PART 5

THE TEST UNIT DESIGN

0195P

PART 5

THE TEST UNIT DESIGN

5. INTRODUCTION

This section of the thesis deals with the preliminary design of two test units:

a. A training aid and confidence building unit.

b. A workshop unit that actively measures the various outputs of the firing unit.

Preliminary work was done on these two units. The scope of the original contract did not make provision for this extra equipment and consequently only basic design information is submitted. The final design of these units is considered outside the scope of this document.

5.2 THE TRAINING UNIT

The concept behind this unit is that it is totally portable and independant of any external power supply. Consequently the unit is both small and very simple, drawing its power requirements from the energy output of the firing unit.

5.2.1 The Circuit Diagram

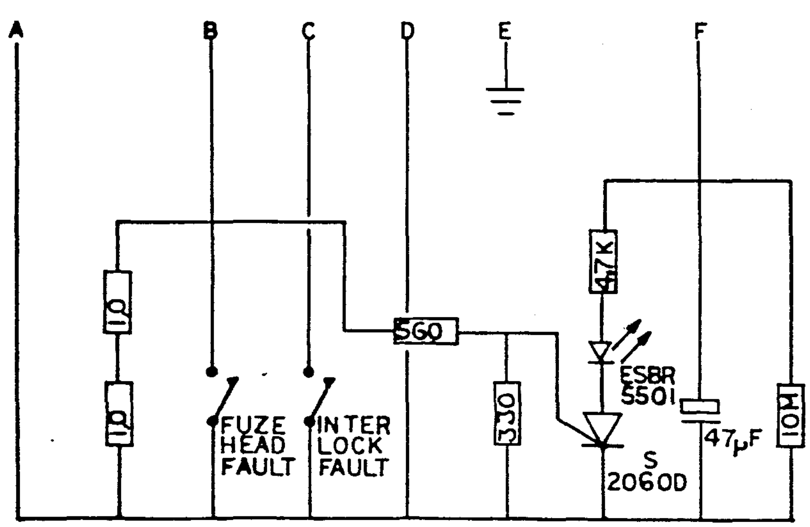


FIGURE 155: CIRCUIT DIAGRAM OF TEST UNIT

5.2.2 Circuit Operation

As can be seen from the circuit diagram, this is a very simple and consequently, inexpensive unit.

The unit plugs directly into the firing unit, with no further external connections.

Two switches are provided. One simulates a short circuit fuze head (fuze-head fault) and the other an interlock error. These two functions are indicated on the firing unit when it is tested.

The trigger voltage for the thyristor is developed across the 2 ohm fuze-head simulating resistor, further divided by the 560 ohm and 330 ohm resistors. The Anode current is provided by a charge stored in the 47 microfarad capacitor. The passage of this charge through the LED and the thyristor informs the operator that the system has a fuze-head initiating voltage and an SAD capacitor supply. If either of these are absent the LED will not illuminate.

5.2.3 Disadvantages of this Unit

The training unit will only test if the firing pulse and SAD charging energy are present. It does not check the absolute values of these energy outputs of the firing unit. Absolute range of fuze-head resistance acceptable to the firing unit is not provided, but only a short circuit. This has the result that only the basic firing unit functions, consistent with operator training, are provided and/or checked.

5.2.4 Future Development Needed

The thyristor does not trigger reliably at low temperature, consequently the holding current and/or the trigger voltage need revising.

This is intended to be a small hand held unit, which is likely to be badly treated. The packaging of this unit consequently will need much thought. Encapsulation in epoxy is worth considering.

5.3 THE WORKSHOP UNIT

This unit is intended to approximate the laboratory situation where expensive electronic equipment is available. This has the result that it is substantially more complex than that in 5.1 and requires an external supply. After much deliberation this supply is to be 28 volt DC, nominally supplied by the parent vehicle. This contributed its own particular problems, outlined below.

The description is divided into two sections. 5.3.1, the power supply and 5.3.2 the measuring section.

5.3.1 The Power Supply

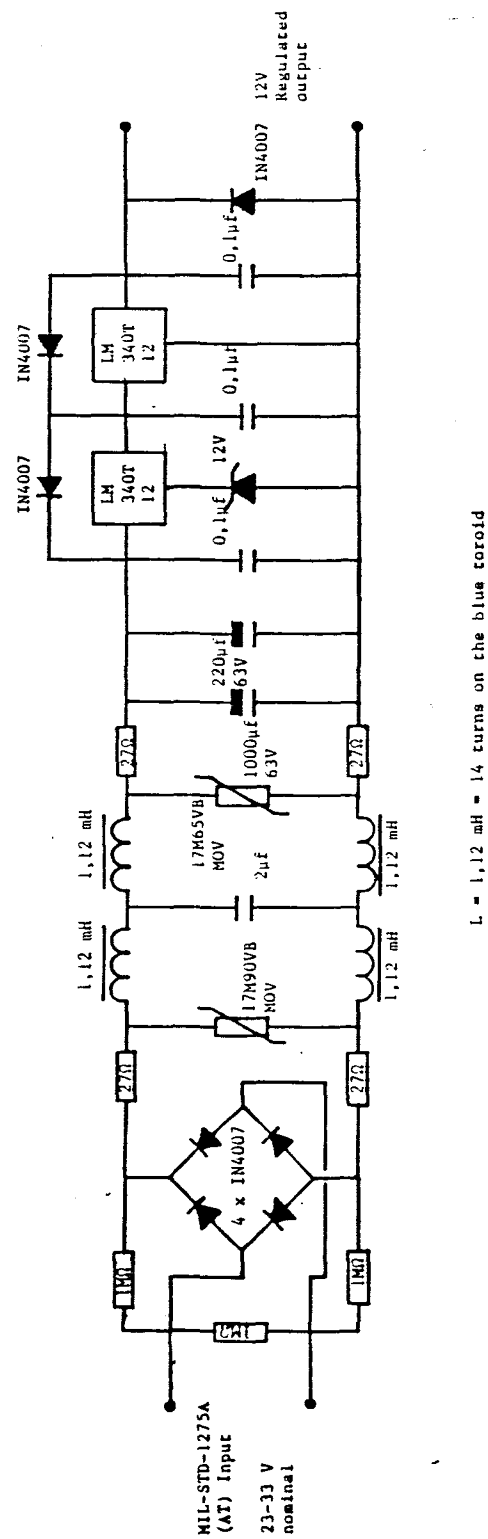


FIGURE 156: POWER SUPPLY FOR WORKSHOP UNIT

5.3.2 Circuit Operation

This power supply is designed to give a stable 12 V output from a 28 V vehicle supply. It was assumed that this supply would comply with MIL-STD-1275A(AT) of nominal range 23 to 33 V DC. This MIL-STD requires that specific values of voltage surge, spikes, undervoltage etc. do not affect the output. The express object of the design was to comply with these requirements.

The three 1 mega ohm resistors eliminate unwanted static buildup. The bridge rectifier ensures that the supply is not polarity sensitive and that voltage spikes that go negative with respect to earth are tolerated. The MOV's attenuate any voltage spike applied to the input. The first MOV (17M90VB) limits this spike to approximately 90 V while the second has a cutoff at approximately 65 V. This is further attenuated by the lowpass filter with a 3 dB cutoff frequency of approximately 3,5 kHz when matched to a 50 ohm supply.

The filter's output is decoupled by 1220 microfarad of capacitance for low frequency variations and a 0,1 microfarad low inductance capacitor for high frequency interference. The one LM340T12, with the Zener diode in the ground line, regulates the input to the second regulator to 24 V. If the input supply drops to 23 V, this regulator saturates, with its output approximately 16 V. The second regulator output therefore remains constant at a nominal 12 V. The 0,1 microfarad capacitors on the outputs of the regulators improve transient response. Two 1N4007 diodes prevent the regulator's output going higher than their inputs respectively while the third prevents the ground rail from going positive with respect to the positive rail.

5.3.3 The Measuring Section

5.3.3.1 The circuit diagram

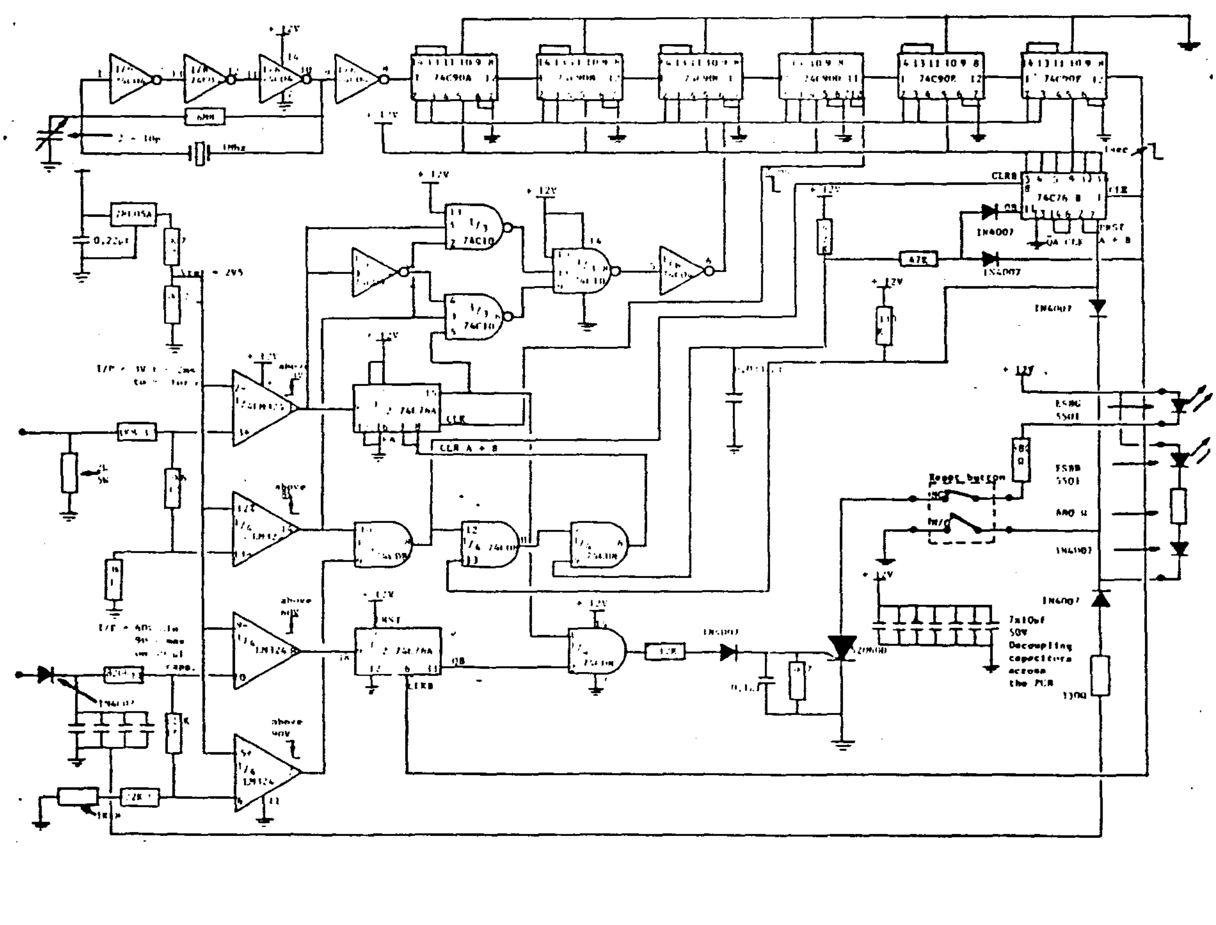


FIGURE 157: CIRCUIT DIAGRAM FOR THE MEASURING SECTION

5.3.3.2 <u>Description of operation</u>

For convenience and ease of explanation this circuit is divided into sub-sections. Each subsection is dealt with in turn, as outlined below.

