 1ST. L412 GRAPH PAPER SEMI-LOGARITHMIC 4 CYCLES X 12 DIVISIONS PER INCH

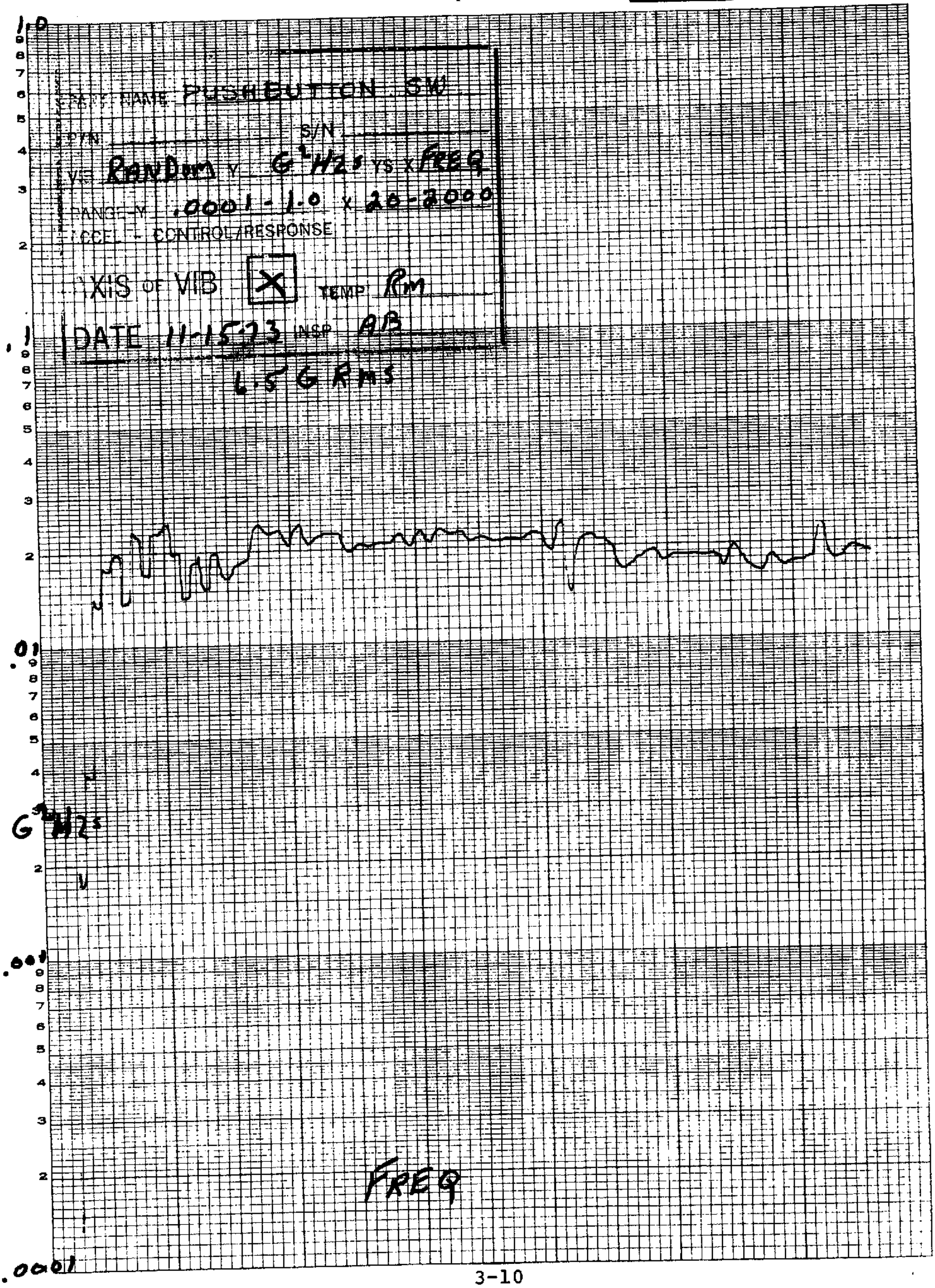

PART NAME TOGGLE SW.
P/N
S/N
VIB RANDOM G²/Hz x FREQ
RANGE-Y .0001-1.0 X 20-2000
ACCEL - CONTROL/RESPONSE
AXIS OF VIB X
TEMP Rm
DATE 11-15-73 INSP AB
6.56 Rms
G²/Hz
FREQ
1.0
.1
.01
.001
.0001
VISIGRAPH MADE IN U.S.A.
NO. 1ST. L412 GRAPH PAPER SEMI-LOGARITHMIC 4 CYCLES X 120 DIVISIONS PER INCH


PART NAME TOGGLE SW.
P/N
S/N
VIB RANDOM Y G²/Hz x FREQ
RANGE-Y .0001 - 1.0 x 20 - 2000
ACCEL - CONTROL/RESPONSE
AXIS OF VIB Y
TEMP Rm
DATE 11-15-73 INSP AB
6.5 G Rms
G²/Hz
FREQ
1.0
.1
.01
.001
.0001



PART NAME PUSHBUTTON SW.
P/N S/N
VIB. RANDOM Y G²HZ's VS X FREQ
RANGE Y .0001-1.0 X 20-2000
ACCEL CONTROL/RESPONSE
AXIS OF VIB Y TEMP RM
DATE 11-15-73 INSP AB
6.5 G Rms
1.0
.1
.01
.001
.0001
G²HZ's
FREQ
VISIGRAPH MADE IN U.S.A.
NO 1ST. L412 GRAPH PAPER SEMI-LOGARITHMIC 4 CYCLES X 12 DIVISIONS PER INCH


1.0
PART NAME PUSHBUTTON SW.
P/N S/N
VIB RANDOM Y G²/Hz VS X FREQ
RANGE-Y .0001 - 1.0 X 20-2000
ACCEL - CONTROL/RESPONSE
AXIS OF VIB Z TEMP Rm
DATE 11-15-73 INSP AB
.1
6.5 G Rms
.01
G²/Hz
.001
FREQ
.0001
VISIGRAPH MADE IN U.S.A.
NO 1ST. L412 GRAPH PAPER SEMI-LOGARITHMIC 4 CYCLES X 12 DIVISIONS PER INCH


PART NAME PUSHBUTTON SW
P/N
S/N
VIB RANDOM Y G²HZs VS X FREQ
RANGE-Y .0001-1.0 X 20-2000
ACCEL - CONTROL/RESPONSE
AXIS OF VIB X
TEMP RM
DATE 11-15-73 INSP AB
1.5 G RMS
1.0
.1
.01
.001
.0001
G²/HZs
FREQ

SINGER
KEARFOTT DIVISION

Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN	MODEL NO	SER NO.
POTENTIOMETER	NASA	

TEST MODE: POWER ON

SPECIFICATION	PARAGRAPH	TEST
		+5V.D.C.

CONDUCTED BY	DATE	CHECKED BY	DATE
A.G.	11-17-73	B.J.	11-17-73

TEST FREQ	METER READING	CORRECTION FACTOR	FINAL READING	SPECIFICATION LIMIT	INTER. TYPE (SEE NOTE B)	REMARKS
	dB/μa 1MHZ	C.P.	dB/μa/MHZ	DB/μa 1MHZ		PROBE
.020	46	11	57	124	1	
.025	45	10	55	120	1	
.035	38	7	45	116	1	
.045	35	5	40	112	1	
.065	34	4	38	106	1	
.080	32	3	35	102	1	
.100	11	2	13	98	1	
.120	30	1	31	96	1	
.150	33	1	34	92	1	
.200	30	0	30	87	1	
.300	30		30	80	1	
.400	30		30	76	1	
.500	30			72	1	
.800	30			64	1	
1.0	30			60	1	
1.5	30			54	1	
2.0	30			50	1	
3.0	30					
4.0	30				1	
5.0	30					
6.0	30				1	
9.0	30				1	
12.0	30				1	
15.0	30				1	
20.0	30				1	
30.0	30				1	
40.0	30				1	
50.0	30				1	

NOTE: A – All frequencies not listed are scanned for maximum interference.
B – Interference Type: (1) Broadband, Steady–State
(2) Broadband, Transients
(3) Narrowband (CW)

SINGER
KEARFOTT DIVISION

Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN	MODEL NO	SER NO.
POTENTIOMETER	NASA	

TEST MODE: POWER ON

SPECIFICATION	PARAGRAPH	TEST
		+12 V.D.C

CONDUCTED BY	DATE	CHECKED BY	DATE
AG	11-20-73	B.J.	11-20-73

TEST FREQ	METER READING	CORRECTION FACTOR	*FINAL READING	SPECIFICATION LIMIT	INTER. TYPE (SEE NOTE B)	REMARKS
	DB/uA/MHZ	C.F.	DB/uA/MHZ	DB/uA/MHZ		PROBE
.020	62	11	73	124	1	
.025	62	10	72	120	1	
.035	61	7	68	116	1	
.045	58	5	63	112	1	
.065	47	4	51	106	1	
.080	46	3	49	102	1	
.100	40	2	46	98	1	
.120	41	1	42	96	1	
.150	37	1	38	92	1	
.200	35	0	35	87	1	
.300	38		38	80	1	
.400	36		36	76	1	
.500	31		31	72	1	
.800	30		30	64	1	
1.0	30		30	60	1	
1.5	30		30	54	1	
2.6	30		30	50	1	
3.0	30		30		1	
4.0	30		30		1	
5.0	30		30		1	
6.0	30		30		1	
9.0	30		30		1	
12.0	30		30		1	
15.0	30		30		1	
20.0	31		31		1	
30.0	30		30		1	
40.0	30		30		1	
50.0	30		30		1	

NOTE: A – All frequencies not listed are scanned for maximum interference.
B – Interference Type: (1) Broadband, Steady–State
(2) Broadband, Transients
(3) Narrowband (CW)

Y256A226 REV

SINGER
KEARFOTT DIVISION

Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN	MODEL NO	SER NO.
POTENTIOMETER	NASA	

TEST MODE: POWER ON.

SPECIFICATION	PARAGRAPH	TEST
		-12 V.D.C.

CONDUCTED BY	DATE	CHECKED BY	DATE
A.G.	11/20/73	BJ.	11-20-73

TEST FREQ	METER READING	CORRECTION FACTOR	FINAL READING	SPECIFICATION LIMIT	INTER. TYPE (SEE NOTE B)	REMARKS
	DB/ua/MHZ	C.F.	DB/ua/MHZ	DB/ua/MHZ		
.020	68	11	79	127	1	PROBE
.025	[illegible]	10	78	120	1	
.035	66	7	73	116	1	
.045	62	5	67	112	1	
.065	51	4	55	106	1	
.080	46	3	49	102	1	
.100	45	2	47	98	1	
.120	41	1	43	96	1	
.150	35	1	36	92	1	
.200	30	0	30	87	1	
.300	40		40	80	1	
.400	30		30	76	1	
.500	30		30	72	1	
.800	30		30	64	1	
1.0	30		30	60	1	
1.5	30		30	54	1	
2.0	30		30	50	1	
3.0	30		30		1	
4.0	30		30		1	
5.0	30		30		1	
6.0	30		30		1	
9.0	30		30		1	
12.0	30		30		1	
15.0	30		30		1	
20.0	30		30		1	
30.0	30		30		1	
40.0	30		30		1	
50.0	30		30		1	

NOTE: A – All frequencies not listed are scanned for maximum interference.
B – Interference Type: (1) Broadband, Steady–State
(2) Broadband, Transients
(3) Narrowband (CW)

SINGER
KEARFOTT DIVISION

Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN	MODEL NO	SER NO.
POTENTIOMETER	NASA	

TEST MODE: POWER ON

SPECIFICATION	PARAGRAPH	TEST
		SIGNAL LEADS

CONDUCTED BY	DATE	CHECKED BY	DATE
AG	11-20-73	BJ	11-20-73

TEST FREQ	METER READING	CORRECTION FACTOR	FINAL READING	SPECIFICATION LIMIT	INTER. TYPE (SEE NOTE B)	REMARKS
	DB/uA/MHZ	C.F.	DB/uA/MHZ	DB/uA/MHZ		
.020	105	11	116	124	1	PROBE
.025	101	10	111	120	1	
.035	90	7	97	116	1	
.045	85	5	90	112	1	
.065	71	4	75	106	1	
.080	71	3	74	102	1	
.100	71	2	73	98	1	
.120	65	1	66	96	1	
.150	60	1	61	92	1	
.200	52	0	52	87	1	
.300	41		41	80	1	
.400	41		41	76	1	
.500	37		37	72	1	
.800	30		30	64	1	
1.0	30		30	60	1	
1.5	30		30	54	1	
2.0	30		30	50	1	
3.0	30		30		1	
4.0	30		30		1	
5.0	30		30		1	
6.0	30		30		1	
9.0	30		30		1	
12.0	30		30		1	
15.0	30		30		1	
20.0	30		30		1	
30.0	31		31		1	
40.0	30		30		1	
50.0	30		30		1	

NOTE: A – All frequencies not listed are scanned for maximum interference.
B – Interference Type: (1) Broadband, Steady-State
(2) Broadband, Transients
(3) Narrowband (CW)

SINGER
KEARFOTT DIVISION

Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN	MODEL NO	SER NO.
POTENTIOMETER	NASA	

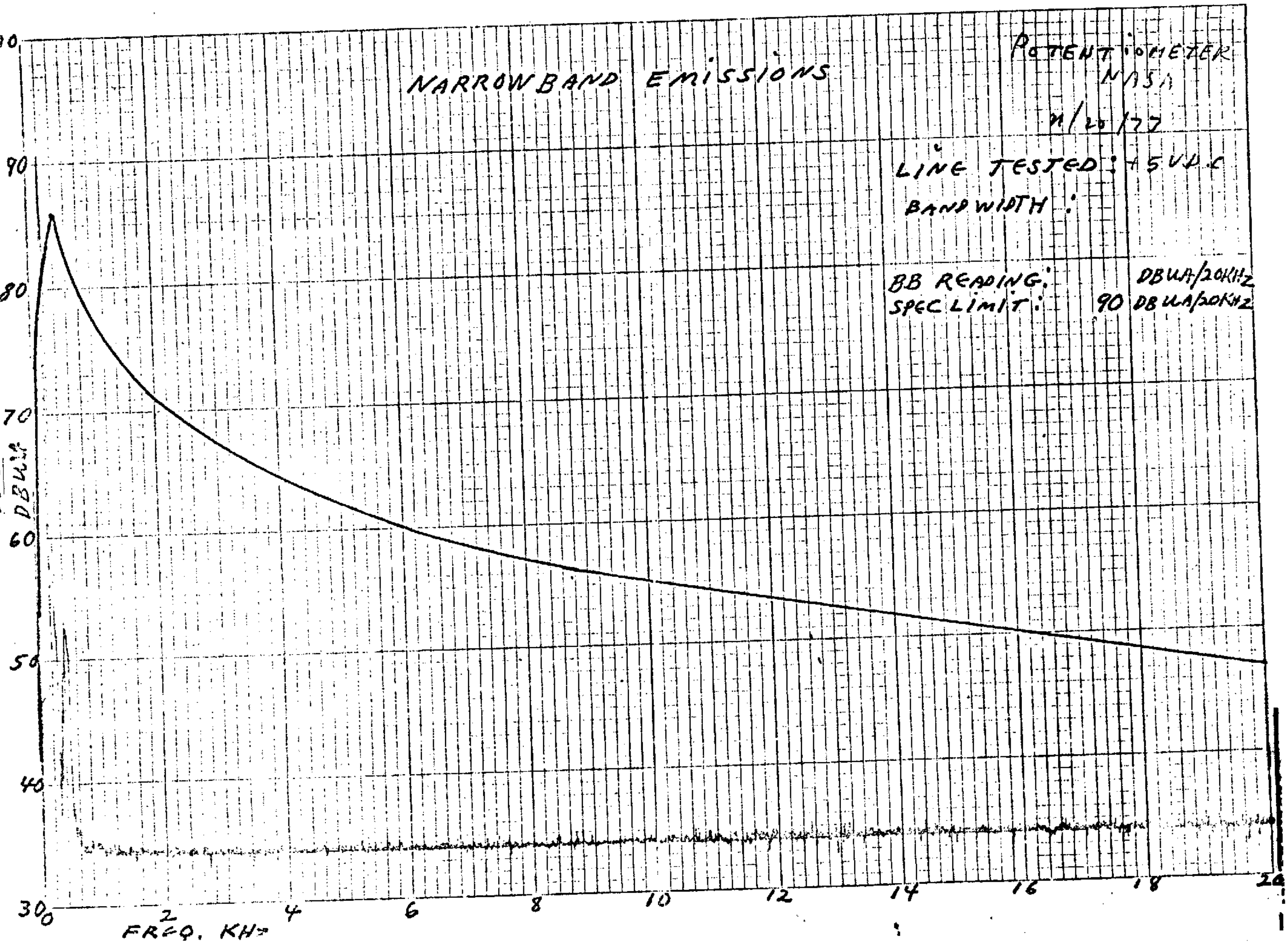
TEST MODE: POWER ON

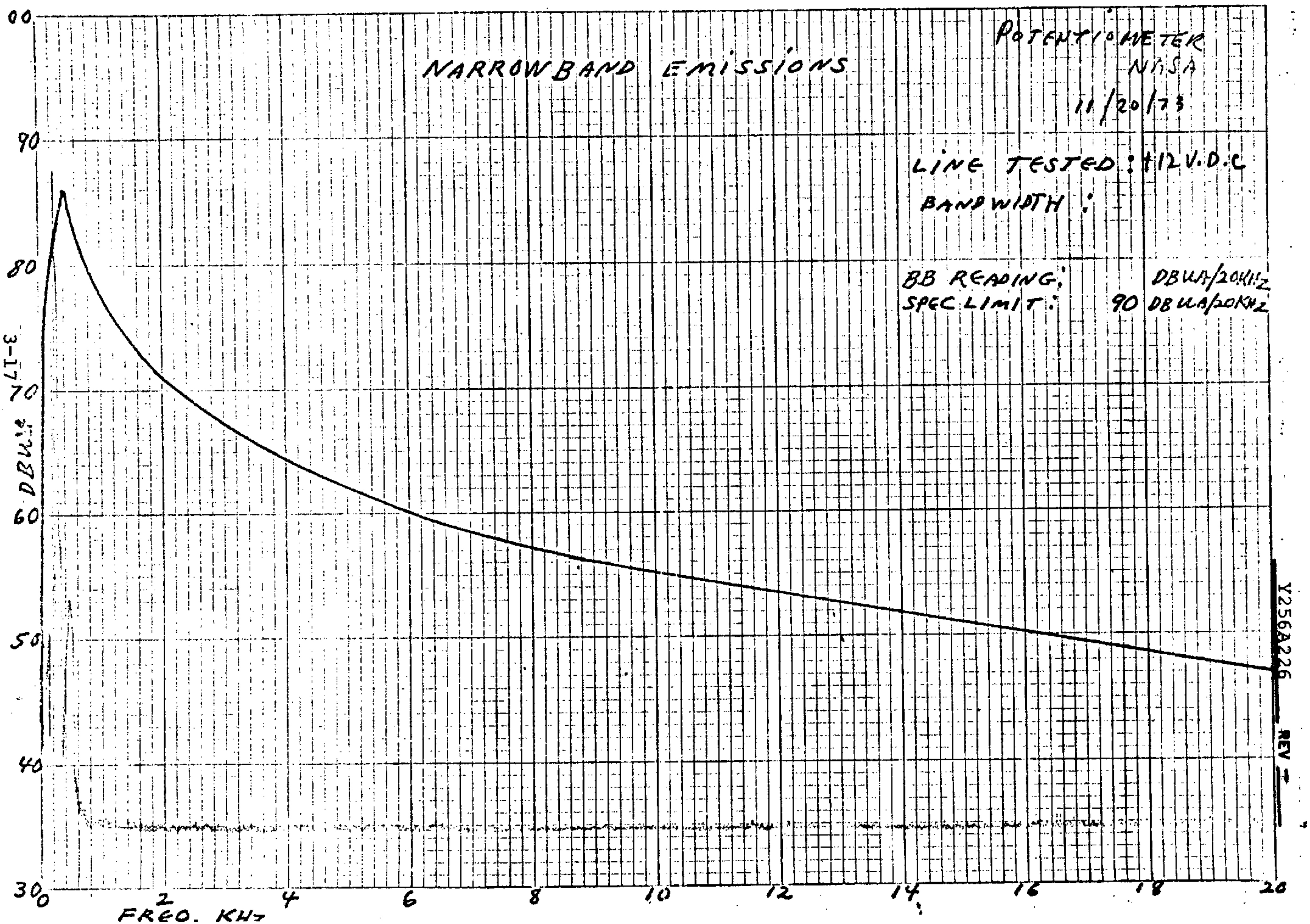
SPECIFICATION	PARAGRAPH	TEST
		-12V, D.C

CONDUCTED BY	DATE	CHECKED BY	DATE
A.G.	11/20/73	B.J	11-20-73

TEST FREQ	METER READING	CORRECTION FACTOR	FINAL READING	SPECIFICATION LIMIT	INTER. TYPE (SEE NOTE B)	REMARKS
	DB/UA/MHZ	C.F.	DB/UA/MHZ	DB/UA/MHZ		
.200	37	0	37	51	3	PROBE
.300	43	0	43	60	3	"
.400	45	0	45	76	3	"
.500	33	0	33	72	3	"

NOTE: A – All frequencies not listed are scanned for maximum interference.
B – Interference Type: (1) Broadband, Steady–State
(2) Broadband, Transients
(3) Narrowband (CW)


NARROWBAND EMISSIONS
POTENTIOMETER
NASA
11/20/77
LINE TESTED: +5VDC
BANDWIDTH:
BB READING: DBUA/20KHZ
SPEC LIMIT: 90 DBUA/20KHZ
100
90
80
70
60
50
40
30
DBUA
0
2
4
6
8
10
12
14
16
18
20
FREQ. KHZ


10 X 10 TO THE INCH 46 0703
KEUFFEL & ESSER CO.
NARROWBAND EMISSIONS
POTENTIOMETER
NASA
11/20/73
LINE TESTED: +12V.D.C
BANDWIDTH:
BB READING: DBUA/20KHZ
SPEC LIMIT: 90 DBUA/20KHZ
DBUA
FREQ. KHZ
100
90
80
70
60
50
40
30
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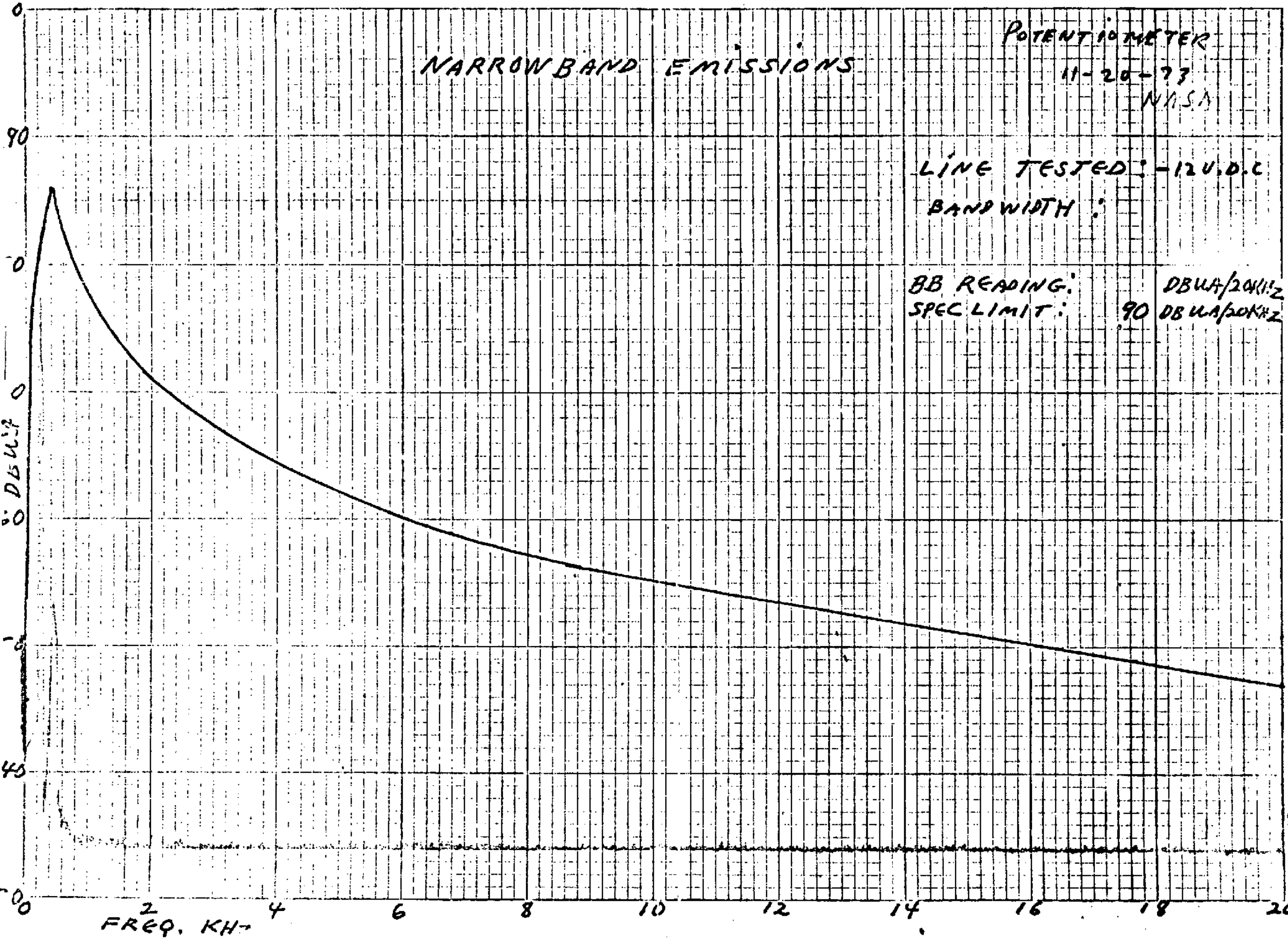
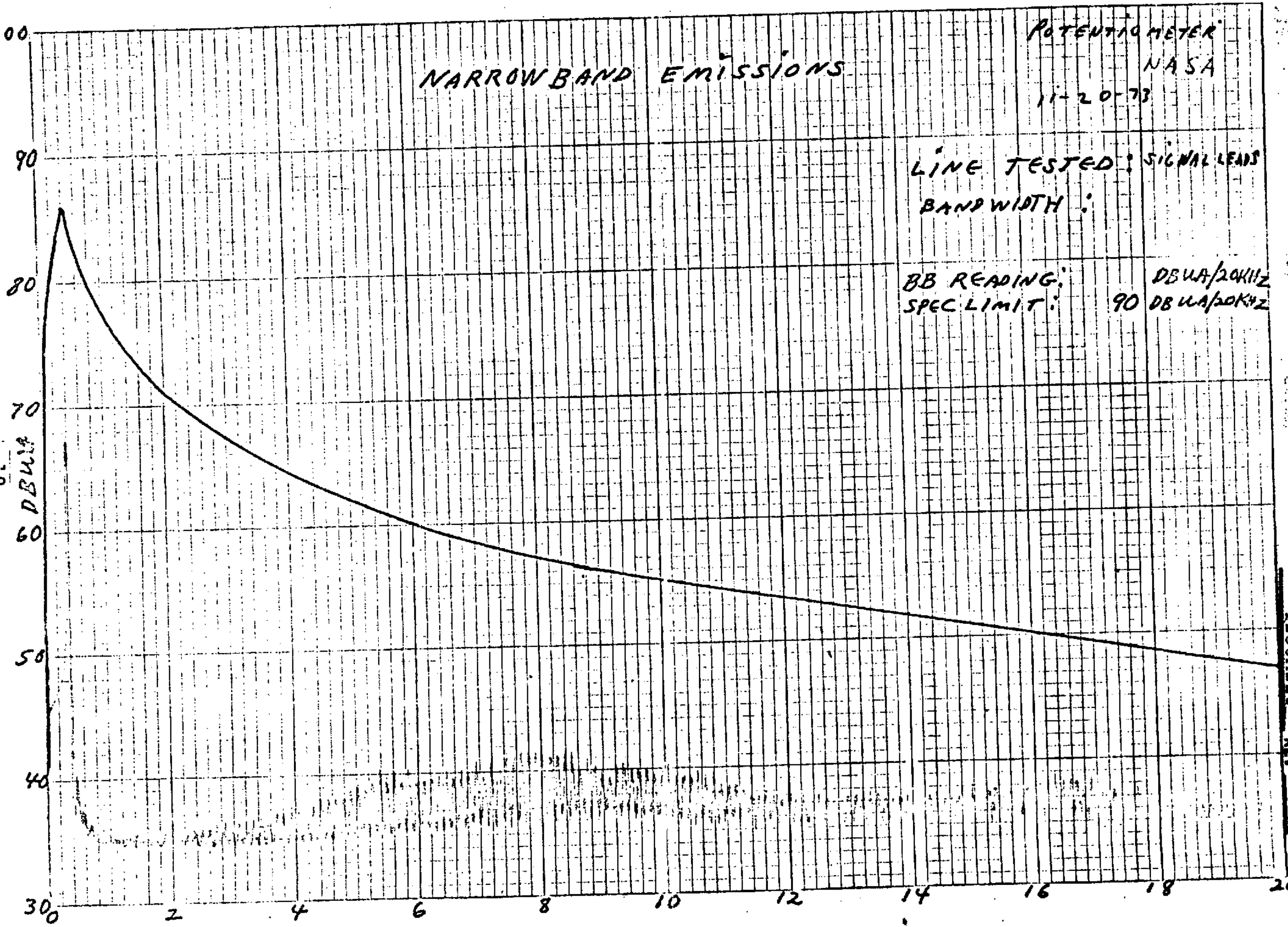
2
4
6
8
10
12
14
16
18
20



Y256A226 REV



Y256A226 REV -

Y256A226

SINGER
KEARFOTT DIVISION

Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN	MODEL NO	SER NO.
NASA	0-1-2	

TEST MODE: Power ON

SPECIFICATION	PARAGRAPH	TEST
		OUTPUT # 1

CONDUCTED BY	DATE	CHECKED BY	DATE
A.G.	11/12/73	B.J.	11/18/73

TEST FREQ	METER READING	CORRECTION FACTOR	FINAL READING	SPECIFICATION LIMIT	INTER. TYPE (SEE NOTE B)	REMARKS
	[illegible]		dB/μA/MHz			
4.7	22	0	22	20	3	PROBE
10.7	16	0	16	20	3	"
22.0	22	0	22	20	3	"

NOTE: A — All frequencies not listed are scanned for maximum interference.
B — Interference Type: (1) Broadband, Steady-State
(2) Broadband, Transients
(3) Narrowband (CW)

Y256A226 REV –

SINGER
KEARFOTT DIVISION

Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN	MODEL NO	SER NO.
NASA	0-1-2	

TEST MODE: POWER ON

SPECIFICATION	PARAGRAPH	TEST
		OUTPUT #2

CONDUCTED BY	DATE	CHECKED BY	DATE
A. G	11/18/73	B. J.	11/18/73

TEST FREQ	METER READING	CORRECTION FACTOR	FINAL READING	SPECIFICATION LIMIT	INTER. TYPE (SEE NOTE B)	REMARKS
	DB/μA/MHz		DB/μA/MHz			
4.19	14	0	14	20	3	PASS
10.83	12	0	12	20	3	"
21.5	27	0	27	20	3	"

NOTE: A – All frequencies not listed are scanned for maximum interference.
B – Interference Type: (1) Broadband, Steady–State
(2) Broadband, Transients
(3) Narrowband (CW)

SINGER
KEARFOTT DIVISION

Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN	MODEL NO	SER NO.
NASA	0-1-2	

TEST MODE: POWER ON

SPECIFICATION	PARAGRAPH	TEST
		+50 V.D.C.