5.3.3.3 <u>The clock</u>

This section of the circuit comprises a 1MHz oscillator and a division network consisting of six decade counters. Two outputs are given, one going low after 2 ms and the second, after one second. They are used to ensure that the output firing pulse is longer than 2 ms and that the SAD capacitors (40 microfarad) are charged within one second. The 74C76 connected to the ripple counter is used to terminate the measuring action after two seconds. This ensures that repetitive inputs do not result in an erroneous "firing unit operating correctly" indication.

5.3.3.4 <u>The level measuring circuitry</u>

The reference voltage is supplied by a 78L05, whose output is divided to 2,5 V. The two parameters measured each have maxima and minima. To this end four op-amps, configured as comparators, are used. Their input thresholds are as marked on the circuit diagram.

5.3.3.5 The control logic

This circuitry senses the outputs of the op-amps. When the minimum fire pulse level is exceeded, the timer is enabled and the unit expects the four 10 microfarad capacitors to be charged to a minimum of 60 V within one second. If this is so, the thyristor is triggered and the green LED illuminates. This indicates that the energy output of the firing unit is within specification.

If any of the following events occur, the circuit immediately goes into a hold mode and the green LED does not illuminate.

a. If the firing pulse input is shorter than 2 ms, less than 3 V or greater than 8 V.

b. If the SAD capacitor voltage rises too slowly, is less than 60 V or greater than 90 V.

To ready the unit for the next test the reset button is pressed. This resets all the counters, discharges the SAD capacitors and ensures that the green LED is switched off.

Normal measuring is complete after 1 second, the integrator on 74C76B QB ensuring that a race does not occur between the thyristor switching on and the internally generated "event complete" pulse. QB also goes low immediately any of the allowed maxima are exceeded.

5.3.3.6 The impedance and interlock section

This section of the test unit introduces, by means of mechanical switches, known resistances and short circuits into the firing unit measuring path. The firing unit then accepts or rejects these resistances, as marked on the test unit front panel.

5.3.4 Future Development Needed

74CXX devices are being withdrawn from the market and are consequently becoming more costly and difficult to obtain. 74HC devices should be substituted. These are pin for pin compatible but require a 5 V supply. This unit is intended to be fully repairable and therefore careful thought is needed to procure a suitably robust housing.

PART 6

QUALIFICATION TEST REPORT FOR THE FIRING

UNIT USED TO INITIATE TWO PYROTECHNIC CHAINS

0196P

SECTION 1: GENERAL

1.1 INTRODUCTION

This report deals with the qualification tests, and the results of those tests needed to bring the firing unit to qualification status.

The firing unit supplies the energy used to detonate two pyrotechnic chains.

1.2 SUMMARY

The three firing units submitted for qualification were built and tested according to sealed documentation. The three units passed all the tests as stipulated.

The test groups for Qualification were as follows:

TABLE 7 : QUALIFICATION TEST GROUPS

FIRING UNIT SERIAL NUMBER			301	303	302
REFERENCE	TEST	CONDITION			
The firing units were subjected to the following tests as indicated.					
4.2.5.1	Visual and Dimensional Inspection		1	1	1
4.2.5.2.1	Low Pressure (Altitude)	Ambient Temp	1	1	
4.2.5.2.2	Vibration*	Ambient Temp	1	1	
4.2.5.2.3(a)	High Temperature : Storage*	+65°C	1	1	
	: Operation*	+60°C	1	1	
4.2.5.2.3(b)	Low Temperature : Operation*	-15°C	1	1	
4.2.5.2.3(c)	Temperature Cycling*	-15°C/+65°C	1	1	
4.2.5.2.4	Rain*	+30°C	1	1	
4.2.5.2.5	Shock: (a) Functional*	Ambient Temp	1	1	
	(b) Transit Temp*	Ambient Temp	1	1	
	(c) Crash hazard	As specified	(Test peformed on a simulated Firing Unit)		
4.2.5.3	Electromagnetic Interference				1

* On completion of each of these tests the Firing Units were subjected to functional testing as specified.

SECTION 2 - QUALIFICATION TEST RESULTS

2.1 INTRODUCTION

This section of the report deals with the environmental testing of the Firing Units and the results of those tests completed during the qualification phase of this project. The tests were conducted in the order outlined in table 1, while the procedures for testing are as described previously. Prior to the commencement of qualification testing the firing units were subjected to the requirements of Acceptance Testing and were deemed to be acceptable.

2.1.1 Deviations from the Sealed Documentation

The firing units were built according to the requirements of the sealed documentation.

During manufacture it was noticed that there were certain grammatical shortcomings in the documentation and a manufacturing fault on the printed circuit board. These were dealt with by means of engineering change proposals (ECP).

A further ECP was also generated as an error had been made in calculating a test voltage. The change is covered fully in the FMECA, paragraph 4.5.4, Safety Reliability.

2.2 VISUAL AND DIMENSIONAL CHECKS

The three units, built as the qualification lot, were inspected and accepted. (Serial numbers 301, 302 and 303). Thereafter firing unit no. 302 was selected to be subjected to electromagnetic testing at the CSIR, Pretoria, while 301 and 303 were selected to undergo environmental testing.

2.3 LOW PRESSURE TESTS

These tests ensure that the firing units can be transported by air in its normal configuration. Firing Units 301 and 303 were placed in a chamber and the pressure reduced to 55 kPa ± 5 kPa for a minimum period of one hour. Thereafter the pressure was allowed to return to ambient and a visual and functional test was carried out. Both firing units passed this test.

2.4 VIBRATION TEST

Vibration testing, according to MIL-STD-810D, was performed to ensure adequate protection of the equipment agains vibrational stresses likely to be encountered during the equipment lifetime. The units were vibrated for a period of 15 hours per orthogonal axis. The acceleration and frequency spectra measured during these tests are shown below.

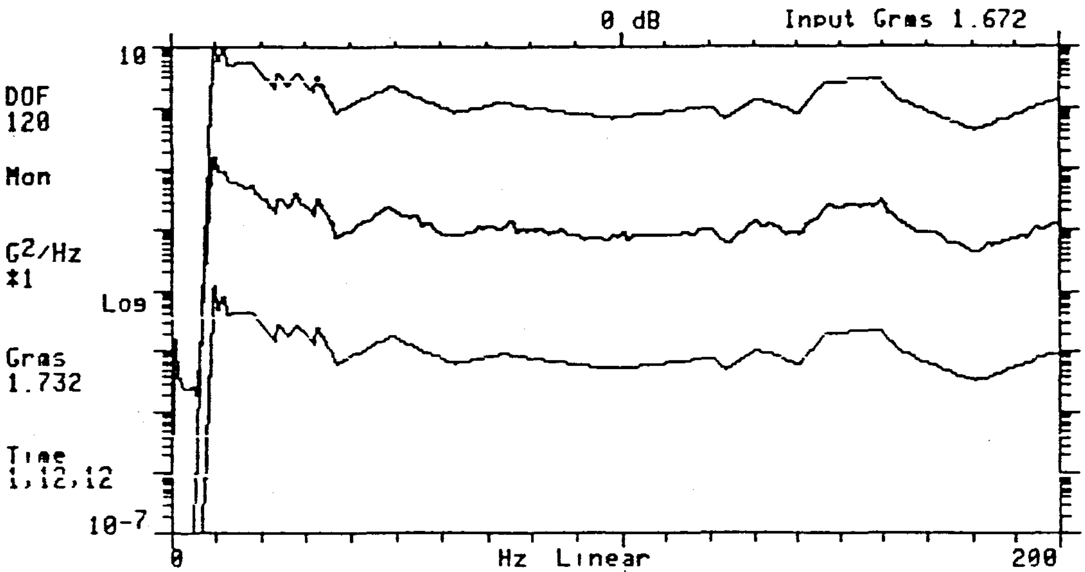


FIGURE 158: VIBRATION, VERTICAL AXIS

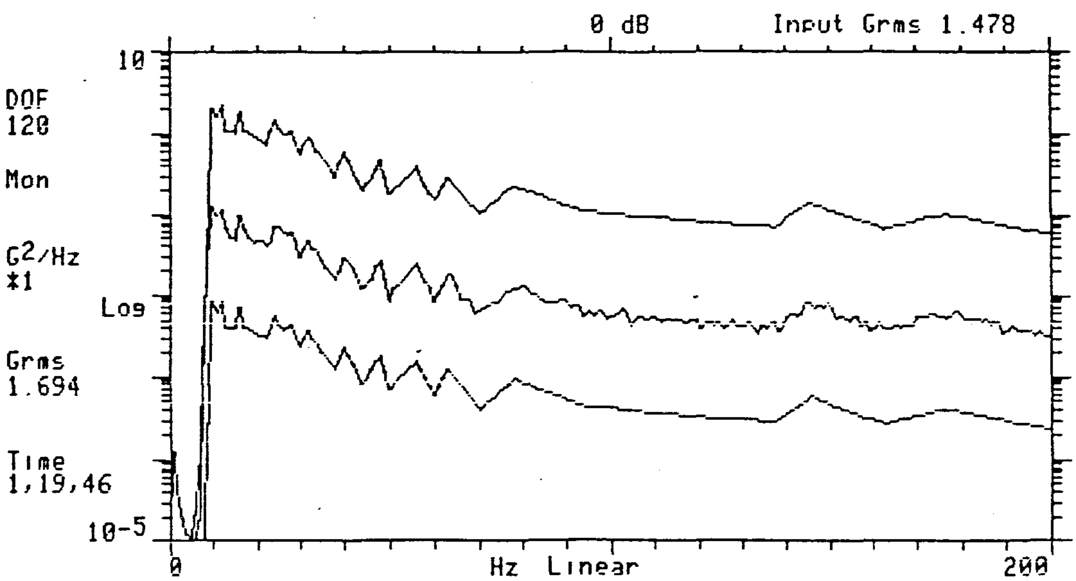


FIGURE 159: VIBRATION, TRANSVERSE AXIS

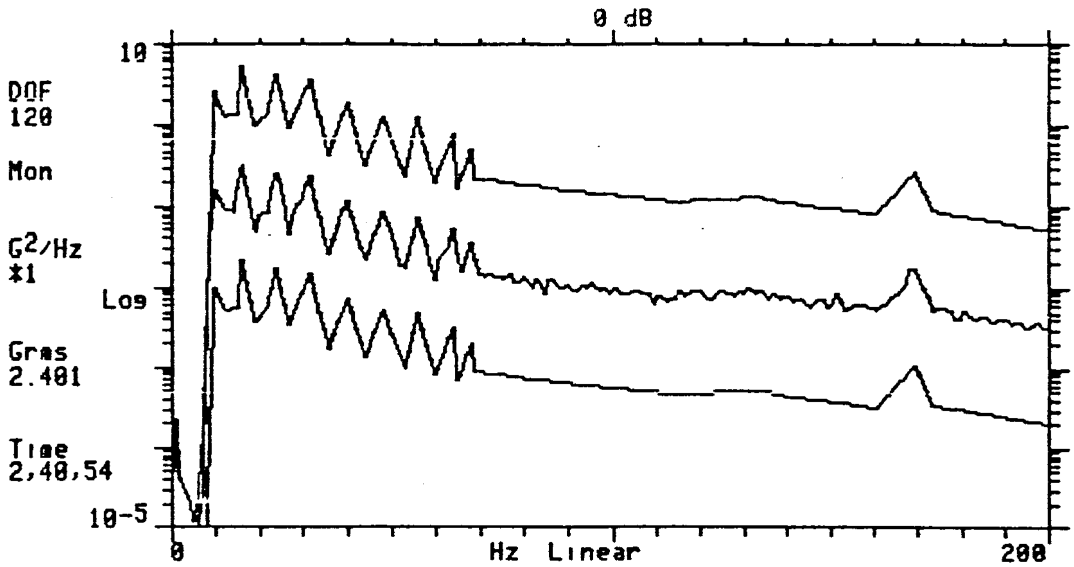


FIGURE 160: VIBRATION, LONGITUDINAL AXIS

After completion of vibration testing, the units were subjected to a functional test, which was passed.

2.5 HIGH TEMPERATURE TEST

This test was divided into two sections, storage (+65°C) and operation (+60°C).

2.5.1 Storage

The two firing units were subjected to +65°C for the required minimum of 24 hours, allowed to cool and then functionally tested. No problems were encountered.

2.5.2 Operation

The firing units were heated to +60°C for the minimum of 12 hours and then functionally tested before being allowed to cool. The tests were successfully completed.

2.6 LOW TEMPERATURE TEST

The two firing units were cooled to -15°C for more than 36 hours and then subjected to a functional test immediately on removal from the cooling chamber. No problems were experienced with either firing unit.

2.7 TEMPERATURE SHOCK

The firing units were tested as depicted in the temperature shock graph below.

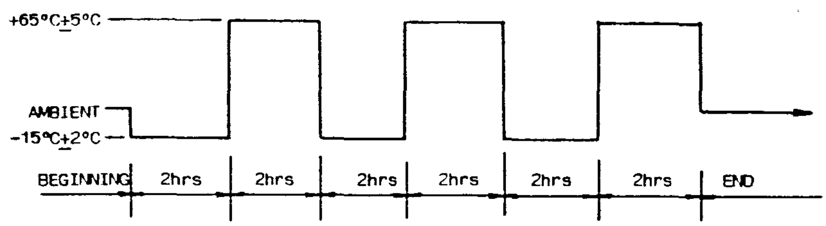


FIGURE 161: TEMPERATURE SHOCK CYCLE

The firing units were transferred between the chambers within five minutes after the required minimum of two hours at each extreme.

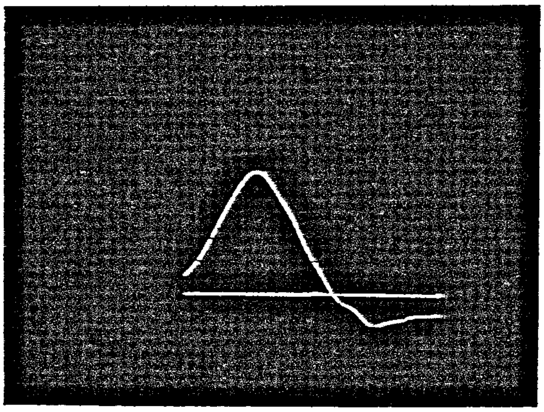
The visual and functional test revealed no faults.

2.8 RAIN TEST

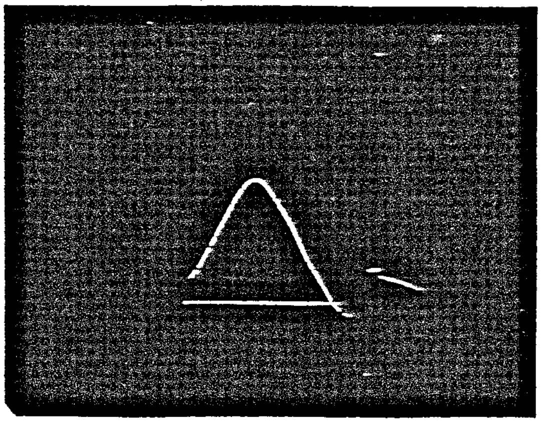
The rain tests were conducted as specified in the qualification test instruction. After completion of the test the units were dried externally, opened and examined for water ingress. No trace of water within the firing units was noted. The functional test also revealed no problems.

2.9 SHOCK TEST

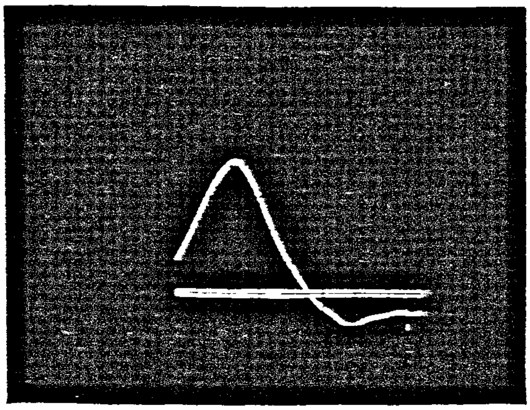
2.9.1 Eighteen shocks of 40 g's ± 3 g's lasting between 6 and 9 milliseconds were applied to each firing unit. On completion of the test the firing units were again subjected to a functional test, revealing no problems. Photographic records of these shocks are shown below.



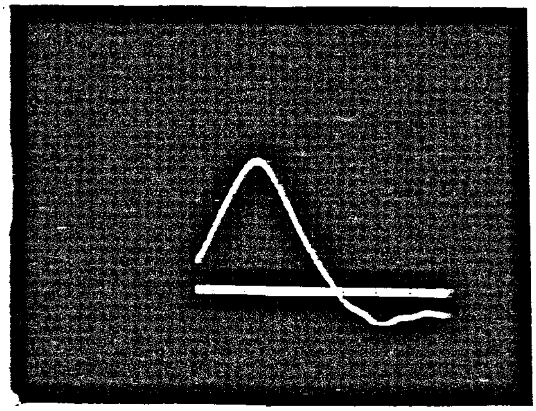
TRANSVERSE 1 37g's 9 mS.



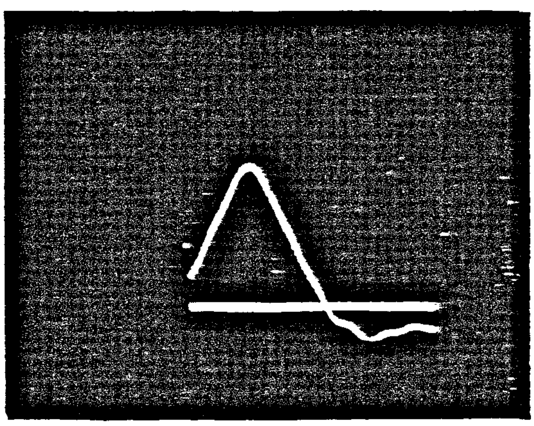
TRANSVERSE 2 38g's 9 mS.



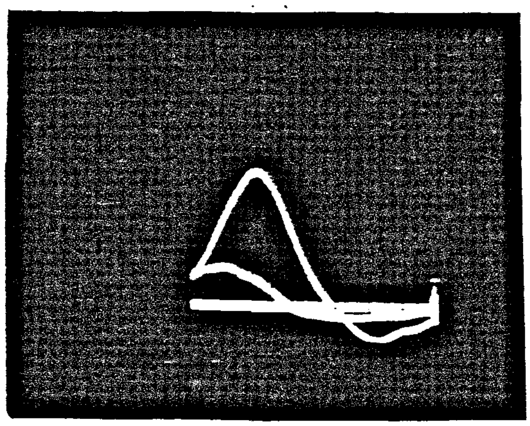
AXIAL 1 41g's 9 mS.



AXIAL 2 40g's 10 mS.



LONGITUDINAL 1 42g's 9 mS.



LONGITUDINAL 2 41g's 9 mS.

FIGURE 162: SHOCK TEST SPECTRA

2.9.2 Transit Drop Test

The two firing units were attached to a drop tester and dropped onto a 51 mm (nominal) thick piece of plywood, backed by concrete. After each unit was dropped 26 times (once on each edge, corner and face), a visual and functional test was carried out. The rivets holding the two guards protecting the hand-crank were bent by the force of the impacts. The guards were not loosened and are still capable of protecting the hand-crank as intended. Refer to Figure 163. No further physical damage was noted. Both units passed the functional test.

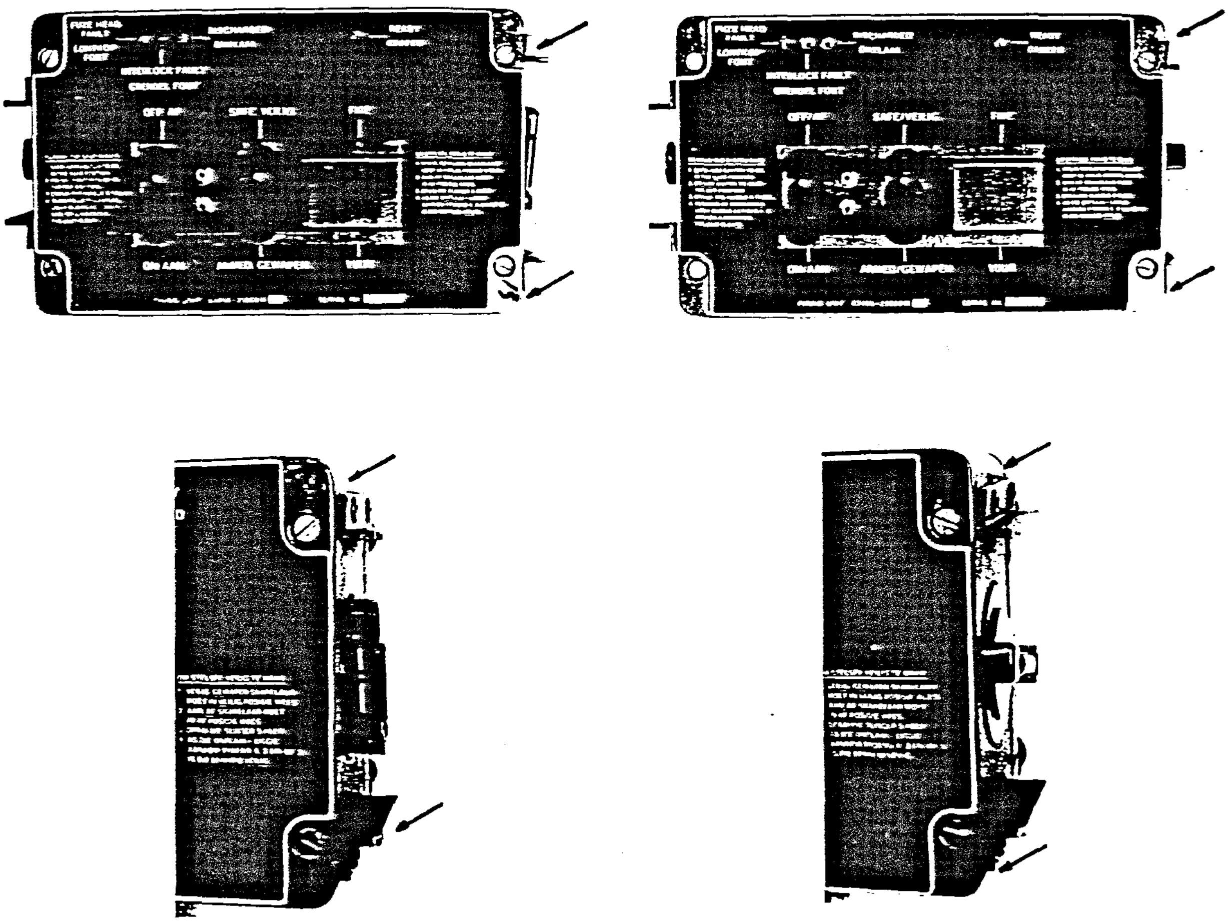
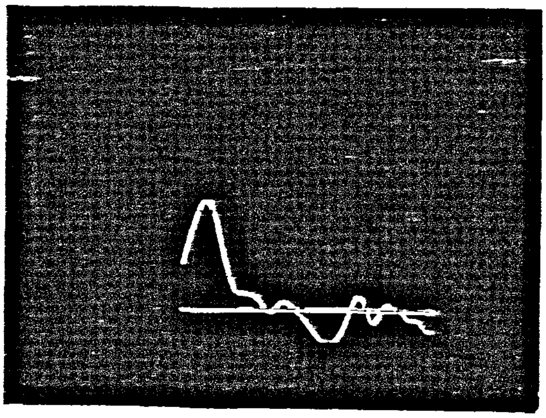


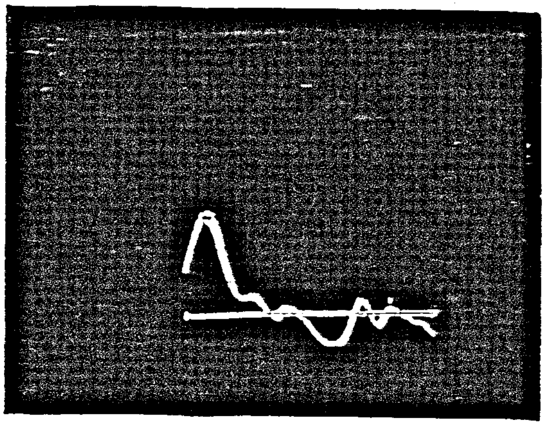
FIGURE 163: DAMAGE TO GUARDS

2.9.3 Crash Hazard Test

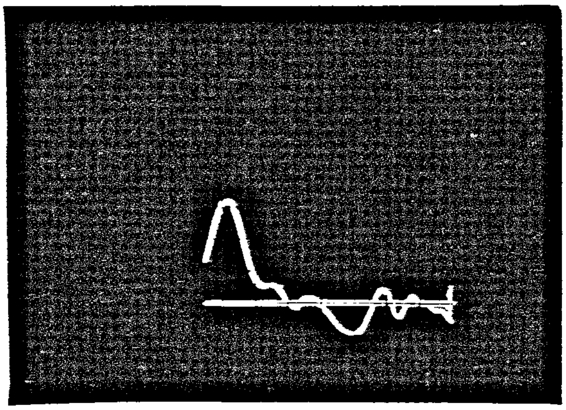
The XDM model firing units were used as a mechanically equivalent mock-up and accordingly attached to the mounting plate of the two firing units. Twelve shocks, as specified, were applied. The firing units did not break free from their mountings and no buckling of the base plate was noted. Minor damage consistent with that expected at the end of the designed life of the rubber mounts was noted on two of the eight mounts. Accordingly the two firing units passed this test.