CONDUCTED BY	DATE	CHECKED BY	DATE
A.G.	11-18-73		11-18-73

TEST FREQ	METER READING	CORRECTION FACTOR	FINAL READING	SPECIFICATION LIMIT	INTER. TYPE (SEE NOTE B)	REMARKS
	DB					
4.8	50	0	50	20	3	PROBE
10.7	26	0	26	20	3	"
22.0	22	0	22	20	3	"

NOTE: A – All frequencies not listed are scanned for maximum interference.
B – Interference Type: (1) Broadband, Steady–State
(2) Broadband, Transients
(3) Narrowband (CW)

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TEST NO.

X256A226 REV —

SINGER
KEARFOTT DIVISION

Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN NASA	MODEL NO 0-1-2	SER NO.
TEST MODE POWER ON		
SPECIFICATION	PARAGRAPH	TEST 28 V.D.C.

CONDUCTED BY A. G.	DATE 11/18/73	CHECKED BY B. J.	DATE 11/18/73

TEST FREQ	METER READING	CORRECTION FACTOR	FINAL READING	SPECIFICATION LIMIT	INTER. TYPE (SEE NOTE B)	REMARKS
4.9	58	0	58	20	3	PROBE
10.7	42	0	42	20	3	"
19.7	21	0	21	20	3	"

NOTE: A – All frequencies not listed are scanned for maximum interference.
B – Interference Type: (1) Broadband, Steady–State
(2) Broadband, Transients
(3) Narrowband (CW)

SINGER
KEARFOTT DIVISION

Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN	MODEL NO	SER NO.
NASA DOUBLE POLE	01-2	

TEST MODE: POWER ON

SPECIFICATION	PARAGRAPH	TEST
		28V. D.C

CONDUCTED BY	DATE	CHECKED BY	DATE
A.G.	11-17-73	B.J.	11-17-73

TEST FREQ	METER READING	CORRECTION FACTOR	FINAL READING	SPECIFICATION LIMIT	INTER. TYPE (SEE NOTE B)	REMARKS
	DB/µA/MHZ	C.P.	DB/µA/MHZ	DB/µA/MHZ		
.020	43	11	54	124	1	PROBE
.025	42	10	52	120		
.035	32	7	39	116		
.045	34	5	39	112		
.065	32	4	36	106		
.083	30	3	33	102		
.100	30	2	32	98		
.120	30	1	31	96		
.150	30	1	31	92		
.200	30	0	30	87		
.300	30	0	30	80		
.400	30		30	76		
.500	55		55	72		
.800	30		30	64		
1.0	30		30	60		
1.5	35		35	54		
2.0	30		30	50		
3.0	30		30			
4.0	30		30			
5.0	55		55			
6.0	37		37			
9.2	38		38			
12.0	30		30			
15.0	30		30			
20.0	30		30			
30.0	30		30			
40.0	30		30			
50.0	37		37			

NOTE: A – All frequencies not listed are scanned for maximum interference.
B – Interference Type: (1) Broadband, Steady–State
(2) Broadband, Transients
(3) Narrowband (CW)

SINGER
KEARFOTT DIVISION

Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN	MODEL NO	SER NO.
NASA	0-1-2	

TEST MODE: POWER ON

SPECIFICATION	PARAGRAPH	TEST
		OUTPUT #2

CONDUCTED BY	DATE	CHECKED BY	DATE
AG	11-17-73	BJ	11-17-73

TEST FREQ	METER READING	CORRECTION FACTOR	FINAL READING	SPECIFICATION LIMIT	INTER. TYPE (SEE NOTE B)	REMARKS
	DB/uA/MHZ	C.F.	DB/uA/MHZ	DB/uA/MHZ		
.020	48	11	51	124	2	PROBE
.027	42	10	52	120		
.035	41	7	48	116		
.045	41	5	46	112		
.060	43	4	47	106		
.080	42	3	45	102		
.100	42	2	44	98		
.120	42	1	43	96		
.150	35	1	36	92		
.200	33	0	33	87		
.300	33	0	33	80		
1.5	32	0	32	54		

NOTE: A – All frequencies not listed are scanned for maximum interference.
B – Interference Type: (1) Broadband, Steady–State
(2) Broadband, Transients
(3) Narrowband (CW)

SINGER
KEARFOTT DIVISION

Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN	MODEL NO	SER NO.
NASA	0-1-2	

TEST MODE: POWER ON

SPECIFICATION	PARAGRAPH	TEST
		OUTPUT NO. ONE

CONDUCTED BY	DATE	CHECKED BY	DATE
A.G.		B.J.	11-17-73

TEST FREQ	METER READING	CORRECTION FACTOR	FINAL READING	SPECIFICATION LIMIT	INTER. TYPE (SEE NOTE B)	REMARKS
	[illegible]	C.F.	DB/μA/MHZ	DB/μA/MHZ		
.020	46	11	57	124	1	PROBE
.025	41	10	51	120		
.035	34	7	41	116		
.045	34	5	39	112		
.065	32	4	36	106		
.080	31	3	34	102		
.100	30	2	32	98		
.120	30	1	31	96		
.150	30	1	31	92		
.200	30	0	30	87		
.300	30		30	80		
.400	30		30	76		
.500	30		30	72		
.800	30		30	64		
1.0	30		30	60		
1.5	30		30	54		
2.0	30		30	50		
3.0	30		30			
4.0	[illegible]		30			
5.0	30		30			
6.0	30		30			
4.2	30		30			
12.0	30		30			
15.0	30		30			
20.0	30		30			
25.0	30		30			
30.0	32		32			
40.0	30		30			
50.0	43		43			

NOTE: A – All frequencies not listed are scanned for maximum interference.
B – Interference Type: (1) Broadband, Steady-State
(2) Broadband, Transients
(3) Narrowband (CW)

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SINGER
KEARFOTT DIVISION

Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN	MODEL NO	SER NO.
NASA	0-1-2	

TEST MODE
POWER ON

SPECIFICATION	PARAGRAPH	TEST
		OUTPUT # 1

CONDUCTED BY	DATE	CHECKED BY	DATE
AG	11-17-73	BJ	11-17-73

TEST FREQ	METER READING	CORRECTION FACTOR	FINAL READING	SPECIFICATION LIMIT	INTER. TYPE (SEE NOTE B)	REMARKS
.020	51	11	62	124	2	PROBE
.025	46	10	56	120		
.035	42	7	49	116		
.045	41	5	46	112		
.065	43	4	47	106		
.080	43	3	46	102		
.100	42	2	44	98		
.120	42	1	43	96		
.150	34	1	35	92		
.200	34	0	34	87		
.300	33		33	80		
.400	33		33	76		
.500	32		32	72		
.800	32		32	64		
1.0	32		32	60		
1.5	33		33	54		
2.0	35		35	50		

NOTE: A – All frequencies not listed are scanned for maximum interference.
B – Interference Type: (1) Broadband, Steady–State
(2) Broadband, Transients
(3) Narrowband (CW)

PL 390A 9/70

TEST NO.

SINGER
KEARFOTT DIVISION

Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN	MODEL NO	SER NO.
NASA	0-1-2	

TEST MODE: POWER ON

SPECIFICATION	PARAGRAPH	TEST
		5 V. D.C

CONDUCTED BY	DATE	CHECKED BY	DATE
A.G	11-17-73	B.J.	11-17-73

TEST FREQ	METER READING	CORRECTION FACTOR	FINAL READING	SPECIFICATION LIMIT	INTER. TYPE (SEE NOTE B)	REMARKS
	DB μA/MHZ	C.P	DB μA/MHZ	DB μA/MHZ	SWITCH TO OFF	
.020	[illegible]	[illegible]	59	124	2	PROBE
.025	43	10	53	120		
.035	38	7	45	116		
.045	38	5	43	112		
.065	44	4	48	106		
.080	42	3	45	102		
.106	41	2	43	98		
.120	40	1	41	96		
.150	38	1	39	92		
.200	37	0	37	87		
.300	37		37	80		
.400	34		34	76		
.500	33		33	72		
.800	31		31	64		
1.0	35		35	60		
1.5	32		32	54		
2.0	32		32	50		
5.0	37		37	50		
6.0	56		56	50		

NOTE: A – All frequencies not listed are scanned for maximum interference.
B – Interference Type: (1) Broadband, Steady–State
(2) Broadband, Transients
(3) Narrowband (CW)

Y256A226 REV –

SINGER
KEARFOTT DIVISION

Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN	MODEL NO	SER NO.
NASA	0-1-2	

TEST MODE
POWER ON

SPECIFICATION	PARAGRAPH	TEST
		5 V. D.C

CONDUCTED BY	DATE	CHECKED BY	DATE
AG	11/17/73	BJ	11/17/73

TEST FREQ	METER READING	CORRECTION FACTOR	FINAL READING	SPECIFICATION LIMIT	INTER. TYPE (SEE NOTE B)	REMARKS
	DBM	C.P.	DB/UA/MHZ	DB/UA/MHZ		
.020	42	11	53	124		PROBE
.025	[illegible]	10	45	120		
.035	[illegible]	7	46	116		
.045	32	5	37	106		
.065	32	4	36	102		
.080	30	3	33	98		
.100	30	2	32	96		
.120	30	1	31	92		
.150	30	1	31	87		
.200	30	0	30	80		
.300	30		30	76		
.400	30		30	72		
.500	30		30	64		
.800	30		30	60		
1.0	30		30	54		
1.5	30		30	50		
2.0	30		30			
3.0	30		30			
4.0	30		30			
5.0	31		31			
6.6	50		50			
9.2	54		54			
12.0	30		30			
15.0	30		30			
20.00	30		30			
25.0	36		36			
30.0	30		30			
40.0	33		33			
50.0	32		32			

NOTE: A – All frequencies not listed are scanned for maximum interference.
B – Interference Type: (1) Broadband, Steady–State
(2) Broadband, Transients
(3) Narrowband (CW)

SINGER
KEARFOTT DIVISION

Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN	MODEL NO	SER NO.
NASA	0-1-2	

TEST MODE: POWER ON

SPECIFICATION	PARAGRAPH	TEST
		28.V.D.C.

CONDUCTED BY	DATE	CHECKED BY	DATE
AG	11-17-73	BJ	11-17-73

TEST FREQ	METER READING	CORRECTION FACTOR	FINAL READING	SPECIFICATION LIMIT	INTER. TYPE (SEE NOTE B)	REMARKS
.020	51	11	61	124	2	PROBE
.025	49	10	59	120		
.035	38	7	45	116		
.045	40	5	45	112		
.065	48	4	52	106		
.080	42	3	45	102		
.100	42	2	44	98		
.120	42	1	43	96		
.150	38	1	39	92		
.200	38	0	38	87		
.300	35		35	80		
.400	34		34	76		
.500	58		58	72		
.800	34		34	64		
1.0	34		34	60		
1.5	39		39	54		
2.0	32		32	50		
6.0	39		39	50		
9.2	41		41	50		

NOTE: A — All frequencies not listed are scanned for maximum interference.
B — Interference Type: (1) Broadband, Steady-State
(2) Broadband, Transients
(3) Narrowband (CW)

SINGER
KEARFOTT DIVISION

Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN	MODEL NO	SER NO.
NASA	0-1-1	

TEST MODE: POWER ON

SPECIFICATION	PARAGRAPH	TEST
		OUTPUT #2

CONDUCTED BY	DATE	CHECKED BY	DATE
A.G	11-17-73	B.J.	11-17-73

TEST FREQ	METER READING	CORRECTION FACTOR	FINAL READING	SPECIFICATION LIMIT	INTER. TYPE (SEE NOTE B)	REMARKS
	[illegible]	[illegible]	DBμa/MHz	DBμa/MHz		
.020	2	.	53	124	1	PROBE
.025	35	10	45	120		
.030	35	7	42	116		
.045	34	5	[illegible]	112		
.065	32	4	36	106		
.080	30	3	33	102		
.100	30	2	32	98		
.120	30	1	31	96		
.150	30	1	31	92		
.200	30	0	30	87		
.300	30		30	80		
.400	30		30	76		
.500	30		30	72		
.800	30		30	64		
1.0	30		30	66		
1.5	30		30	54		
2.0	30		30	50		
3.0	30		30			
4.0	30		30			
5.0	30		30			
6.0	30		30			
9.0	30		30			
12.0	30		30			
15.0	30		30			
20.0	30		30			
25.0	30		30			
30.0	30		30			
40.0	30		30			
50.0	30		30			

NOTE: A — All frequencies not listed are scanned for maximum interference.
B — Interference Type: (1) Broadband, Steady-State
(2) Broadband, Transients
(3) Narrowband (CW)

SINGER
KEARFOTT DIVISION

Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN	MODEL NO	SER NO.
NASA	0-1-1	

TEST MODE: Power on

SPECIFICATION	PARAGRAPH	TEST
		5 V.D.C. LINE

CONDUCTED BY	DATE	CHECKED BY	DATE
A.G.	11/17/73	B.J	11/17/73

TEST FREQ	METER READING	CORRECTION FACTOR	FINAL READING	SPECIFICATION LIMIT	INTER. TYPE (SEE NOTE B)	REMARKS
	[illegible]	C.P	DB/UA/MHZ	DB/UA/MHZ		
.020	43	11	54	124	1	PROBE
.025	40	10	50	120		
.035	33	7	40	116		
.045	34	5	39	112		
.065	30	4	34	106		
.080	30	3	33	102		
.100	30	2	32	98		
.120	30	1	31	96		
.150	30	1	31	92		
.200	30	0	30	87		
.300	30		30	80		
.400	30		30	76		
.500	30		30	72		
.800	30		30	64		
1.0	30		30	60		
1.5	30		30	54		
2.0	30		30	50		
3.0	30		30			
4.0	30		30			
5.0	30		30			
6.0	30		30			
9.2	29		30			
12.0	30		30			
15.0	30		30			
20.0	30		30			
25.0	30		30			
30.0	30		30			
40.0	30		30			
50.0	30		30			

NOTE: A – All frequencies not listed are scanned for maximum interference.
B – Interference Type: ✓(1) Broadband, Steady-State
(2) Broadband, Transients
(3) Narrowband (CW)

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TEST NO.