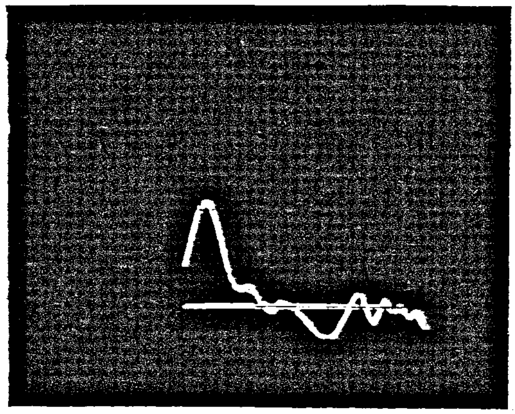
TRANSVERSE 1 78g's 4 mS.



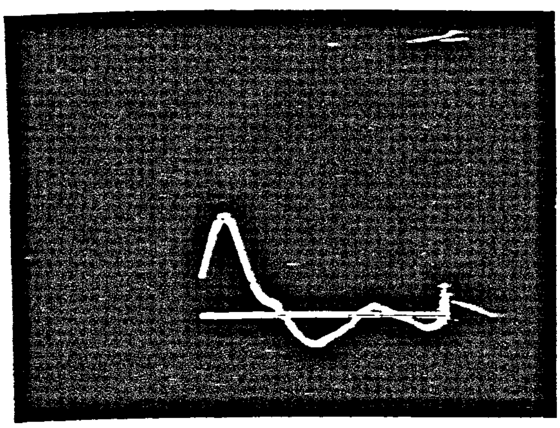
TRANSVERSE 2 76g's 5 mS.



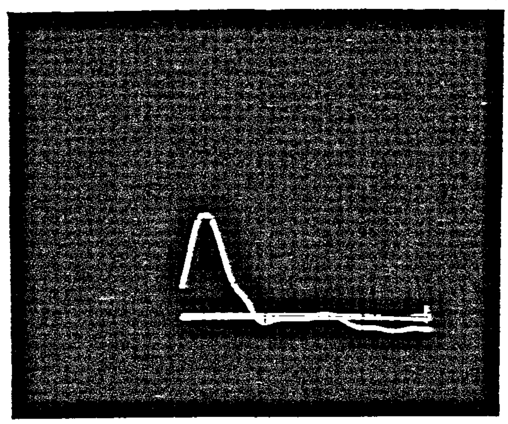
AXIAL 1 76g's 4 mS.



AXIAL 2 77g's 4 mS.



VERTICAL 1 75g's 4 mS.



VERTICAL 2 75g's 4 mS.

FIGURE 164: CRASH HAZARD SPECTRA

2.10 ELECTROMAGNETIC COMPATIBILITY TEST

Firing Unit S/N 302 was subjected to electromagnetic testing to ensure correct operation in an R.F. emission environment. The firing unit performed according to specification while being irradiated in the required electric and magnetic fields.

2.11 CONCLUSION

The three firing units passed all the tests as stipulated.

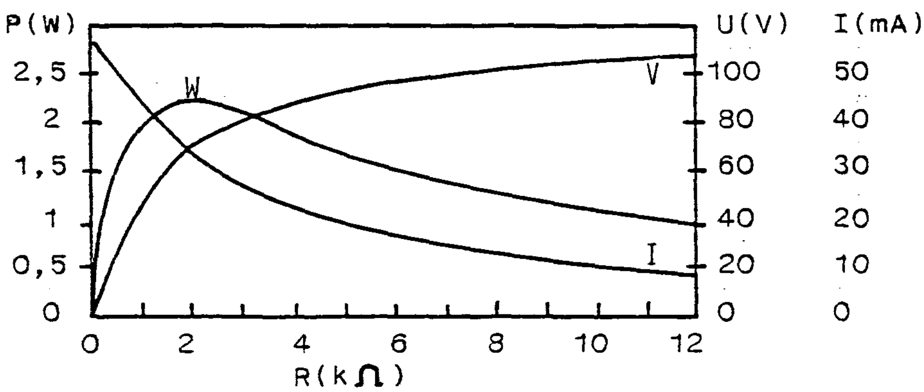
APPENDIX 1

P.T.I. COMMUNICATIONS GENERATOR TYPE 288-0000-4A

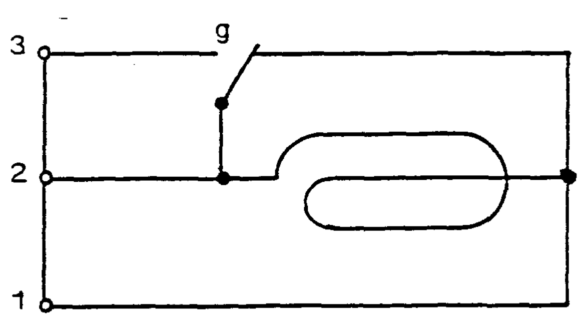
The G3-2 is a hand operated magneto-type generator of small size and weight and with a relatively high power. The voltage produced is nearly sinusoidal while linear distortions are relatively low. It operates reliably in a temperature range from -30°C to +60°C and is resistive against mechanical shocks and vibrations. Its weight is approximately 400 g. The generator is fitted with a built-in commutator.

At 180 turns of the generator handle in one minute.

- min. voltage 100 V_{rms} at no-load.
- min. short-circuit current 50 mA_{rms}.
- frequency 25 Hz.
- power from 1.3 to 1.8 VA at a 5000 Ohms load.
- The coil winding resistance is 840 Ohms.



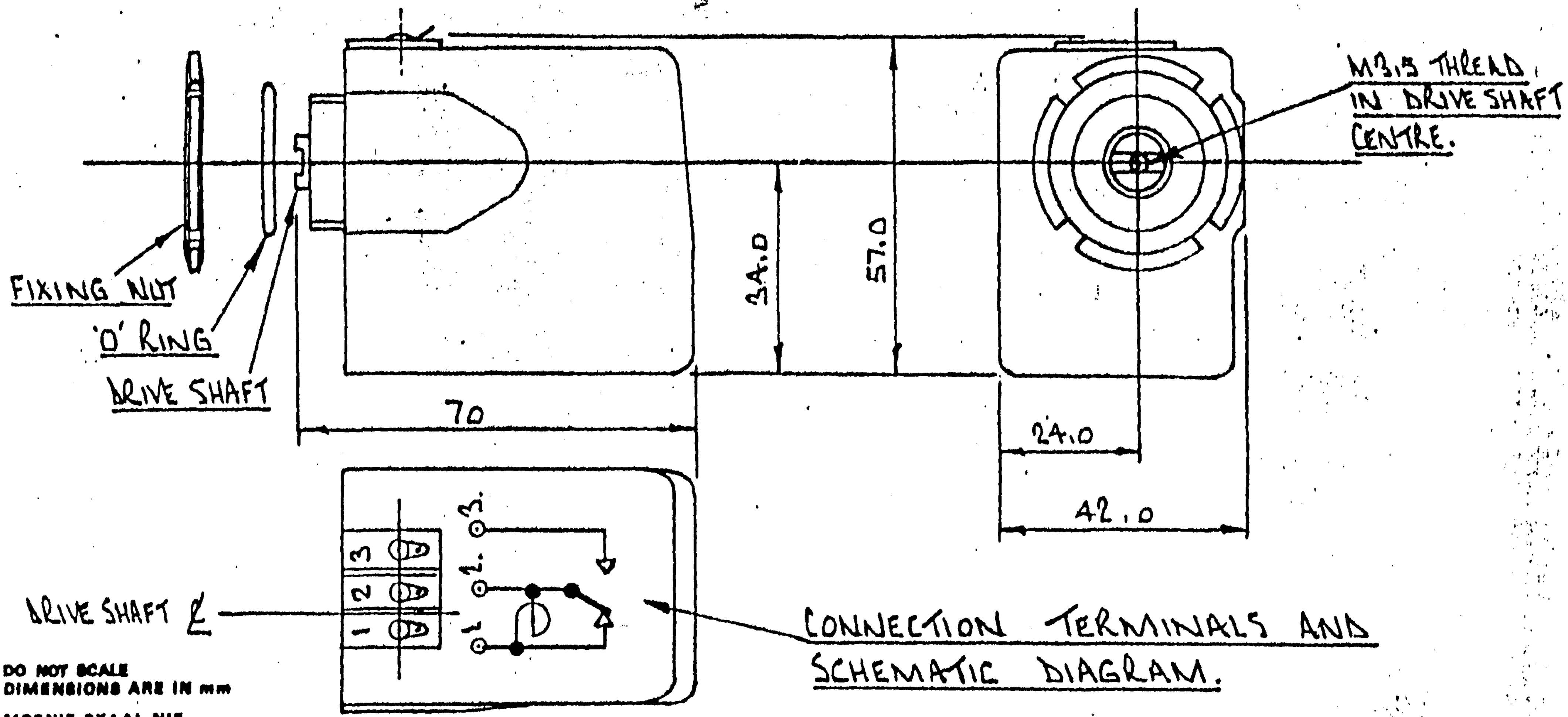
POWER VOLTAGE AND CURRENT AS THE FUNCTIONS OF LOAD AT 25 Hz



SWITCHING DIAGRAM OF GENERATOR G3-2

A4

NEXT ASSEMBLY VOLG. SAMESTEL	REPLACES DRG. No. VERVANG TEK.	REV. HERS.	APPROVED GOEDGEKEUR	DATE DATUM	PARTICULARS BESONDERHEI



DO NOT SCALE
DIMENSIONS ARE IN mm

MOENIE SKAAL NIE
AFMETINGS IS IN mm

-28B00004 A

APPROVED/GOEDGEKEUR	MATL. ASSEMBLY.	PRETORIA TELECOMMUNICATION INDUSTRIES 309-313 CARL STREET, PTA. WEST	No. D28B00004
APPROVED/GOEDGEKEUR	TITLE/TITEL RINGER. TELEPHONE.	ARMSCOR — KRYGKOR	No.
APPROVED/GOEDGEKEUR			
DATE DATUM 1978-11-24.		DRAWN GETEKEN D.K.H. / CHECKED NAGESIEN	REVISION HERSIENING

WILLIAM BARKER

Charging of Cells

B. Charging of Cells

Normal Charge and Fast Charge

The **rate of excess charge** for sealed Ni-Cad batteries is 1.4. This means that to obtain 100 % energy, a charge of 140 % is needed.

Nominal charge current refers to a 10 hour discharge current I_{10} (0.1 $C_{10}A$) needed to recharge a discharged battery for 14 hours. Charging is also possible at a lower current, e.g. ⅓ I_{10} (0.033 $C_{10}A$) or ½ I_{10} (0.05 $C_{10}A$) with c espondingly longer charging times.

Occasional **overcharging** of Ni-Cad cells at nominal charge current I_{10} (0.1 $C_{10}A$) is permissible.

Experience has shown that the effective capacity values are generally higher than those given in this leaflet.

When charging at nominal charge current, it is sufficient to stop the charging process manually. However, when charging at higher currents, it is advisible to use some automatic control (e.g. timer).

Cells with sintered electrodes can be charged as follows:

9.5 h at 1.5 x I_{10} (0.15 $C_{10}A$)

7.0 h at 2 x I_{10} (0.2 $C_{10}A$)

or 4.5 h at 3 x I_{10} (0.3 $C_{10}A$)

Charging of button cells is more restrictive. Some cells can be charged 9.5 h at 1.5 x I_{10} (0.15 $C_{10}A$) or 7 h at 2 x I_{10} (0.2 $C_{10}A$). The charging table gives the permissible charge currents and times for all battery series.

For certain applications it is necessary to recharge a discharged battery in a relatively short time. Most cells can be fast charged, using different conditions however.

Fast Charge of Button Cells

Using a charge current of 3 x I_{10} (0.3 $C_{10}A$) limited fast charge can be achieved. This means that 60 to 75 % of the withdrawn capacity can be recharged in 2 to 2.5 h. Charging by this method must be switched off at a particular voltage and changed to a lower charge current of between $^1/_{10}$ I_{10} (0.01 $C_{10}A$) to I_{10} (0.1 $C_{10}A$). The voltages for the necessary switching over are:

1.45 + 0.01 V/cell for DKZ series

1.49 + 0.01 V/cell for DK series.

These values apply to a temperature range of 10 °C to 40 °C without temperature compensation.

Cell type 10 DK should not be fast charged.

Fast Charge for Cells with Sintered Electrodes

Cells of RS, RSH, RSX and SD series can be fast charged at currents of 8 to 12 x I_{10} (0.8 to 1.2 $C_{10}A$). At charging times of 0.8 to 1.2 h., capacities of 70 to 90 % of the nominal capacity can be achieved.

RST serie cells can be fast charged at currents of 5 to 10 I_{10} (0.5 to 1 $C_{10}A$). About 90 % of nominal capacity can be achieved after charge time of 1 to 2 h.

Except for the RST series, all cells with sintered electrodes may be charged at currents up to 20 x I_{10} (2 $C_{10}A$). Higher currents require special treatment. When fast charging up to a cell voltage of 1.50 to 1.52 V/cell at room temperature (20 °C), temperature compensation of −4mV/°C in ranges of 0 to 45 °C will be necessary. A voltage of 1.6 V/cell at 0 °C should not be exceeded.

When the specified voltage has been reached, fast charge must be stopped and switched to a charge current of I_{10} (0.1 $C_{10}A$).

The simplest method to fast charge a battery is to fully discharge and then fast recharge. This method is frequently used by model builders. The battery must be monitored and discharged at 3 to 4 I_{10} (0.3 to 0.4 $C_{10}A$) to 0.9 V/cell, then recharged for 1 h at 10 x I_{10} ($C_{10}A$) or 0.5 h at 20 x I_{10} (2 $C_{10}A$). It is important to adhere to the charging times. A 12 V automotive battery can be used as energy source if 7 to 8 cells are to be charged.

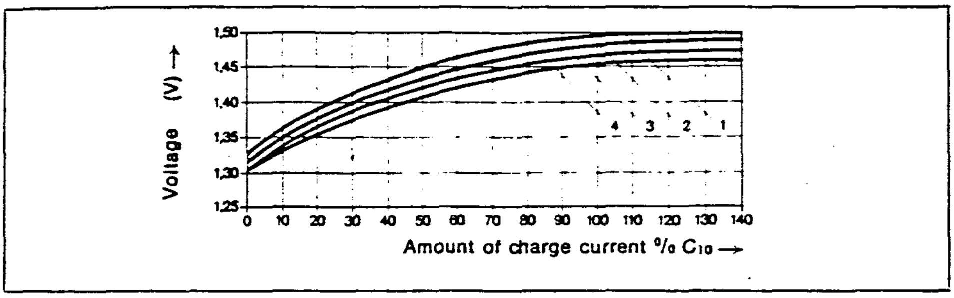
Charging Table

	Series	Charge time/charge current			* Overcharging
Button cells		I_{10} (0.1 $C_{10}A$)	1.5 x I_{10} (0.15 $C_{10}A$)	2 x I_{10} (0.2 $C_{10}A$)	I_{10} (0.1 $C_{10}A$)
	DK DKO DKZ	all types 14 to 18 h	only 250 and 280 DK 9.5 h possible	– – 7 h	all types 100 h
Cylindrical cells	RS RSH RST	all series 14 h at I_{10} (0.1 $C_{10}A$) 9.5 h at 1.5 x I_{10} (0.15 $C_{10}A$) 7 h at 2 x I_{10} (0.2 $C_{10}A$) 4.5 h at 3 x I_{10} (0.3 $C_{10}A$)			500 h at 2 x I_{10} (0.2 $C_{10}A$) 300 h at 3 x I_{10} (0.3 $C_{10}A$)
	RSX	* following prior discharge or depending on voltage 10 x I_{10} ($C_{10}A$) or 20 x I_{10} (2 $C_{10}A$)			500 h at 3 x I_{10} (0.3 $C_{10}A$) 300 h at 10 x I_{10} ($C_{10}A$)
Prismatic cells	SD	14 h at I_{10} (0.1 $C_{10}A$) 9.5 h at 1.5 x I_{10} (0.15 $C_{10}A$) 7 h at 2 x I_{10} (0.2 $C_{10}A$) 4.5 h at 3 x I_{10} (0.3 $C_{10}A$)			100 h at 3 x I_{10} (0.3 $C_{10}A$)

* RST-cells can be quick-charged with charge current 5–10 x I_{10} (0.5–1 $C_{10}A$) depending on voltage.

Voltage Curve during Charging

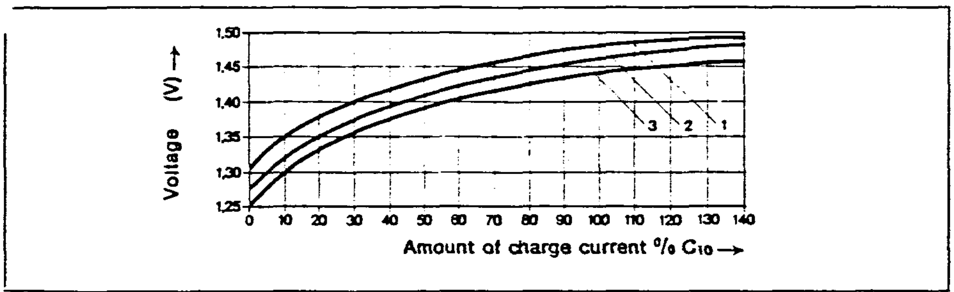
Voltage curve during charging
For certain applications it is necessary to know the voltage curve of Ni-Cad batteries during charging. The curves show the voltage which is dependent on the rate of charge current.



Button Cells DK

1 ≙ I_{10} (0.1 C_{10}A)
2 ≙ $^1/_2$ I_{10} (0.05 C_{10}A)
3 ≙ $^1/_3$ I_{10} (0.033 C_{10}A)
4 ≙ $^1/_{10}$ I_{10} (0.01 C_{10}A)

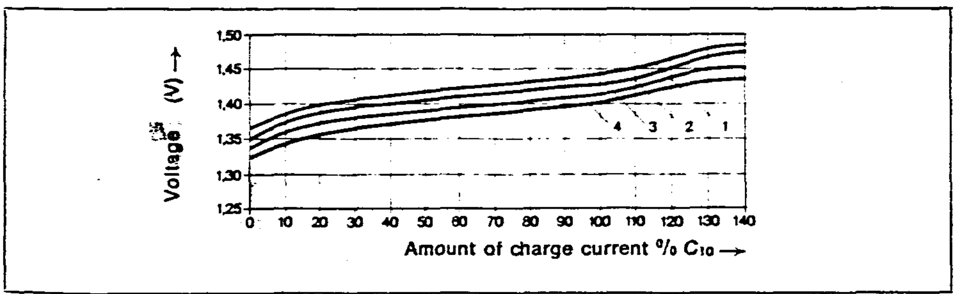
Fig. 21:
The charge voltage of cells series **DK** with different charge currents as percentage of charged capacity (at +20 °C)



Button Cells DKZ

1 ≙ I_{10} (0.1 C_{10}A)
2 ≙ $^1/_2$ I_{10} (0.05 C_{10}A)
3 ≙ $^1/_{10}$ I_{10} (0.01 C_{10}A)

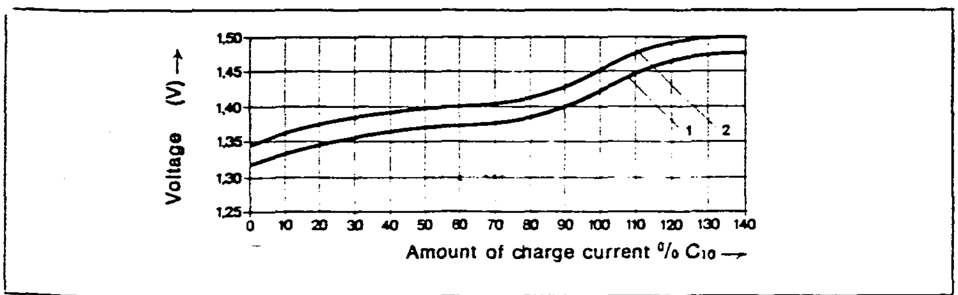
Fig. 22:
The charge voltage of cells series **DKZ** with different charge currents as percentage of charged capacity (at +20 °C)



Cylindrical Cells RS, RSH, RSX

1 ≙ I_{10} (0.1 C_{10}A)
2 ≙ $^1/_2$ I_{10} (0.05 C_{10}A)
3 ≙ $^1/_3$ I_{10} (0.033 C_{10}A)
4 ≙ $^1/_5$ I_{10} (0.02 C_{10}A)

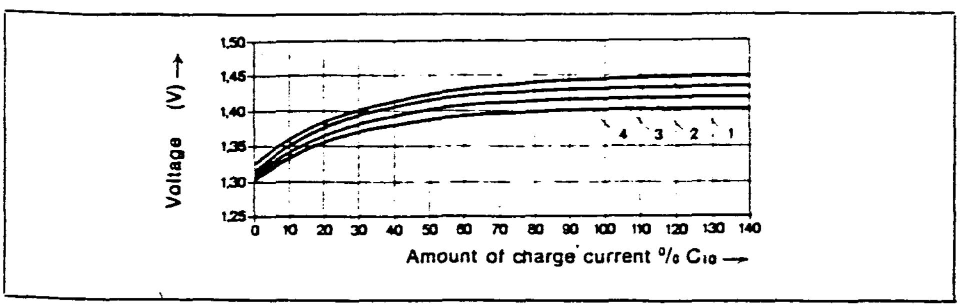
Fig. 23:
The charge voltage of cells series **RS, RSH, and RSX** with different charge currents as percentage of charged capacity (at +20 °C)



Cylindrical Cells RST

1 ≙ I_{10} (0.1 C_{10}A)
2 ≙ 2 x I_{10} (0.2 C_{10}A)

Fig. 24:
The charge voltage of cells series **RST** with different charge currents as percentage of charged capacity (at +20 °C)



Prismatic Cells SD

1 ≙ I_{10} (0.1 C_{10}A)
2 ≙ $^1/_2$ I_{10} (0.05 C_{10}A)
3 ≙ $^1/_3$ I_{10} (0.033 C_{10}A)
4 ≙ $^1/_5$ I_{10} (0.02 C_{10}A)

Fig. 25:
The charge voltage of cells series **SD** with different charge currents as percentage of charged capacity (at +20 °C)

Temperature Conditions

Standby Operation

With the exception of the smallest cell (10 DK), all Ni-Cad batteries are suitable for standby duty, that is they can be trickle charged.