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KEARFOTT DIVISION

Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN	MODEL NO	SER NO.
NASA	0-1-1	

TEST MODE: POWER ON

SPECIFICATION	PARAGRAPH	TEST
		OUTPUT #2

CONDUCTED BY	DATE	CHECKED BY	DATE
A.G	11-17-73	B.J	11-17-73

TEST FREQ	METER READING	CORRECTION FACTOR	FINAL READING	SPECIFICATION LIMIT	INTER. TYPE (SEE NOTE B)	REMARKS
	DB/uA/MHZ	C.P.	DB/uA/MHZ	DB/uA/MHZ		
.020	43	11	53	124	1	PROBE
.025	41	10	51	120		
.035	36	7	43	116		
.045	34	5	39	112		
.065	34	4	38	106		
.080	32	3	35	102		
.100	30	2	32	98		
.120	30	1	31	96		
.150	30	1	31	92		
.200	30	0	30	87		
.300	30		30	80		
.400	30		30	76		
.500	30		30	72		
.800	30		30	64		
1.0	30		30	60		
1.5	30		30	54		
2.0	30		30	50		
3.0	30		30			
4.0	30		30			
5.0	30		30			
6.0	30		30			
9.2	61		61			
12.0	30		30			
15.0	30		30			
20.0	30		30			
25.0	30		30			
30.0	30		30			
40.0	30		30			
50.0	30		30			

NOTE: A – All frequencies not listed are scanned for maximum interference.
B – Interference Type: (1) Broadband, Steady–State
(2) Broadband, Transients
(3) Narrowband (CW)

SINGER
KEARFOTT DIVISION

Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN	MODEL NO	SER NO.
NASA	0-1-1	

TEST MODE: POWER ON

SPECIFICATION	PARAGRAPH	TEST
		12 V. D.C. LINE

CONDUCTED BY	DATE	CHECKED BY	DATE
A G	11-17-73	B. J.	11/17/73

TEST FREQ	METER READING		CORRECTION FACTOR	FINAL READING		SPECIFICATION LIMIT	INTER. TYPE (SEE NOTE B)	REMARKS
MHZ	SW ON LITE OFF	SW OFF LITE ON	CF	SW ON LITE OFF	SW ON LITE OFF	DB/UA/MHZ		
.020	44		11	55		124	1	PROBE
.025	40		10	50		120		
.035	33		7	40		116		
.045	34		5	39		112		
.065	37		4	41		106		
.080	38		3	41		102		
.100	38		2	40		98		
.120	30		1	31		96		
.150	30	46	1	31	46	92		
.200	30	43	0	30	43	87		
.300	30	40		30	44	80		
.400	30	49		30	49	76		
.500	30	47		30	47	72		
.800	30	51		30	51	64		
1.0	30	56		30	56	60		
1.5	30	57		30	57	54		
2.0	30	54		30	54	50		
3.0	30	49		30	49			
4.0	30	40		30	45			
5.0	48	48		48	48			
6.0	30	50		30	50			
9.2	38	73		38	73			
12.0	30	42		30	42			
15.0	30	35		30	35			
20.0	30	26		30	36			
25.0	30	30		30	30			
30.0	30	30		30	30			
[illegible]	30	30		30	30			
50.0	30	30		30	30			

NOTE: A — All frequencies not listed are scanned for maximum interference.
B — Interference Type: ✓(1) Broadband, Steady-State
(2) Broadband, Transients
(3) Narrowband (CW)

SINGER
KEARFOTT DIVISION

Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN	MODEL NO	SER NO.
NASA	0-1-1	

TEST MODE: POWER ON

SPECIFICATION	PARAGRAPH	TEST
		12.0 V.D.C

CONDUCTED BY	DATE	CHECKED BY	DATE
A.G	11/18/73	B.J.	11/18/73

TEST FREQ	METER READING	CORRECTION FACTOR	FINAL READING	SPECIFICATION LIMIT	INTER. TYPE (SEE NOTE B)	REMARKS
	DB/UA					C.W.
5.1	60	0	60	20	3	PROBE
10.0	46	0	46	20	3	"
26.0	26	0	26	20	3	"

NOTE: A – All frequencies not listed are scanned for maximum interference.
B – Interference Type: (1) Broadband, Steady–State
(2) Broadband, Transients
(3) Narrowband (CW)

SINGER
KEARFOTT DIVISION

Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN	MODEL NO	SER NO.
NASA	0-1-1	-

TEST MODE: POWER ON

SPECIFICATION	PARAGRAPH	TEST
		+5.0V.D.C

CONDUCTED BY	DATE	CHECKED BY	DATE
A.G		B.J	11-18-73

TEST FREQ	METER READING	CORRECTION FACTOR	FINAL READING	SPECIFICATION LIMIT	INTER. TYPE (SEE NOTE B)	REMARKS
	DB/UA/MC			DB/UA MC		C.W,
5.1	30	0	30	20	3	PROBE
10.0	27	0	27	20	3	"
19.8	26	0	26	20	3	"

NOTE: A – All frequencies not listed are scanned for maximum interference.
B – Interference Type: (1) Broadband, Steady–State
(2) Broadband, Transients
(3) Narrowband (CW)

SINGER
KEARFOTT DIVISION

Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN	MODEL NO	SER NO.
NASA	0-1-1	

TEST MODE: POWER ON.

SPECIFICATION	PARAGRAPH	TEST
		OUTPUT # 1

CONDUCTED BY	DATE	CHECKED BY	DATE
AG	11/18/73	B.J.	11/18/73

TEST FREQ	METER READING	CORRECTION FACTOR	FINAL READING	SPECIFICATION LIMIT	INTER. TYPE (SEE NOTE B)	REMARKS
5.1	20	0	20	20	3	PASS
10.0	12	0	20	20	3	"
20.5	27	0	27	20	3	"

NOTE: A – All frequencies not listed are scanned for maximum interference.
B – Interference Type: (1) Broadband, Steady–State
(2) Broadband, Transients
(3) Narrowband (CW)

SINGER
KEARFOTT DIVISION

Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN	MODEL NO	SER NO.
NASA	0-1-1	

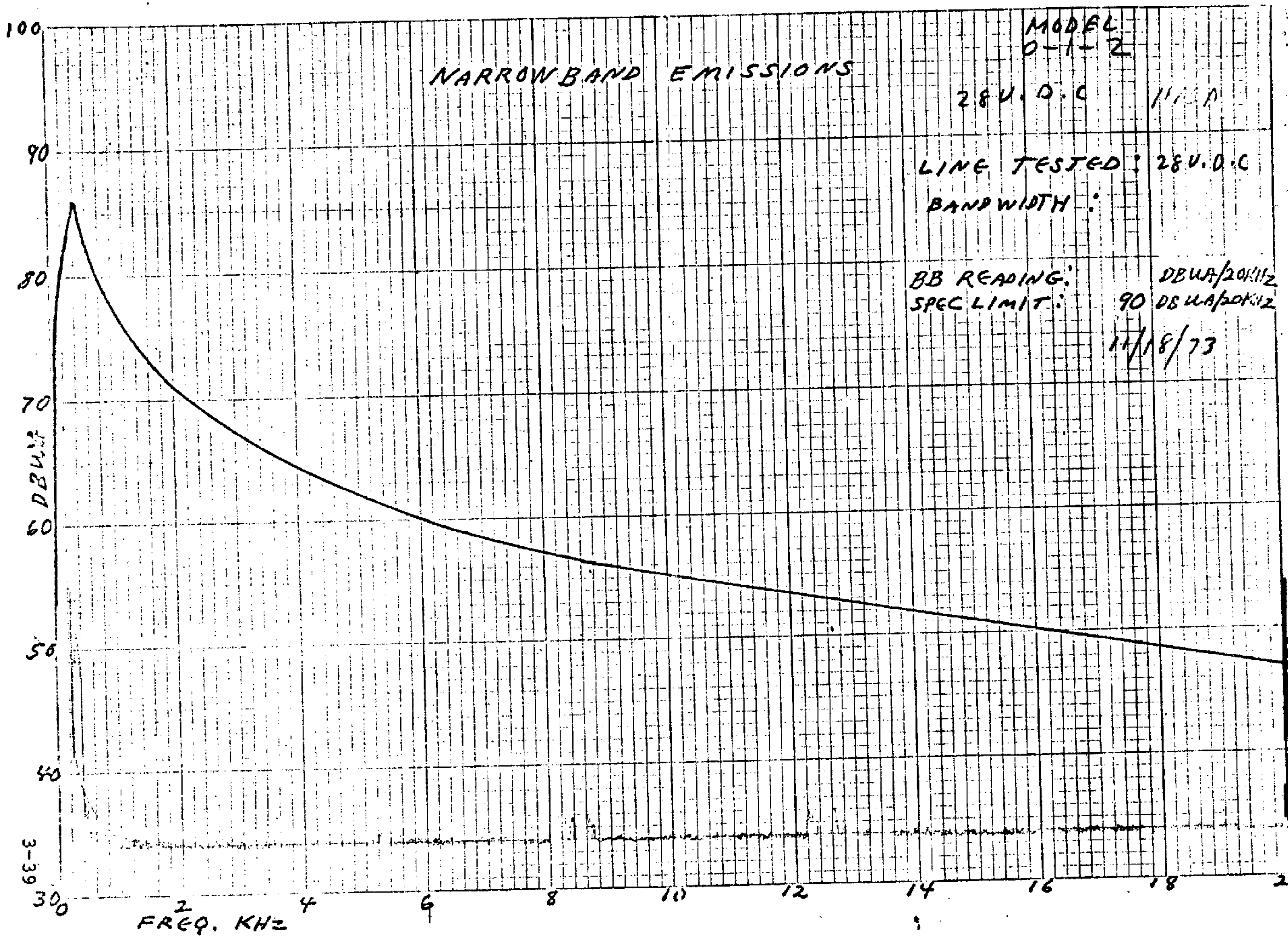
TEST MODE: Power on.

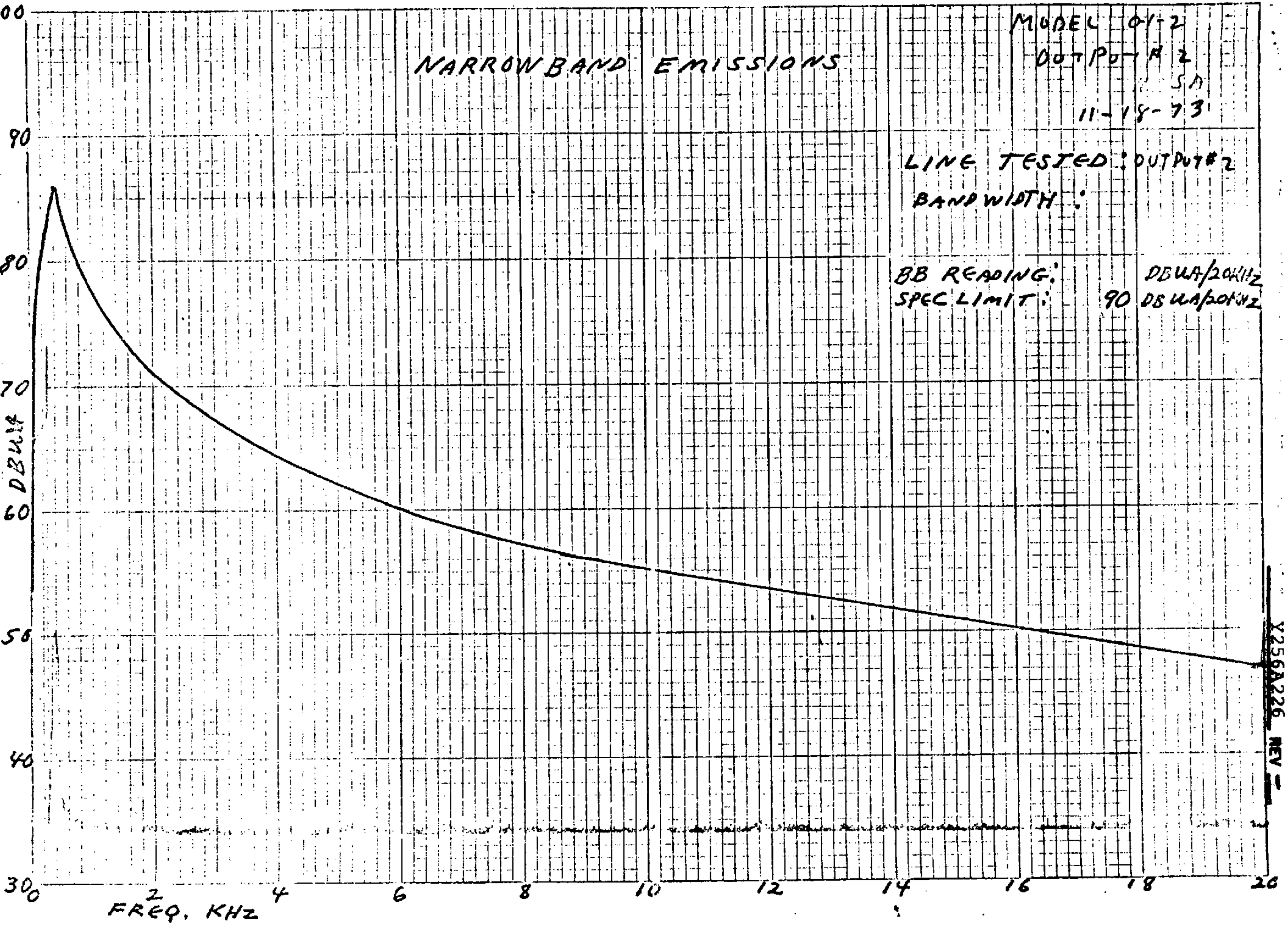
SPECIFICATION	PARAGRAPH	TEST
		OUTPUT # 2