Button Cells

Because of the low self-discharge of mass cells, the trickle charge current can be kept very low. Different currents may be used depending on the application. For example, a current of $^1/_{100}$ I_{10} (0.001 $C_{10}A$) is sufficient for e standby operation in case of mains failure. A current up to $^1/_{10}$ I_{10} (0.01 $C_{10}A$) assumes that energy is constantly, regularly or irregularly, withdrawn from the battery.

Cylindrical Cells

In order to compensate for continuous energy loss through self-discharge, or for example to recharge a battery which has been discharged due to mains failure, we recommende a trickle charge current of ⅓ to ½ I_{10} (0.033 to 0.05 $C_{10}A$). Maximum permissible trickle charge current is I_{10} (0.1 $C_{10}A$).

Prismatic Cells

A trickle charge current of $^1/_5$ to $^1/_3$ I_{10} (0.02 to 0.033 $C_{10}A$) is recommended for prismatic cells. The maximum permissible current for SD cells is ½ I_{10} (0.05 $C_{10}A$). The limit for the 5 M series is $^1/_5$ I_{10} (0.02 $C_{10}A$).

C. Temperature Conditions

The charging, discharging, and storage of Ni-Cad cells is possible at set temperature ranges. The ambient temperature has a marked influence on capacity, voltage stability and service life of cells.

In order to avoid damage to the cells and batteries, please keep to the temperature ranges given in the table below:

Temperature Table

Series	Charge		Discharge		Store	
	recommended	permissible	recommended	permissible	recommended	permissible
DK	10 to 35 °C	0 to 45 °C	0 to 45 °C	−20 to 50 °C	0 to 45 °C	−40 to 50 °C
			Note: 1. For temperatures under 0 °C, max. discharge current ≦ 5 x I_{10} (0.5 $C_{10}A$) 2. Max. of 24 h up to 60 °C poss.		Note: Max. of 24 h up to 60 °C possible	
DKZ	10 to 35 °C	0 to 45 °C	0 to 45 °C	−20 to 50 °C	0 to 45 °C	−40 to 50 °C
			Note: 1. For temperatures under 0 °C, max. discharge current ≦ 10 x I_{10} ($C_{10}A$) 2. Max. of 24 h up to 60 °C poss.		Note: Max. of 24 h up to 60 °C possible	
RS RSH RSX	10 to 35 °C	−20 to 50 °C	−20 to 45 °C	−45 to 50 °C	0 to 45 °C	−45 to 50 °C
	Note: at temperatures below 0 °C limit charge current to a max. ½ I_{10} (0.05 $C_{10}A$) and charge voltage to 1.55 V/cell		Note: Max. of 24 h up to 60 °C possible			
RST	10 to 35 °C	−20 to 65 °C	−20 to 45 °C	−40 to 65 °C	0 to 45 °C	−45 to 65 °C
	Note: at temperatures below 0 °C limit charge current to a max. ½ I_{10} (0.05 $C_{10}A$) and charge voltage to 1.55 V/cell		Note: Max. of 24 h up to 75 °C possible			
SD and 5 M	10 to 35 °C	−20 to 50 °C	−20 to 50 °C	−30 to 50 °C	0 to 45 °C	−30 to 50 °C
	Note: at temperatures below 0 °C limit charge current to a max. ½ I_{10} (0.05 $C_{10}A$) and charge voltage to 1.55 V/cell		Note: max. of 24 h up to 60 °C possible. At temperatures lower than −20 °C, the efficiency of SD cells and 5 M batteries is reduced so that their use is limited to a few specialized applications.			

Self-Discharge

D. Self-Discharge

The self-discharge of sealed Ni-Cad batteries is strongly influenced by the ambient temperature. The rate of self-discharge is lowest at temperatures under 0 °C, whereas high temperatures and humidity further self-discharge of batteries.

As shown in fig. 26, 27 and 28, prismatic and cylindrical cells with sintered electrodes (types RS, RSH, RSX and 5 M) have different self-discharge characteristics as RST cells and button cells with mass electrodes.

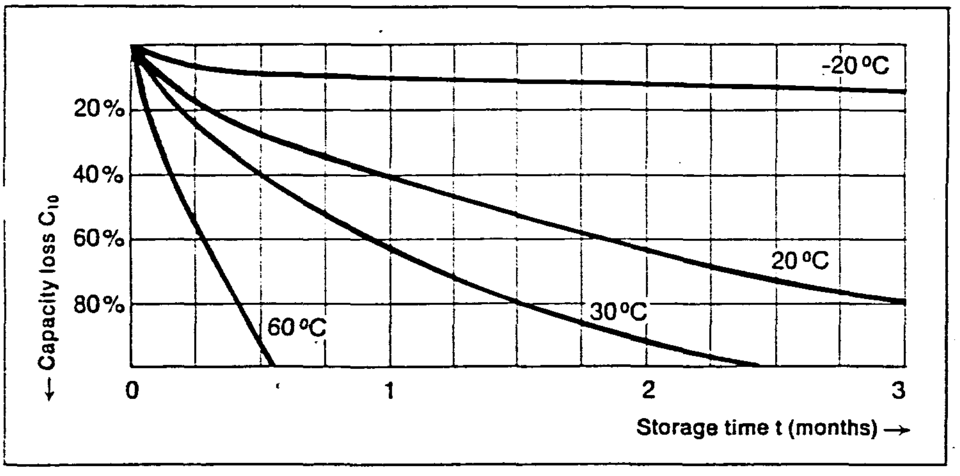


Fig. 26:
Self-discharge curves at different temperatures for cells and batteries series **RS, RSH, RSX, SD** and **5 M**

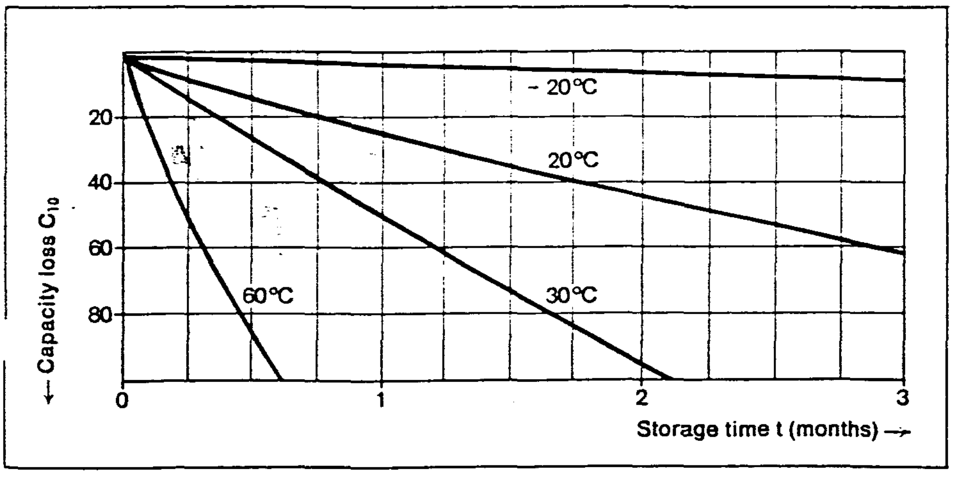


Fig. 27:
Self-discharge curves at different temperatures for cells series **RST**

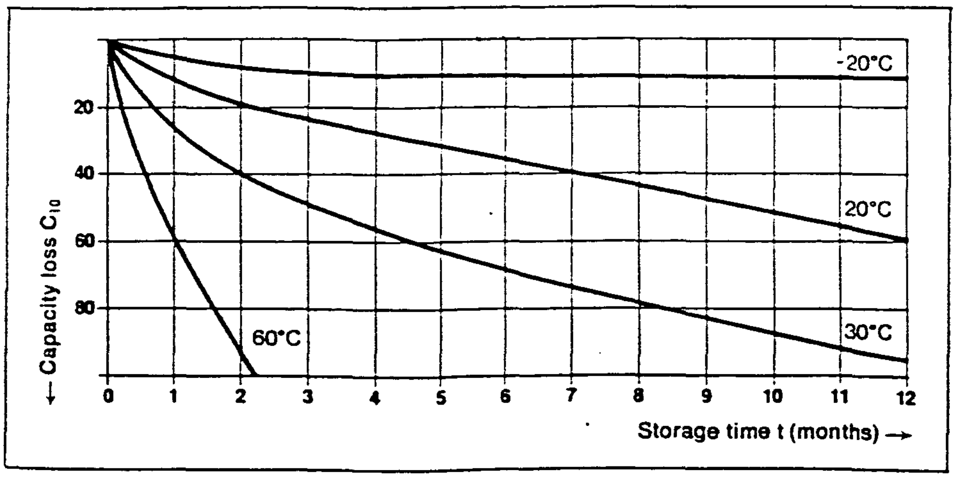


Fig. 28:
Self-discharge curves at different temperatures for cells series **DK** and **DKZ**

Director : C.V. Rutter Pr Eng.

Internal Resistance

Resistance to Extreme Mechanical Stress

4. Internal Resistance

For certain applications it is useful to know the internal resistance values for direct or alternating current. As these values show large variances, the values in the following table (in mΩ) serve as a guideline.
Internal resistance changes only slightly during the entire discharge period with either direct or alternating current. Only towards the end of the discharge period does internal resistance increase significantly. Further details are given in the tables.

Button Cells

Internal resistance with direct current in mΩ											
Type	10 DK	20 DK	60 DK	100 DKO	170 DK	250 DK	280 DK	600 DK	225 DKZ	600 DKZ	1000 DKZ
fully charged	4 800	2 200	1 300	500	375	300	200	190	190	90	50
half discharged	5 000	2 600	1 400	570	450	410	110	210	150	80	47
fully discharged	12 000	4 000	4 000	1 450	1 300	1 000	500	500	300	220	140
Internal resistance with alternating current of a charged cell in mΩ											
50 Hz	1 950	1 030	580	380	240	200	80	65	95	40	23
100 Hz	1 900	940	545	370	230	190	76	60	80	35	19
1 000 Hz	1 750	740	450	310	190	150	60	50	50	28	14
10 000 Hz	1 650	610	350	240	150	120	48	40	38	21	14

Cylindrical Cells

Internal resistance with direct current in mΩ														
Type	100 RS 100 RST	150 RS	180 RS	225 RS 225 RST	452 RS	500 RS 500 RST	501 RS	RS 1	RS 2	RSX 1	750 RSH	RSH 1.2 RST 1.2	RSH 1.8 RST 1.8	RSH 4 RST 4	RSH 7 RST 7
	140	105	80	82	50	35	35	26	17	17	20	15	12	6.50	5.0
Internal resistance with direct current at a frequency of 1000 Hz in mΩ															
	60	30	25	24	11	14	14	15	9	12	10	10	8	3.75	3.4

Prismatic Cells

Internal resistance with direct current in mΩ				
Type	SD 2.4	SD 4.5	SD 10	SD 15
fully charged	16	13	8	2.5
half discharged	19	15	9.5	3
fully discharged	37	30	15	5
Internal resistance with alternating current of a charged cell in mΩ				
50 Hz	18	25	10	3
100 Hz	15	25	9	3
1 000 Hz	16	25	10	3.5
10 000 Hz	22	30	15	12

The values for internal resistance with direct current vary considerably and should be regarded as a guideline. It can be determined by the following method:
Set the load of battery at $2 \times I_{10}$ ($0.2\,C_{10}A$) ≙ (I_1) and measure the voltage ≙ (V_1). Set the load of battery at $42 \times I_{10}$ ($4.2\,C_{10}A$) ≙ (I_2)*. After 4 to 5 sec. measure the voltage again ≙ (V_2). Then internal resistance (Ri) is calculated as:

$$Ri = \frac{V_1 - V_2}{I_2 - I_1} = \frac{\Delta V}{\Delta I}$$

* For button cells, only half load ($I_1 = I_{10}$, $I_2 = 21 \times I_{10}$).

5. Resistance to Extreme Mechanical Stress

The resistance of Ni-Cad batteries to extreme mechanical stress is very high. Tests have shown that there was no damage up to the following defined stress levels:

	a) Ability to withstand sinusoidal vibration. Sweep rate 2 octaves/min	b) Ability to withstand random vibration. Test duration 4 min/axis	c) For all battery series: Shock test acc. to MIL-STD-810 c, method 516.2
Button cells	5 to 200 Hz – 40 g 200 to 2000 Hz – 15 g	5 to 5000 Hz – 0.40 g^2/Hz corresponding to 24.5 $g_{eff.}$	Procedure III (Crash Safety Test) b_p = 75 g t_p = 11 ms
Cylindrical cells	5 to 200 Hz – 30 g 200 to 2000 Hz – 7 g	5 to 2000 Hz – 0.28 g^2/Hz corresponding to 20 $g_{eff.}$	Procedure IV (High Intensity Test)
Prismatic cells	5 to 200 Hz – 35 g 200 to 2000 Hz – 10 g	5 to 2000 Hz – 0.28 g^2/Hz corresponding to 20 $g_{eff.}$	b_p = 100 g t_p = 6 ms

6. Service Life

External mechanical influences have little effect on the service life of Ni-Cad cells when properly operated. As the shelf-life of these cells is very good, also their age has no significant effect. However, the electrical operating conditions and the charging method do have an impact on service life.

For **charge/discharge operation** at nominal voltage and at normal temperature **800** to **1000** cycles can be obtained for series **RS, RSH, RSX, RST** J **SD; 300** to **400** cycles for series **DK** and **5 M;** and **400** to **500** cycles for series **DKZ**. A cycle refers to one complete charge and discharge of capacity in a battery. The service life of the battery is considered at its end when the battery delivers less than 80 % of nominal capacity discharging at nominal voltage. VARTA's Ni-Cad batteries exceed by far the IEC 285 norm for service life of 392 part cycles. Service life is lengthened when the battery is only partially discharged. For example, if a battery is only discharged by 50 %, more than double the number of charge/discharge cycles may be obtained.

Using trickle charge operation, cylindrical cells have a service life of **four** to **six years** as long as the charge rent is limited to $\frac{1}{2}$ I_{10} (0.05 $C_{10}A$).

Prismatic cells and 5 M batteries also have a service life of **four to six years,** if the trickle charge current is limited to $^1/_3$ or $^1/_5$ I_{10} (0.033 or 0.02 $C_{10}A$).

Similarly the service life of button cells is **four to six years,** if the trickle charge current is limited to $^1/_{10}$ I_{10} (0.01 $C_{10}A$).

The service life is considered at its end when the battery delivers only 60 % of its nominal capacity discharging at nominal voltage.

7. Handling and Storage

Sealed Ni-Cad batteries can be operated in any position. However in stationary use, cells with safety vents (cylindrical and prismatic cells with sintered electrodes) should not be mounted upside down. Button cells can be mounted in any position.

Ni-Cad cells are maintenance-free. As any other electrical device, they should be kept dry and clean during operation.

Occasionally crystals may form around the sealing zone of the cell (during operation or storage). This is caused by very active ions of the electrolyte moving through the minute pores of the sealing zone. Even tiny specks of the electrolyte reacting with the carbon dioxide of the air make for visible potassium carbonate crystals. This crystallization has no effect either on the service life or the electrical performance of the cell.

After manufacturing the cells are in a charged state. Through construction into battery units, storage or transport, a longer period of time can elapse between charging at manufacture and customer use. Thus, due to self-discharge influenced by time and possible temperature variations, the charge state becomes undefinable. Therefore always charge batteries before use.

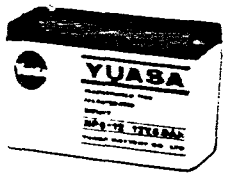
The best way to ensure long service life and smooth operation is to follow charging instructions carefully. Ni-Cad batteries can be stored for years regardless of the charge state they are in. They will suffer no damage if stored at the ideal temperature range of 0 to 35 °C and approx. 50 % relative humidity. The cells should be kept away from dirt and moisture.

Before use and following prolonged storage, cells should be charged for 24 h at I_{10} (nominal charge current), or for a longer period at a lower current. The cells are then activated and will achieve their full capacity after two to three normal charge/discharge cycles.

Direct soldering on the cells may cause damage. Prismatic cells can be linked by electrical connection of the terminal pillars. Cylindrical and button cells can be fitted with different types of connectors, e.g. circular solder tags, strip solder tags, pin solder tags for printed circuit boards.

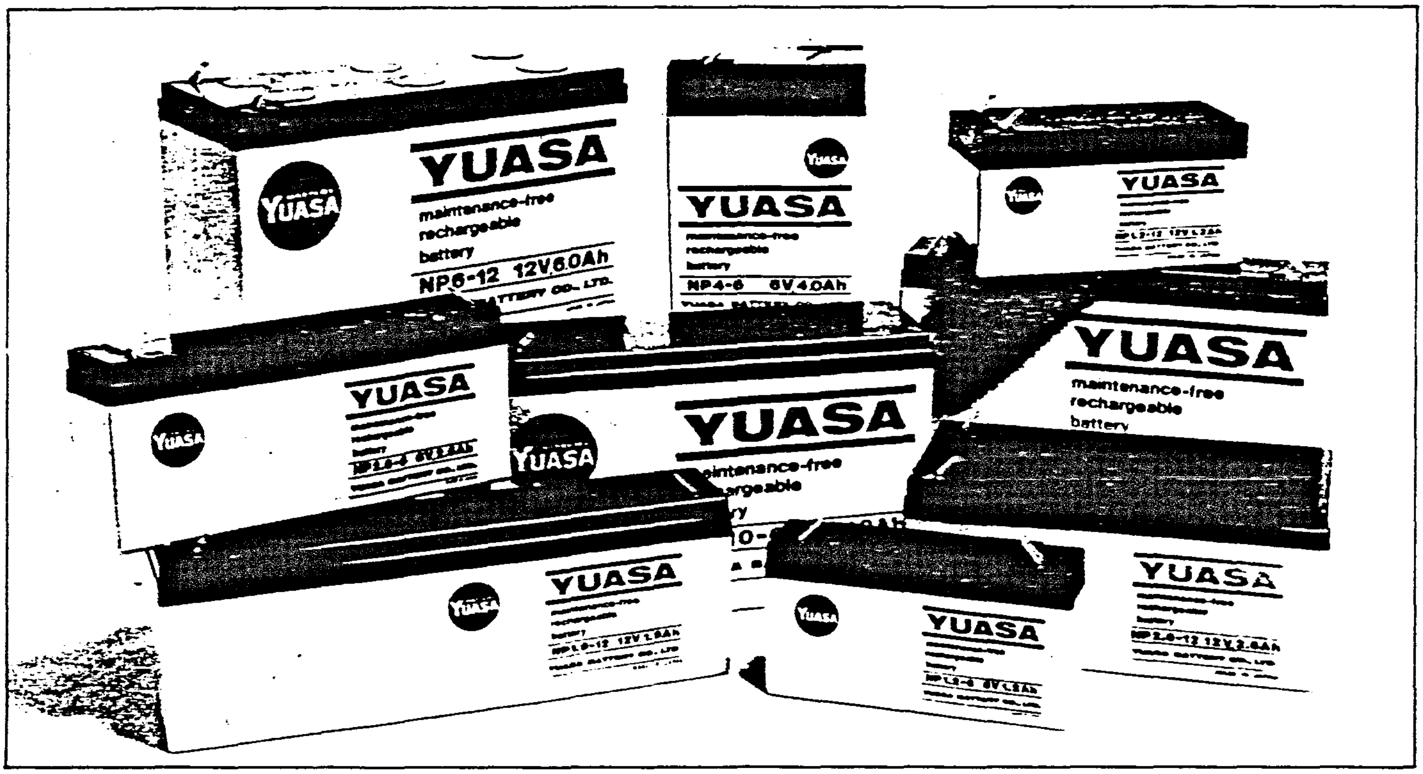
In order to mount button cells or button cell batteries onto printed circuit board, they can be flow soldered in a charged state not exceeding a maximum of 10 sec. Cylindrical cells however, should be discharged before this process because of possible strong short-circuit currents.

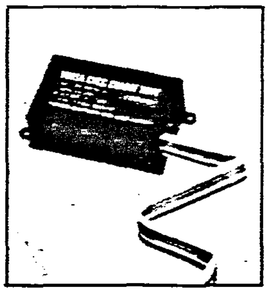
Director : C.V. Rutter Pr Eng.

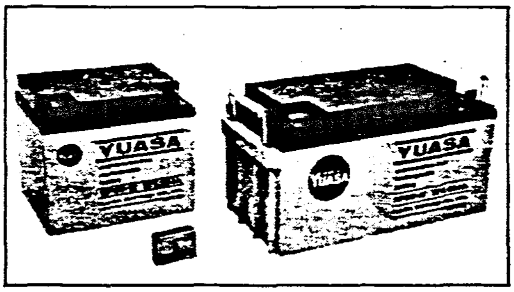


APPLICATION MANUAL

YUASA NP sealed maintenance-free rechargeable batteries







TECHNICAL FEATURES

1. **Totally Sealed**	- no leakage, spillage or gassing - no maintenance or topping up
2. **Liquid Electrolyte**	- immobilized liquid, no gel, for greater performance - no inhibiting jellies or contaminants - do not dry out or open circuit - limited electrolyte, not "flooded"
3. **Standby or Cyclic Service**	- one type only for either duty - wider application
4. **No Memory Effect**	- delivers full capacity when required - requires no special conditioning
5. **Heavy Duty Grids**	- "Third generation" construction utilising advanced calcium alloying techniques - reduced gassing and internal electrolytic corrosion - long life, extra margin of performance
6. **Separators**	- thick fibrous absorbent fibreglass mats wrapped around plates - efficient insulation between plates, with high ionic permeability - positive retention of active material - reduced self-discharge rate - capillary action prevents stratification
7. **No Gassing**	- sealed construction, unique control of gas generation and recombination - new safety venting system prevents damage in abnormal circumstances
8. **Cases**	- high impact ABS resin does not crack or leak
9. **Useable in any position**	
10. **High Power Density**	- One type for standby or cyclic applications
11. **Deep Cycling**	- Superior recoverability after prolonged deep discharge - Over 1 200 cycle life
12. **Float Charge**	- No "boost" rate required in standby applications

DEFINITIONS

"C" or "CA" is the rated capacity of the battery expressed in Amps. For example for type NP65–12. "C" or "CA" is 65 Amps. Therefore C/10 or 0.1CA is 6.5 amps. etc. "V.P.C." means volts per cell.

CHARGING METHODS

The worst battery "Killer" is an inferior charger or incorrect charging methods. Simple garage type trickle chargers comprise a transformer and a couple of diodes, and usually an inaccurate ammeter. Applied charging voltage will vary widely and final charge current will be relatively high. Therefore, charge should be terminated before the battery warms up and before the high ripple current can do any harm.

Batteries are fully charged from a completely discharged state normally in 12 to 20 hours.

Yuasa batteries are capable of accepting very high starting. or initial charge currents (2CA) but normally these would be limited to 0.25CA.

CONSTANT VOLTAGE CHARGING

We recommend this method. A well regulated applied voltage, set for the NP battery operating temperature is most suitable either for cyclic or float applications. For longest battery life, the initial charge current should be limited to the maximum given in the specification table. If there is a standing load, on the output side, the rectifier should be rated to handle this current plus the battery recharge current. For intermittent loads, the rectifier can be rated to handle peak current loads, or it may be more economical to allow the battery to provide high current drains intermittently. With this method, a discharged battery will draw maximum current until its EMF rises. The charge current will then begin to taper down to trickle charge. The battery will then only absorb current to compensate for internal losses. Constant voltage current controlled chargers are known as C.V.C. chargers.