CONDUCTED BY	DATE	CHECKED BY	DATE
J.F.	11/18/73	B.J	11-18-73

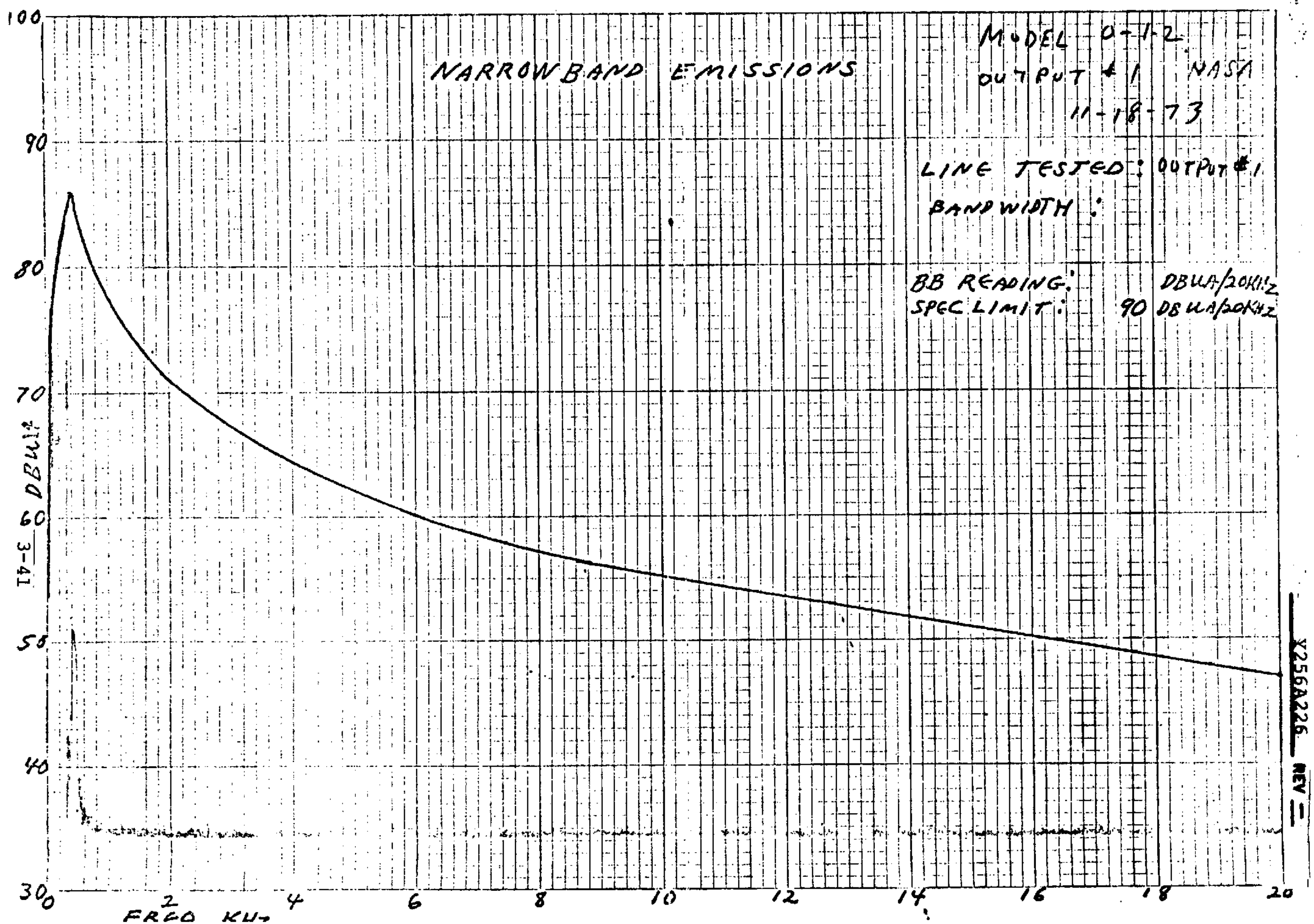
TEST FREQ	METER READING	CORRECTION FACTOR	FINAL READING	SPECIFICATION LIMIT	INTER. TYPE (SEE NOTE B)	REMARKS
5.1	22	0	22	20	3	PROBE
10.1	12	0	12	20	3	"
20.6	6	0	6	20	3	"

NOTE: A – All frequencies not listed are scanned for maximum interference.
B – Interference Type: (1) Broadband, Steady–State
(2) Broadband, Transients
(3) Narrowband (CW)


NARROWBAND EMISSIONS
MODEL
0-1-2
28V.D.C
LINE TESTED: 28V.D.C
BANDWIDTH:
BB READING: DBUA/20KHZ
SPEC LIMIT: 90 DBUA/20KHZ
11/18/73
DBUA
100
90
80
70
60
50
40
30
0
2
4
6
8
10
12
14
16
18
20
FREQ. KHZ
Y256A226 REV -



X256A226 REV -



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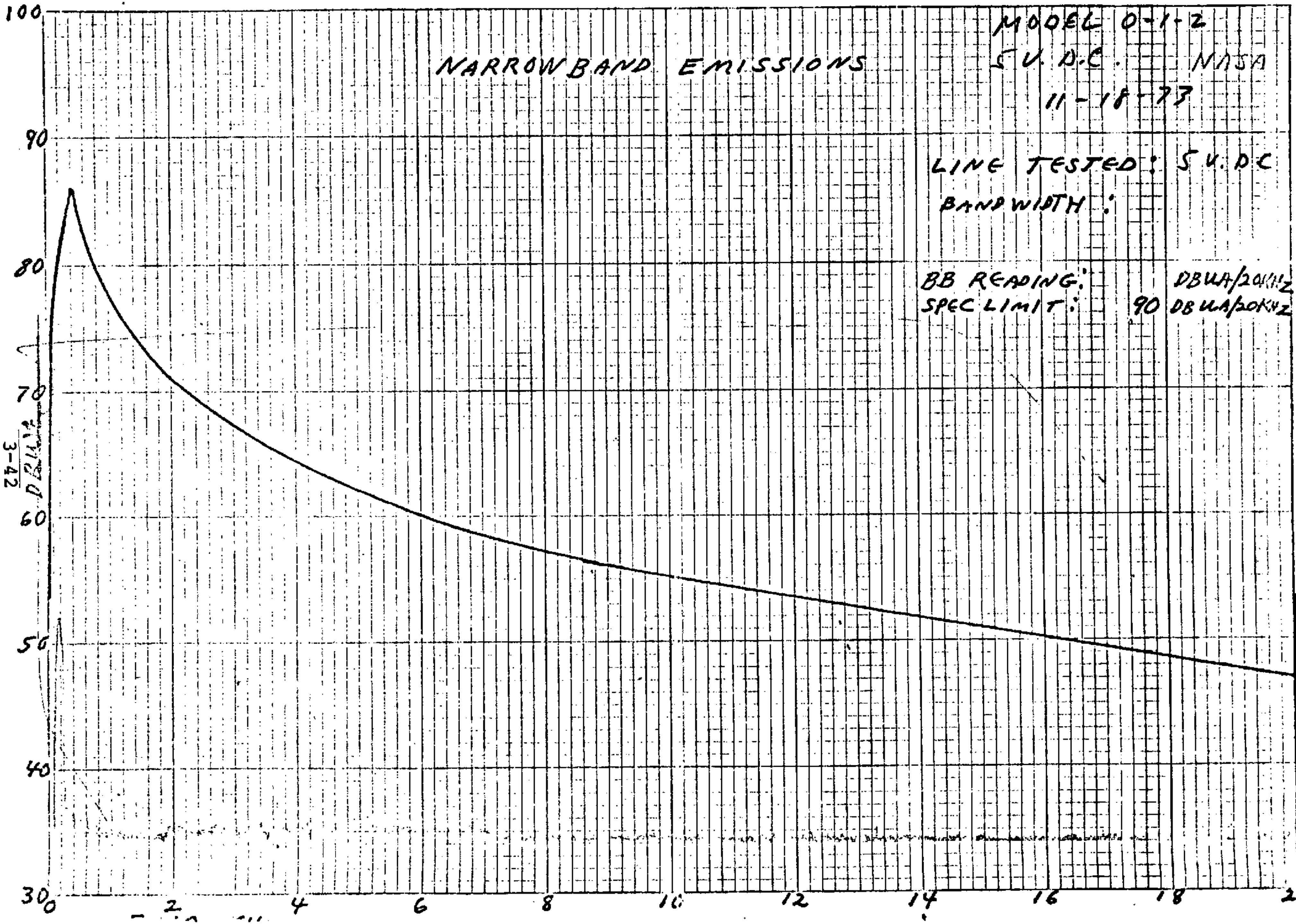
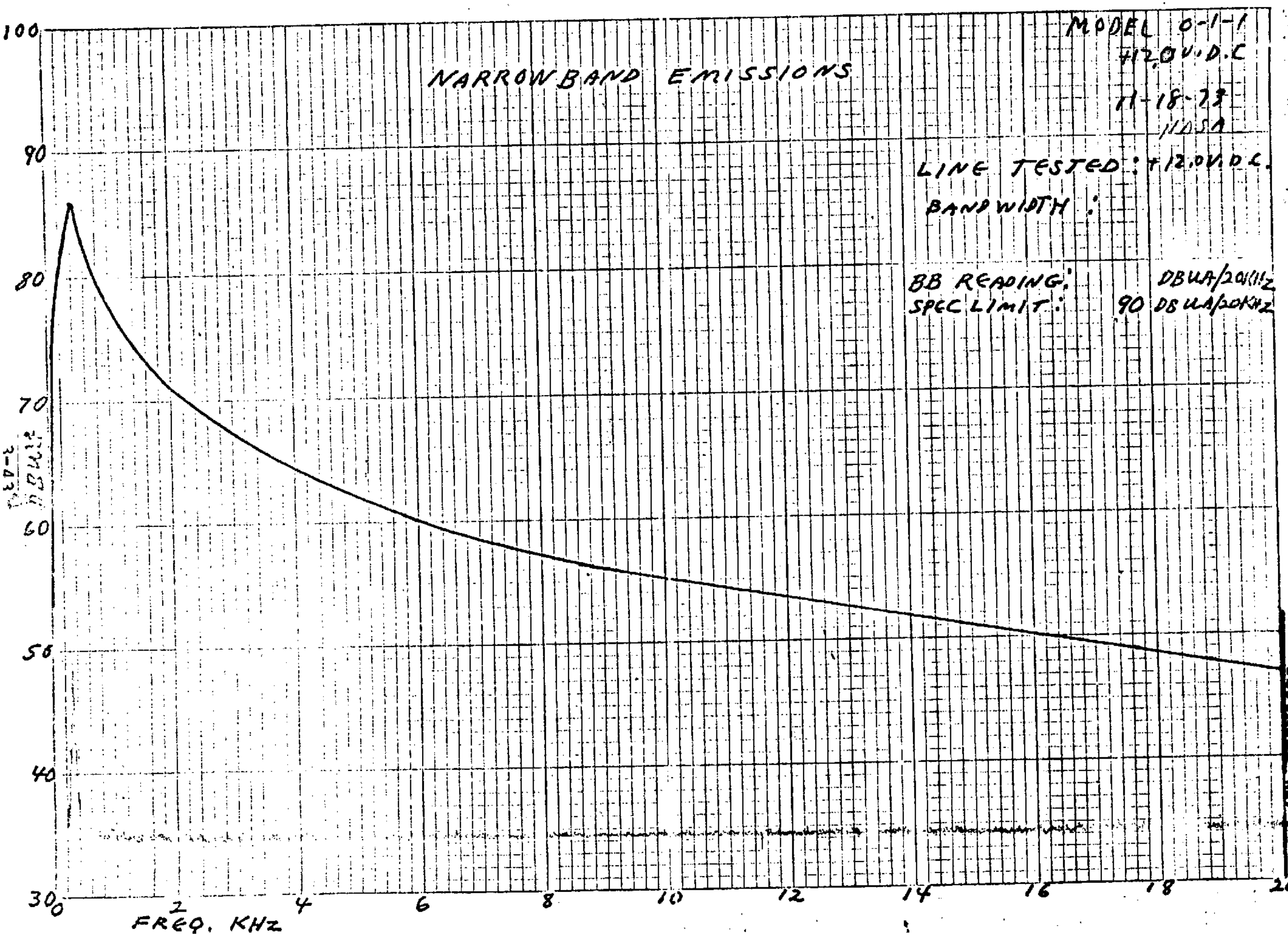
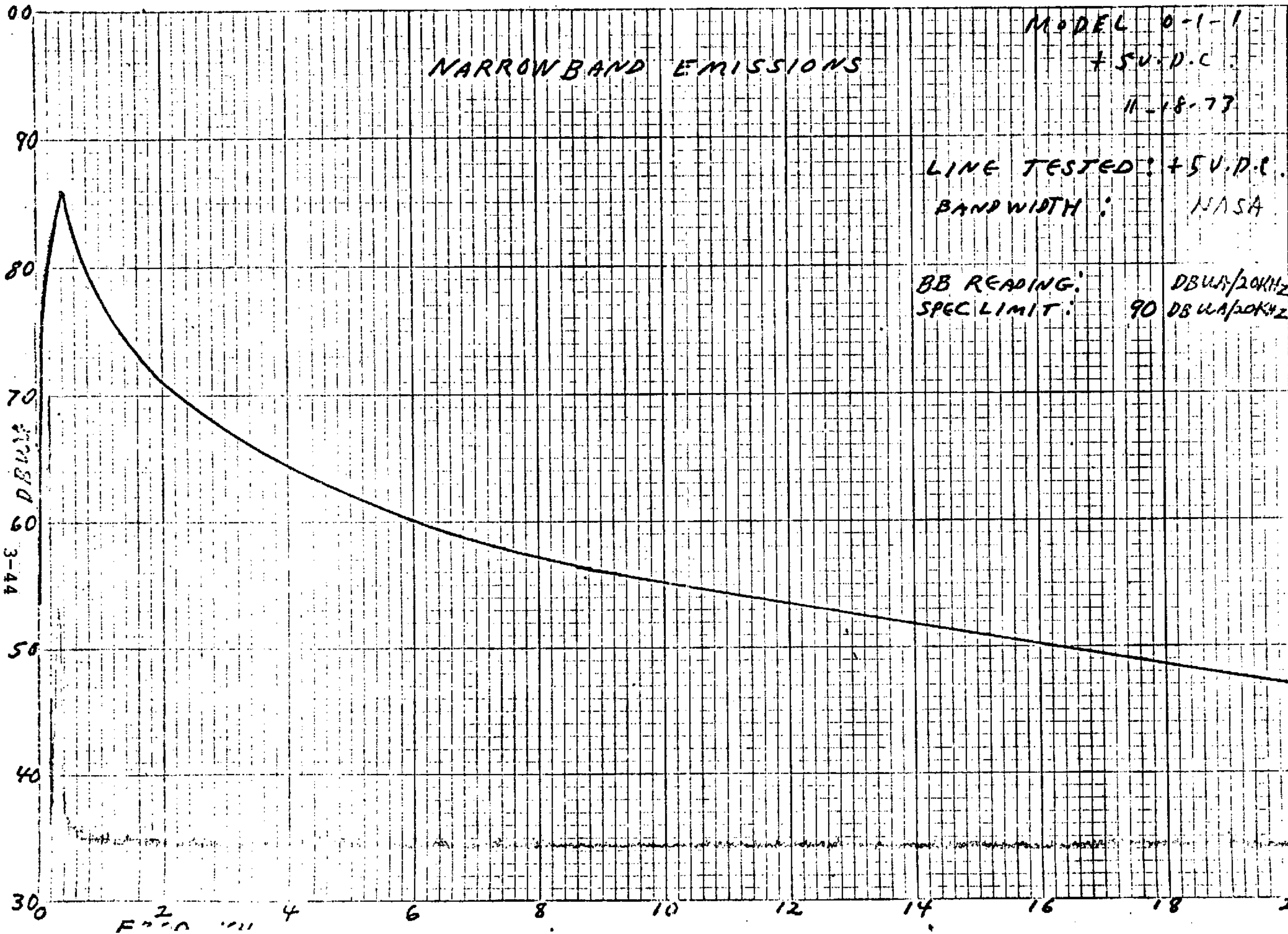


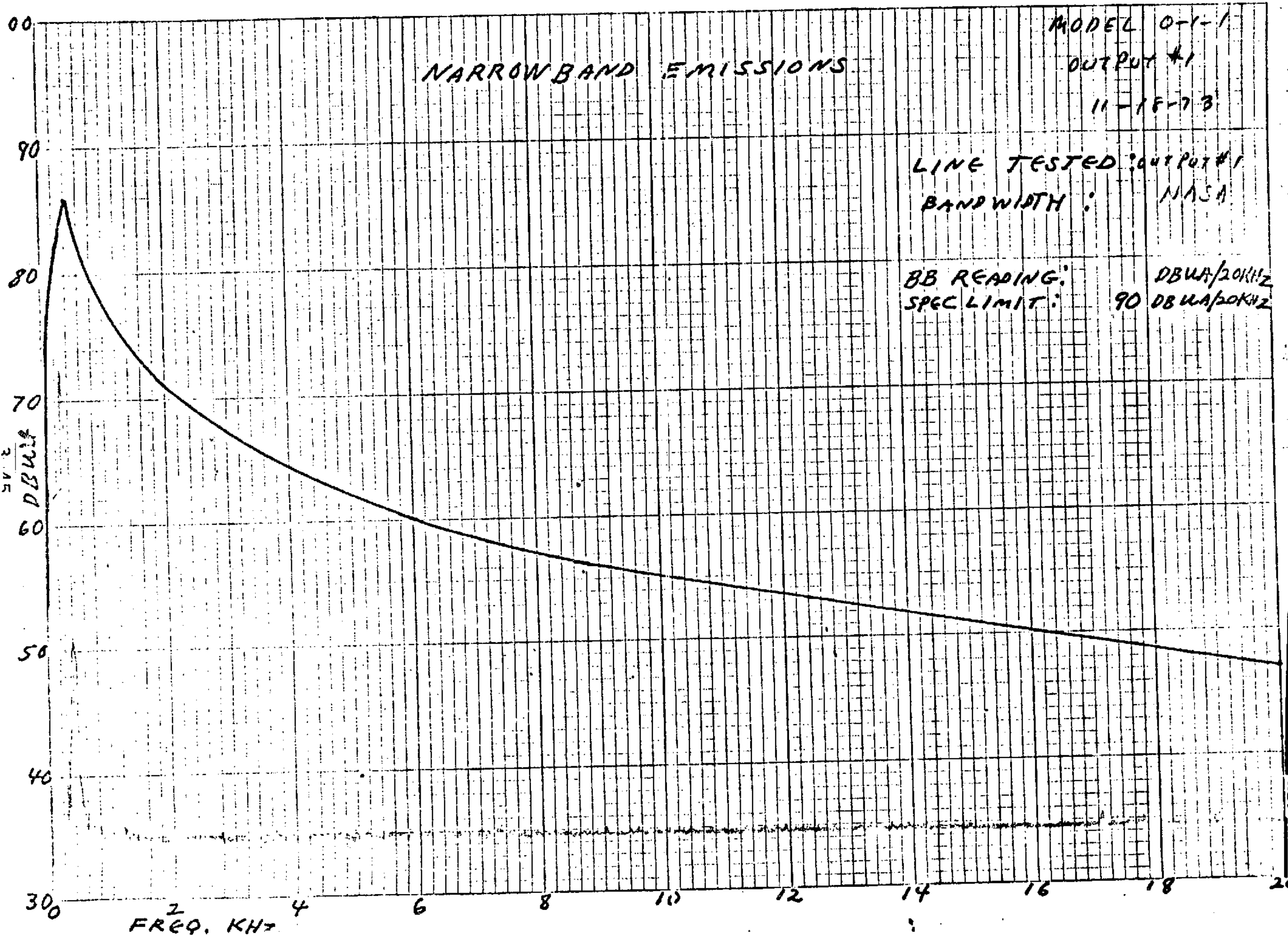
Y256A226 REV —

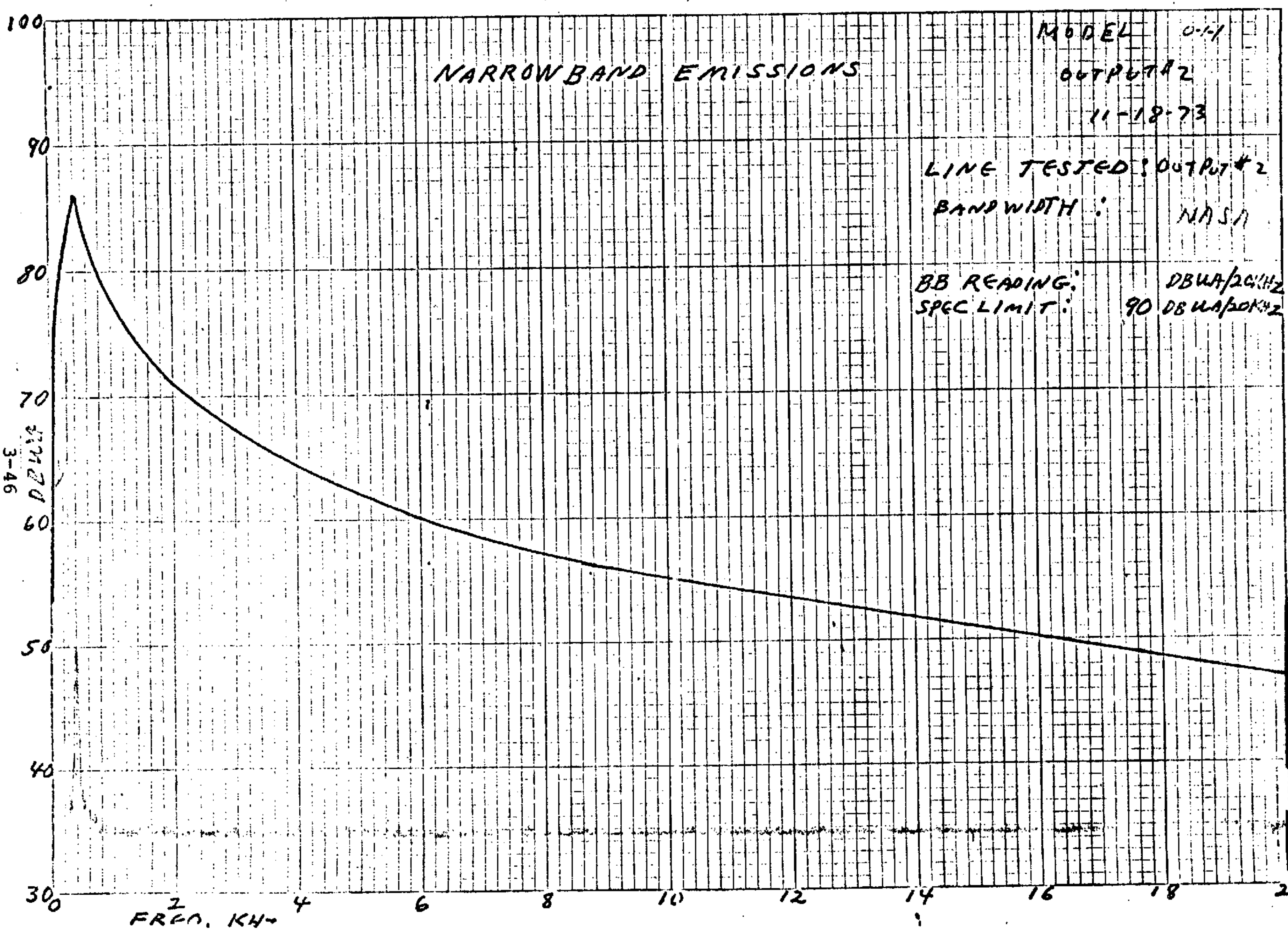


Y256A226 REV 1



Y256A226 REV -


NARROWBAND EMISSIONS
MODEL 0-1-1
OUTPUT #1
11-18-73
LINE TESTED : OUTPUT #1
BANDWIDTH : NASA
BB READING: DBUA/20KHZ
SPEC LIMIT: 90 DB UA/20KHZ
DBUA
100
90
80
70
60
50
40
30
0
2
4
6
8
10
12
14
16
18
20
FREQ, KHZ



X256A226 REV -

RELIABILITY

A reliability prediction was preformed to establish the failure rate of each of the solid state switch devices. This data is summarized on the attached computer data sheets. Also included in this section is a reliability failure mode and effects analysis. This analysis was made on the 10 position rotary, potentiometer, and the double pole switch.

FIXED GROUND ENVIRONMENT NOV. 8,1973

SUBASSEMBLY -- CIRCUIT BOARD =1

AMBIENT TEMPERATURE = 40C

PART TYPE	QUANTITY	K(ENV)	FR	Q.F.K	STRESS
DIODE ZENER	1.0	1.0000	1.0700	1.0700	50
RES COMP RC	2.0	6.0000	0.0035	0.0420	25
RES COMP RC	4.0	6.0000	0.0035	0.0840	10
SOLID STATE RELAY	10.0	1.0000	0.0045	0.0450	10
TRANSISTOR NPN	4.0	1.5000	0.1975	1.1850	10
CIRCUIT BOARD	1.0	1.0000	0.0630	0.0630	10

SUBASSEMBLY TOTAL 2.489

SUBASSEMBLY -- CIRCUIT BOARD =2

AMBIENT TEMPERATURE = 40C

PART TYPE	QUANTITY	K(ENV)	FR	Q.F.K	STRESS
CIRCUIT BOARD	1.0	1.0000	0.0630	0.0630	10
DIODE LED	4.0	1.5000	0.2600	1.5600	20
TRANSISTOR NPN PHOTOTRANSISTOR	4.0	1.5000	0.1975	1.1850	10
TRANSISTOR NPN	7.0	1.5000	0.1975	2.0737	10
RES COMP RC	11.0	6.0000	0.0035	0.2310	10
RES COMP RC	1.0	6.0000	0.0035	0.0210	25
HI-R INTEGRATED CIRCUIT	1.0	1.2000	0.0300	0.0360	10
HI-R INTEGRATED CKT MSI	1.0	1.2000	0.0600	0.0720	10

SUBASSEMBLY TOTAL 5.242

SUBASSEMBLY -- SWITCH ASSY

AMBIENT TEMPERATURE = 40C

PART TYPE	QUANTITY	K(ENV)	FR	Q.F.K	STRESS
SHAFT	1.0	1.0000	0.3500	0.3500	10
BEARING	3.0	1.0000	0.5000	1.5000	10
DIODE LED	1.0	1.5000	0.4175	0.6262	40

SUBASSEMBLY TOTAL 2.476

Y256A226 REV -

SUBASSEMBLY -- ROTARY SW 10 POS

AMBIENT TEMPERATURE = 40C

PART TYPE	QUANTITY	K(ENV)	FR	Q.F.K	STRESS
CIRCUIT BOARD =1	1.0	1.0000	2.4890	2.4890	10
CIRCUIT BOARD =2	1.0	1.0000	5.2417	5.2417	10
SWITCH ASSY	1.0	1.0000	2.4762	2.4762	10

SUBASSEMBLY TOTAL 10.207

SUBASSEMBLY -- PC BOARD =1

AMBIENT TEMPERATURE = 40C

PART TYPE	QUANTITY	K(ENV)	FR	Q.F.K	STRESS
CIRCUIT BOARD	1.0	1.0000	0.0630	0.0630	10
DIODE ZENER	1.0	1.0000	1.0700	1.0700	50
TRANSISTOR NPN	1.0	1.5000	0.1975	0.2962	10
RES COMP RC	5.0	6.0000	0.0035	0.1050	10
CAPACITOR CER CK	2.0	1.0000	0.0020	0.0041	15
HI-R INTEGRATED CIRCUIT	2.0	1.2000	0.0300	0.0720	10
HI-R INTEGRATED CKT MSI	1.0	1.2000	0.0600	0.0720	10

SUBASSEMBLY TOTAL 1.682

X256A226 REV -

FIXED GROUND ENVIRONMENT NOV. 8,1973

SUBASSEMBLY -- PC BOARD =2

AMBIENT TEMPERATURE = 40C

PART TYPE	QUANTITY	K(ENV)	FR	Q.F.K	STRESS
CIRCUIT BOARD	1.0	1.0000	0.0630	0.0630	10
DIODE LED	7.0	1.5000	0.2600	2.7300	20
TRANSISTOR NPN PHOTOTRANSISTOR	7.0	1.5000	0.1975	2.0737	10
RES COMP RC	7.0	6.0000	0.0035	0.1470	10

SUBASSEMBLY TOTAL 5.014

Y256A226 REV

C-2

FIXED GROUND ENVIRONMENT NOV. 8,1973

SUBASSEMBLY -- POT ASSY

AMBIENT TEMPERATURE = 40C

PART TYPE	QUANTITY	K(ENV)	FR	Q.F.K	STRESS
SHAFT	1.0	1.0000	0.3500	0.3500	10
BEARING	3.0	1.0000	0.5000	1.5000	10
DIODE LED	1.0	1.5000	0.4175	0.6262	40
SUBASSEMBLY TOTAL				2.476	

4-8

Y256A226 REV -

SUBASSEMBLY — SOLID STATE POT

AMBIENT TEMPERATURE = 40C

PART TYPE	QUANTITY	K(ENV)	FR	Q.F.K	STRESS
PC BOARD =1	1.0	1.0000	1.6823	1.6823	10
PC BOARD =2	1.0	1.0000	5.0137	5.0137	10
POT ASSY	1.0	1.0000	2.4762	2.4762	10

SUBASSEMBLY TOTAL 9.172

SUBASSEMBLY -- TOGGLE SWITCH SP

AMBIENT TEMPERATURE = 40C

PART TYPE	QUANTITY	K(ENV)	FR	Q.F.K	STRESS
DIODE LED	1.0	1.5000	0.4175	0.6262	40
CIRCUIT BOARD	1.0	1.0000	0.0630	0.0630	10
TRANSISTOR NPN	1.0	1.5000	0.5100	0.7650	50
SOLID STATE RELAY	1.0	1.0000	0.0045	0.0045	10
HI-R INTEGRATED CIRCUIT	1.0	1.2000	0.0300	0.0360	10
SWITCH TOGGLE	1.0	1.0000	0.2500	0.2500	10
MAGNET	1.0	1.0000	0.5500	0.5500	10

SUBASSEMBLY TOTAL 2.295

Y256A226 REV

SUBASSEMBLY -- TOGGLE SWITCH UP

AMBIENT TEMPERATURE = 40C

PART TYPE	QUANTITY	K(ENV)	FR	Q.F.K	STRESS
DIODE LED	1.0	1.5000	0.4175	0.6262	40
CIRCUIT BOARD	1.0	1.0000	0.0630	0.0630	10
TRANSISTOR NPN	1.0	1.5000	0.5100	0.7650	50
SOLID STATE RELAY	2.0	1.0000	0.0045	0.0090	10
HI-R INTEGRATED CIRCUIT	1.0	1.2000	0.0300	0.0360	10
SWITCH TOGGLE	1.0	1.0000	0.2500	0.2500	10
MAGNET	1.0	1.0000	0.5500	0.5500	10
SUBASSEMBLY TOTAL				2.299	

X256A226 REV

FIXED GROUND ENVIRONMENT NOV. 8,1973

EQUIPMENT -- SOLID STATE KEYBOARD

AMBIENT TEMPERATURE = 40C

PART TYPE	QUANTITY	K(ENV)	FR	Q.F.K	STRESS
ROTARY SW 10 POS	2.	1.0000	10.2070	20.4140	10
SOLID STATE POT	2.	1.0000	9.1723	18.3447	10
TOGGLE SWITCH SP	10.	1.0000	2.2947	22.9475	10
TOGGLE SWITCH DP	15.	1.0000	2.2992	34.4887	10
TOTALS				96.195	

TEMPERATURE/TIME PROFILE

PERCENT OF TIME AT TEMPERATURE 1.0000

EQUIVALENT PROFILE FAILURE RATE = 96.1948

PROFILE MTBF = 10395.57 HOURS

Y256A226 REV

EQUIPMENT -- SOLID STATE KEYBOARD

AMBIENT TEMPERATURE 40C

FIXED GROUND ENVIRONMENT

PREDICTION BY PART TYPE

PART TYPE	QUANTITY	TOTAL F.R.	SOURCE OF DATA
CIRCUIT BOARD =1	2.	4.978	PREDICTED SUBASSEMBLY
CIRCUIT BOARD =2	2.	10.463	PREDICTED SUBASSEMBLY
SWITCH ASSY	2.	4.952	PREDICTED SUBASSEMBLY
PC BOARD =1	2.	3.365	PREDICTED SUBASSEMBLY
PC BOARD =2	2.	10.027	PREDICTED SUBASSEMBLY
POT ASSY	2.	4.952	PREDICTED SUBASSEMBLY
DIODE	25.	15.656	MIL-HDBK-217A FIGURE 7.4.3B (MIL-S-19500)
CIRCUIT BOARD	25.	1.575	NINTH SYMPOSIUM (EARLES/EDDINS)
TRANSISTOR NPN	25.	19.125	MIL-HDBK-217A FIGURE 7.4.4B (MIL-S-19500)
SOLID STATE RELAY	40.	0.180	KEARFOTT SECONDARY DATA
SWITCH TOGGLE	25.	6.250	MIL-HDBK-217A FIGURE 7.10.2 (TYPE A)
MAGNET	25.	13.750	KEARFOTT SECONDARY DATA
HI-R INTEGRATED CIRCUIT	25.	0.900	KEARFOTT EXPERIENCE

202. TOTAL PARTS

TOTAL FAILURE RATE = 96.19

MTBF = 10395.57 HOURS

EQUIPMENT -- SOLID STATE KEYBOARD

40C AMBIENT TEMPERATURE

FIXED GROUND ENVIRONMENT

SUBASSEMBLY	FAILURE RATE
ROTARY SW 10 POS	20.41
SOLID STATE POT	18.34
TOGGLE SWITCH SP	22.95
TOGGLE SWITCH DP	34.49

TOTAL FAILURE RATE = 96.19

MTBF = 10395.57 HOURS

SINGER
KEARFOTT DIVISION

KEARFOTT DIVISION
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LITTLE FALLS, NEW JERSEY

RELIABILITY FAILURE MODE & EFFECTS ANALYSIS

10 POSITION SOLID STATE ROTARY SWITCH

ITEM	DESCRIPTION	SYMBOL	FUNCTION	FAILURE MODES	FAILURE RATE PERCENT	FAILURE RATE TOTAL	FAILURE RATE MODE	CAUSE OF FAILURE	FUNCTIONAL FAILURE EFFECT	EQUIPMENT FAILURE EFFECT	CRITICALITY FUNCTION	CRITICALITY EQUIPMENT
	LIGHT EMITTING DIODE PN MLED 910 MOTOROLA	CR1 THRU CR4	TRANSDUCER LIGHT SOURCE	OPEN	100				IMPROPER OUTPUT			
	PHOTO TRANSISTOR PN MRD 604 MOTOROLA	Q1 THRU Q4	TRANSDUCER SWITCH OUTPUT	OPEN SHORT	75 25				IMPROPER OUTPUT IMPROPER OUTPUT			
	DUAL INPUT QUAD EXCLUSIVE "OR" GATE PN CD4030AK RCA	U2	DECODER LOGIC CONTROL	OPEN SHORT TO +5V SHORT TO 0V	80 10 10				IMPROPER OUTPUT IMPROPER OUTPUT IMPROPER OUTPUT			
	BCD TO 1 OUT OF 10 DECODER PN CD4028AK RCA	U1	TRANSDUCER INPUT TO OUTPUT SWITCH DECODER	NO OUTPUT IMPROPER OUTPUT	20 80				NO OUTPUT IMPROPER OUTPUT			
	RESISTOR PN RC05GF104K	R1 THRU R4	GATE INPUT GAIN ADJUST	OPEN	100				INCREASED NOISE SUSCEPTIBILITY			
	RESISTOR PN RC05GF102K	R8 THRU R17	TRANSISTOR BASE BIAS	OPEN	100				INCREASED NOISE SUSCEPTIBILITY			
	TRANSISTOR PN 2N5845	Q6 THRU Q15	RELAY COIL DRIVER	OPEN SHORT	75 25				IMPROPER OUTPUT IMPROPER OUTPUT			
	SOLID STATE RELAY PN 640-1 TELEDYNE	K1 THRU K10	OUTPUT SWITCH CONTACT	OPEN OUTPUT SHORTED OUTPUT OPEN COIL SHORTED COIL	60 15 15 15				IMPROPER OUTPUT IMPROPER OUTPUT IMPROPER OUTPUT IMPROPER OUTPUT			
	LIGHT EMITTING DIODE PN 5082-4420	CR5	SWITCH FAIL INDICATOR	OPEN	100				NO FAIL INDICATION			
	RESISTOR PN	R5	LED CURRENT LIMITER	OPEN	100				NO FAIL INDICATION INCREASED BRIGHT-NESS FAIL IND			
	TRANSISTOR PN 2N2222A	Q5	LED DRIVER	OPEN SHORT	75 25				NO FAIL INDICATION CONTINUOUS FAIL IND			
	ZENER DIODE PN MZ4626	CR6	LED VOLTAGE LIMITER	OPEN SHORT	[illegible] 20				DECREASED FAIL IND BRT NO FAIL INDICATION			
	RESISTOR PN RC05GF202K	R7	TRANSISTOR BASE BIAS	OPEN	100				CONTINUOUS FAIL IND			
	RESISTOR PN RC05	R6	DIODE CURRENT LIMITER	OPEN	100				NO FAIL INDICATION			

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RELIABILITY FAILURE MODE & EFFECTS ANALYSIS

DOUBLE POLE TOGGLE/PUSHBUTTON SWITCH (SOLID STATE)

ITEM	DESCRIPTION	SYMBOL	FUNCTION	FAILURE MODES	FAILURE RATE PERCENT	FAILURE RATE TOTAL	FAILURE RATE MODE	CAUSE OF FAILURE	FUNCTIONAL FAILURE EFFECT	EQUIPMENT FAILURE EFFECT	CRITICALITY FUNCTION	CRITICALITY EQUIPMENT
	HALL EFFECT DEVICE PN 2SS1 MICROSWITCH	A1	TRANSDUCER SWITCH OUTPUT	OPEN SHORT					SWITCH OUTPUT OPEN SWITCH OUTPUT SHORT			
	TRANSISTOR PN 2N5845	Q1	RELAY COIL DRIVER	OPEN SHORT	75 25				SWITCH OUTPUT OPEN SWITCH OUTPUT SHORT			
	RESISTOR PN RC05GF271K	R1	HALL EFFECT CURRENT LIMITER	OPEN	100				SWITCH OUTPUT OPEN			
	RESISTOR PN RC05GF272K	R2	TRANSISTOR BASE BIAS	OPEN	100				IMPROPER OUTPUT			
	SOLID STATE RELAY PN 640-1 TELEDYNE	K1/ K2	OUTPUT SWITCH CONTACT	OPEN OUTPUT SHORTED OUTPUT OPEN COIL SHORTED COIL	60 15 15 16				SWITCH OUTPUT OPEN SWITCH OUTPUT SHORT SWITCH OUTPUT OPEN SWITCH OUTPUT SHORT			
	MAGNET PN 102SS12 MICROSWITCH		TRANSDUCER ACTUATOR									
	LIGHT EMITTING DIODE PN 5082-4420-HP	CR1	SWITCH FAIL INDICATOR	OPEN	100				SWITCH OUTPUT OPEN			

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RELIABILITY FAILURE MODE & EFFECTS ANALYSIS

SOLID STATE POTENTIOMETER

ITEM	DESCRIPTION	SYMBOL	FUNCTION	FAILURE MODES	FAILURE RATE PERCENT	FAILURE RATE TOTAL	FAILURE RATE MODE	CAUSE OF FAILURE	FUNCTIONAL FAILURE EFFECT	EQUIPMENT FAILURE EFFECT	CRITICALITY FUNCTION	CRITICALITY EQUIPMENT
	LIGHT EMITTING DIODE PN MLED910 MOTOROLA	CR1 THRU CR7	TRANSDUCER LIGHT SOURCE	OPEN	100				IMPROPER OUTPUT			
	PHOTOTRANSISTOR PN MRD604 MOTOROLA	Q1 THRU Q7	TRANSDUCER SWITCH OUTPUT	OPEN SHORT	75 25				IMPROPER OUTPUT IMPROPER OUTPUT			
	RESISTOR PN RC05GF104J	R1 THRU R7	GATE INPUT GAIN ADJUST	OPEN	100				INCREASED NOISE SUSCEPTIBILITY			
	DUAL INPUT QUAD EXCLUSIVE "OR" GATE PN CD4030AK RCA	U1/U2	CONVERTER LOGIC CONTROL	OPEN SHORT TO +5V SHORT TO 0V	80 10 10				IMPROPER OUTPUT IMPROPER OUTPUT IMPROPER OUTPUT			
	DIGITAL TO ANALOG CONVERTER PN DAC 02ACUL PREC MON	U3	DIGITAL INPUT TO CONTINUOUS ANALOG VOLTAGE OUTPUT	NO OUTPUT IMPROPER OUTPUT	20 80				NO OUTPUT IMPROPER OUTPUT			
	CAPACITOR PN CK06BX104K	C1/C2	POWER SUPPLY FILTERING	OPEN SHORT	90 10				INCREASED NOISE SUS IMPROPER OUTPUT			
	TRANSISTOR PN 2N2222A	Q8	LED DRIVER	OPEN SHORT	75 25				NO FAIL INDICATION CONTINUOUS FAIL IND			
	ZENER DIODE PN MZ4619 MOTOROLA	CR9	TRANSISTOR BASE VOLTAGE REF	OPEN SHORT	80 20				DECREASED FAIL IND BRGT NO FAIL INDICATION			
	LIGHT EMITTING DIODE PN 5082-4420 HP	CR8	POTENTIOMER FAIL INDICATOR	OPEN	100				NO FAIL INDICATION			
	RESISTOR PN RC05GF272K	R8	TRANSISTOR BASE BIAS	OPEN	100				CONTINUOUS FAIL IND.			
	RESISTOR PN RC05GF560K	R10	LED VOLTAGE LIMITER	OPEN	100				NO FAIL INDICATION			
	RESISTOR PN RC05GF750K	R9	LED CURRENT LIMITER	OPEN	100				INCREASED FAIL IND BRIGHTNESS			
	RESISTOR PN RC05	R11	ANALOG SCALE ADJUST	OPEN	100				INACCURATE OUTPUT			
	RESISTOR PN RC05	R12	ANALOG SCALE ADJUST	OPEN	100				INACCURATE OUTPUT			

APPENDIX I

SCHEMATIC DIAGRAMS

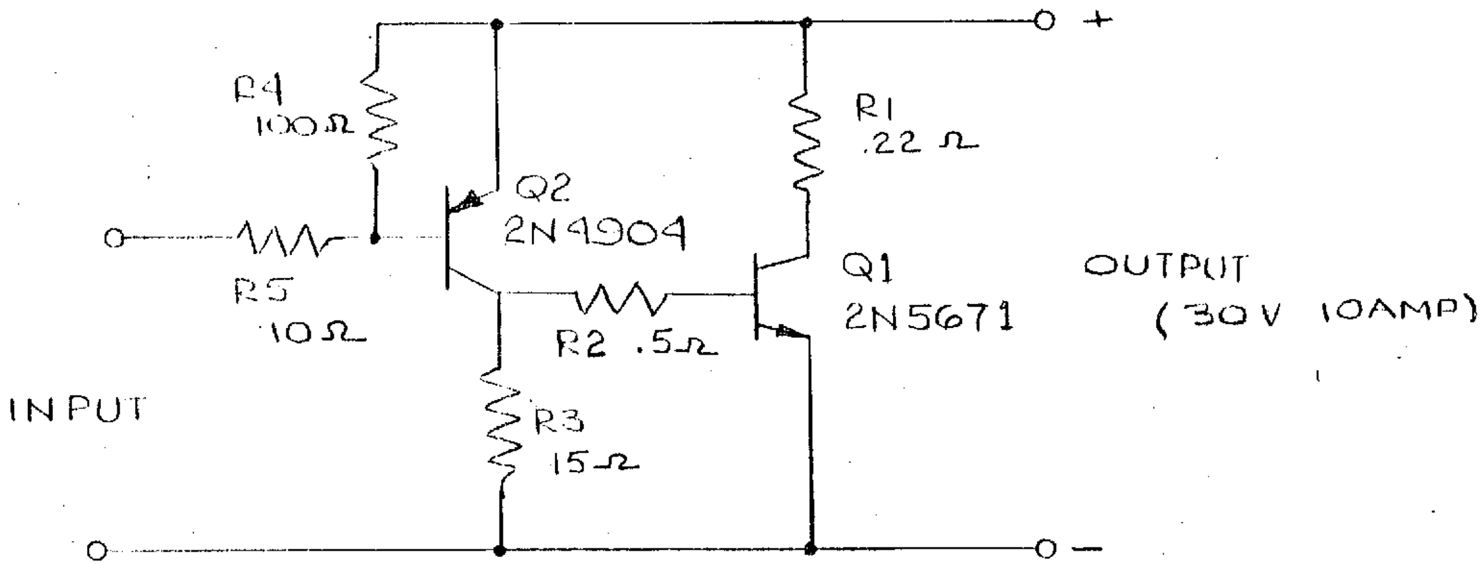

FIGURE I-1. SCHEMATIC DIAGRAM POWER SWITCH

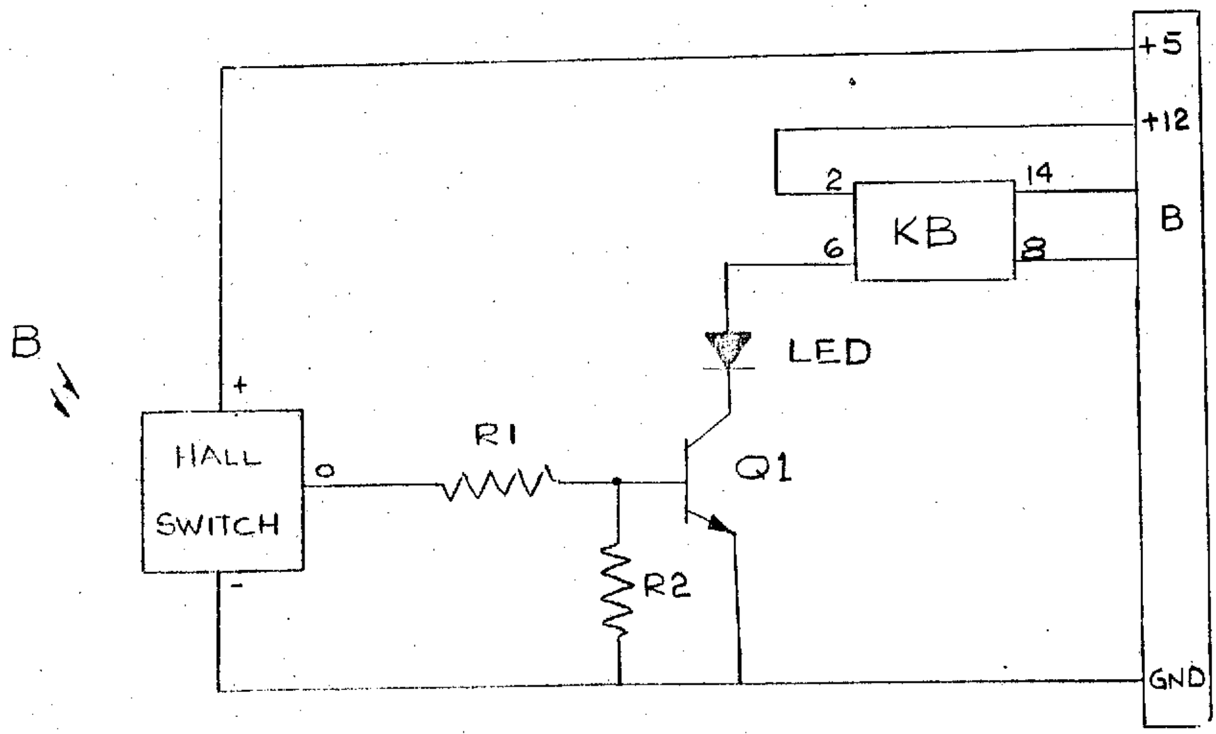

FIGURE I-2. SCHEMATIC DIAGRAM SINGLE POLE SWITCH

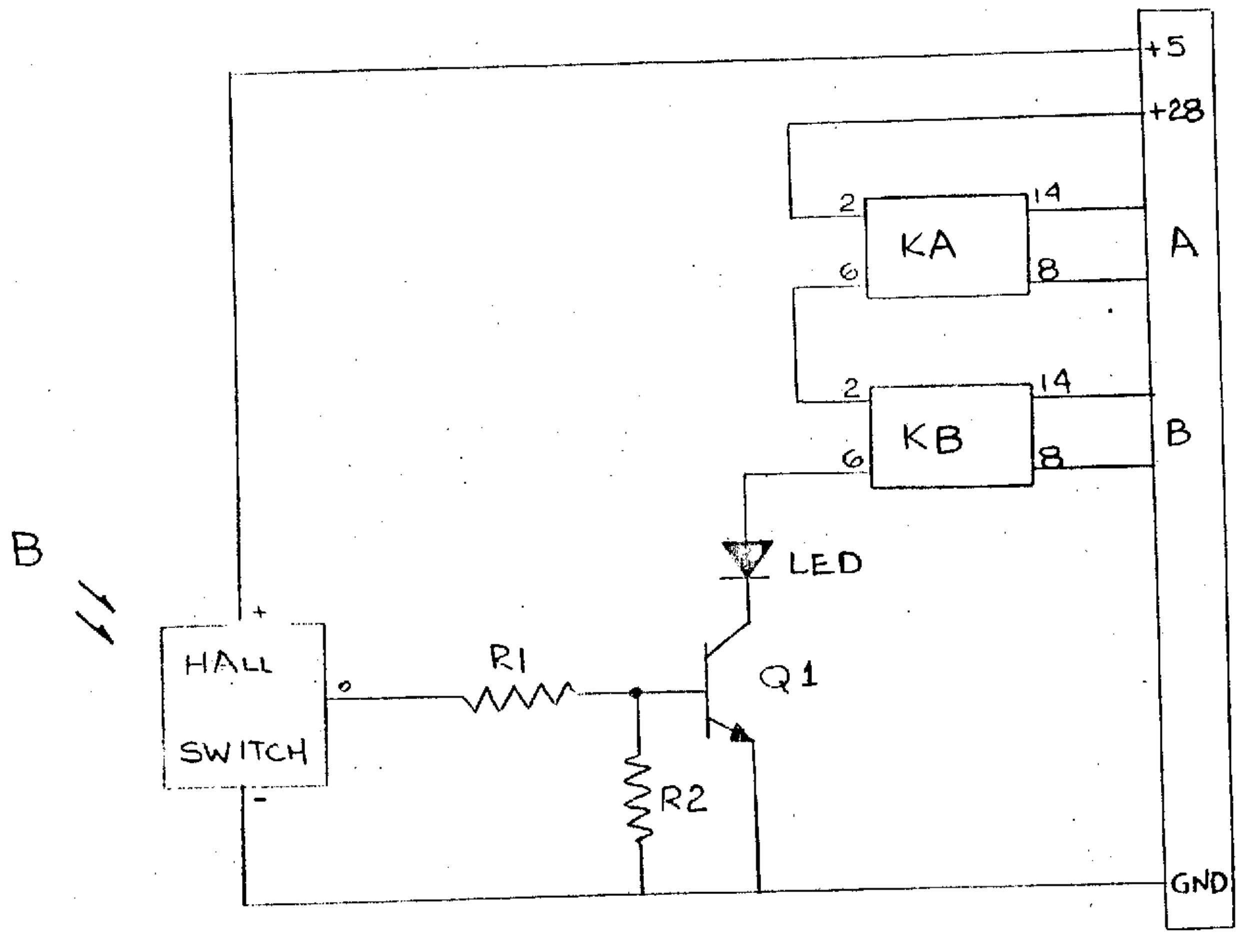

FIGURE I-3. SCHEMATIC DIAGRAM DOUBLE POLE SWITCH

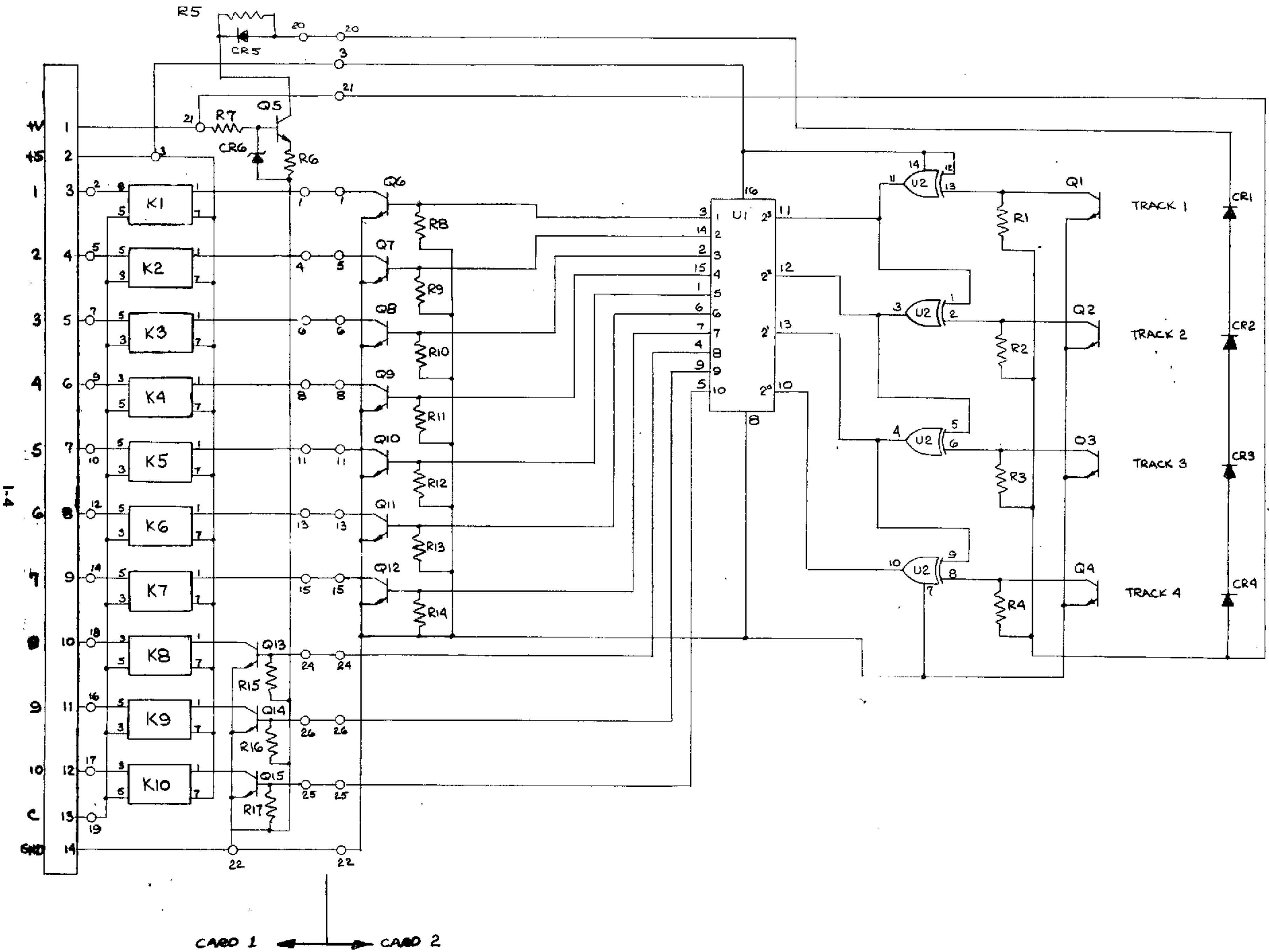

FIGURE I-4 SCHEMATIC DIAGRAM 10 POSITION SOLID STATE ROTARY SWITCH

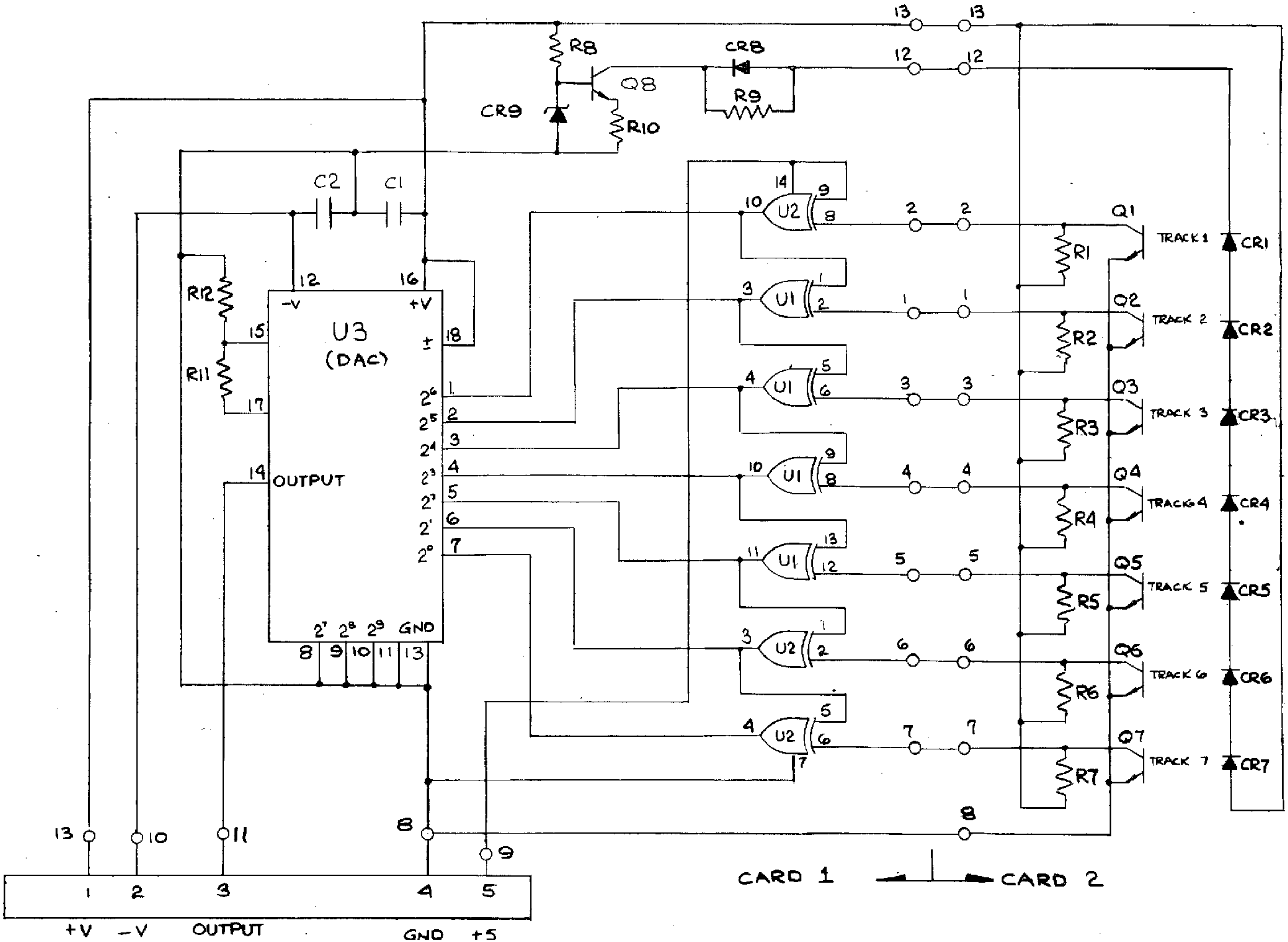

FIGURE I-5 SCHEMATIC DIAGRAM POTENTIOMETER