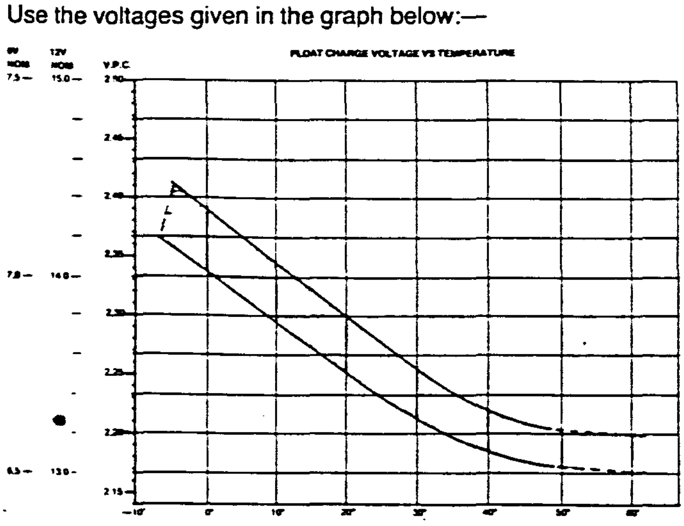
CYCLIC SERVICE CHARGING

Using the constant voltages in the table below, when the cell voltages reach not more than 2,50V per cell (V.P.C.) reduce the applied voltage to the "float" rate voltage, or automatically terminate the charge cycle, by sensing the charge current decrease at end of charge.

Battery Temperature vs Charging Voltage	
Temperature °C	Cyclic Service Charging Voltage (VPC)
5	2.48 to 2.54
15	2.47 to 2.52
25	2.40 to 2.50
35	2.36 to 2.46
45	2.32 to 2.42

FLOAT OR STANDBY SERVICE CHARGING

Use the voltages given in the graph below:—



CONSTANT CURRENT CHARGING

This method is suitable to restore a known ampere-hour charge into a previously discharged battery or when the recharge time is critical. It is necessary to monitor the charge termination point either manually or timed automatically, in order to prevent battery over-charge. Over-charging is the biggest danger with this method, which is therefore not recommended. Not more than 10% overcharge in AH should apply for maximum service life. Completely discharged batteries should not be fully charged in less than 10 hours. For recovering over-discharged batteries, or batteries which have been left standing in a discharged state, the C.C. method at the 72 hr rate should be utilised.

TRICKLE CHARGING

By definition this is the charge required to restore internal losses only (not to recharge batteries) and is 0.5 to 1 milliamps per ampere hour of battery rated capacity or .002C amps to .004C amps and is not a "float" charge.

EQUALIZING CHARGE

It is important that batteries for connection in series-parallel configurations should be equalized to within 0.3V per 12V battery.

An equalizing charge should be applied to any 12V battery with open circuit voltage of less than 12.6V. Charge at 14.4 to 14.7V for 10 to 20 hours and retest. Any battery reading 12.3V or less open circuit should be cycled and equalized before attempting to include it in a group.

Batteries stored for prolonged periods will also require an equalizing, or "topping-up" charge. An alternate method of equalizing charging, is to charge at 0.1CA for between 4 & 10 hours, as required.

TWO RATE CHARGING

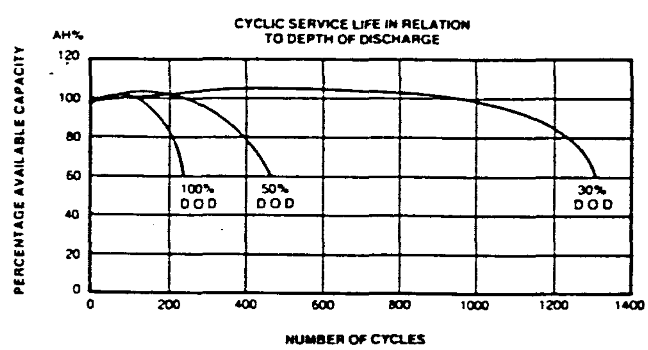
In the first part of the recharge period while the battery is in a low state of charge, the charging rate starts at a high current. When the cells approach a state of full charge, the current is switched back to a low finishing rate, or preferably to the regulated float charge voltage. The switch-down point should be sensed when the state of charge approaches 80% i.e., usually when the voltage reaches 2.45V.P.C. (at 20°C). Voltage sensing is preferable to the use of a timer, in view of the danger of high rate overcharge.

	Starting	Finishing
Charge current:	0,25CA to 1,0CA	0,04CA to 0,08CA
Charge voltage:	2,40VPC to 2,55VPC	2,25VPC to 2,30VPC

For a fully charged battery at the correct float charge voltage, the charge current should be between 0,002CA and 0,004CA.

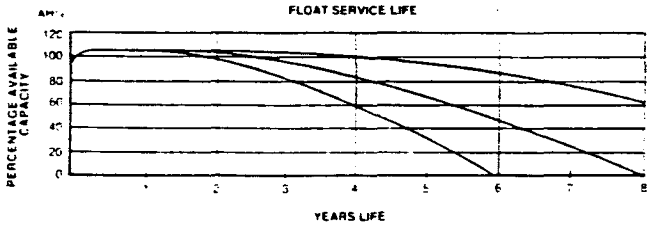
CYCLIC SERVICE LIFE

Several factors affect cyclic life, including depth of discharge, to which life is inversely proportioned, as shown in the graph below. Selection of battery capacity to minimise depth of discharge (D.O.D.) is therefore advantageous. A new battery gives maximum capacity during its initial 50 cycles.



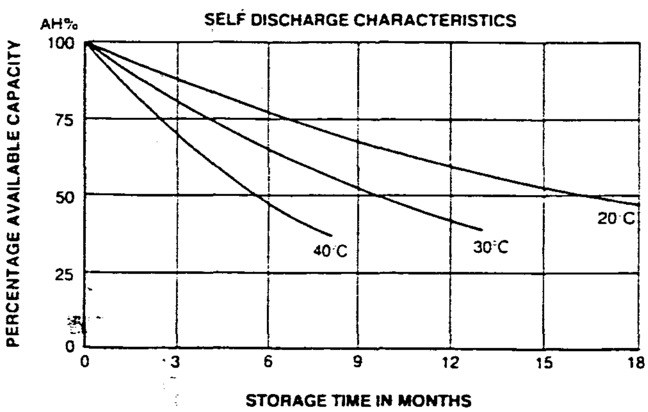
FLOAT SERVICE LIFE

This is affected by temperature, number of discharge cycles, depth of discharge and especially the float voltage. Longest life is achieved between 20°C and 25°C.
Yuasa NP batteries can have a float service life of 8 years as shown on the graph below, showing good, average and poor conditions.



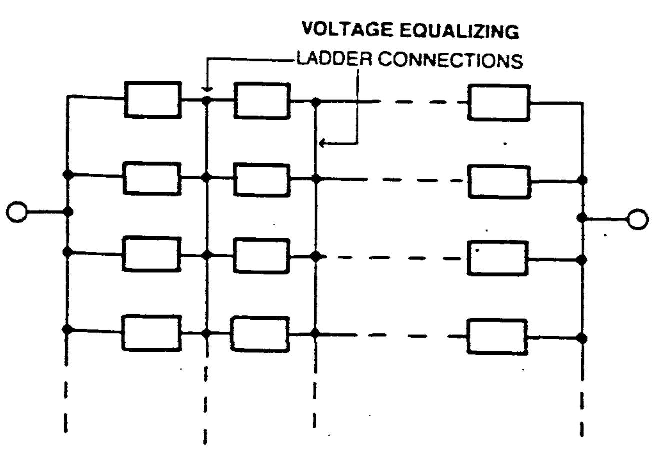
SELF DISCHARGE CHARACTERISTICS

Any rechargeable battery loses charge through internal losses. The ideal storage temperature if 0°C, when all ionic action is retarded. However, the "shelf" life of NP batteries is exceptionally good, but it is recommended they be charged every 6 months.



SERIES/PARALLEL CONNECTION

Any number of NP batteries can be connected in parallel without any deleterious affect on discharge current or discharge wattage. For strings of 2 or more batteries in parallel, voltage-equalizing ladder connections should be made at 48V steps. Equal lengths of uniform cable of sufficient gauge, preferably fused, must be used between the strings to equalise the load sharing. The danger of short circuits should be avoided, and air circulation permitted around each battery. Batteries should be equalized before series-parallel connections are made.

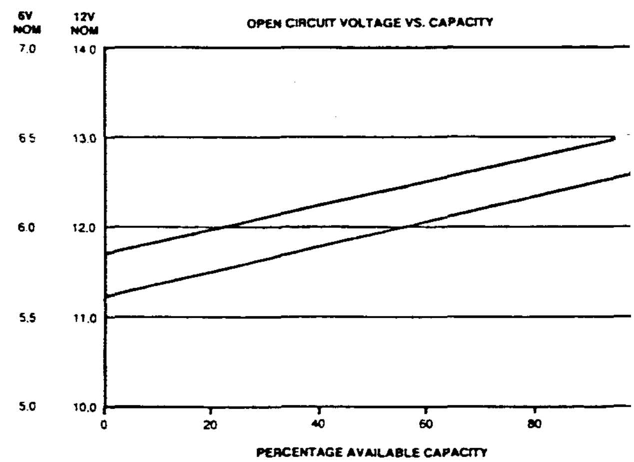


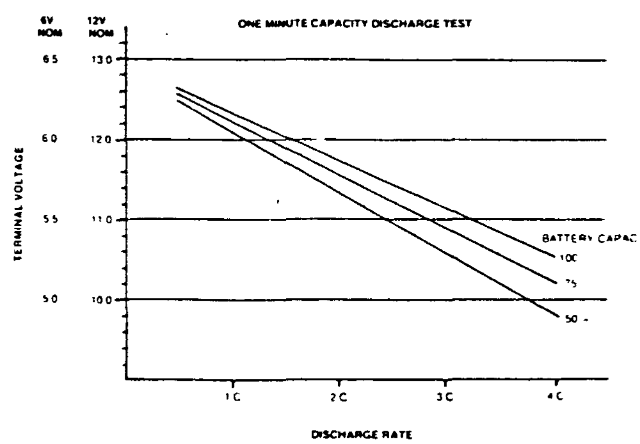
STORAGE OF NP BATTERIES

Yuasa NP batteries have good charge retention charact ristiscs — better than other types of lead-acid batteries a far superior to nickel-cadmium cells. The lower the stora temperature the less the self-discharge of any battery. T ideal storage temperature is 0°C when no internal reacti (hence capacity leakage) takes place. Therefore the batte should be stored in as cool a store as is available, aw from direct sunlight. NP batteries are fully charged wh delivered, however they should be recharged every months to maintain "as new" condition. Batteries must NC be stored in a discharged state.

BATTERY CAPACITY MEASUREMENT

The open circuit voltage of a battery will give some indic tion of its state of charge. The only true test of rate capacity is the 20 Hr discharge rate. As this is impractica shorter periods at higher rates of discharge can be use The graph below is for a one minute test at 1C, 2C, 3C 4C constant discharge rates. After exactly one minute one of these discharge rates, read the load voltage of th battery. From the graph the approximate capacity of th battery can be read off.





DESIGN TIPS FOR MAXIMUM SERVICE

1. Do not store batteries in a discharged state. If they ar delivered in equipment, disconnect them to avoid th possibility of discharging before installation of that equip ment.
2. Operate and recharge the batteries at lowest possibl temperatures.
3. Do not overdischarge batteries (i.e., below minimun voltage in the discharge graph) — this provides no extr power. Low voltage protection devices are a goo investment.
4. Avoid short-circuiting of battery terminals.
5. Beware reverse polarity connections.
6. Recharge batteries as soon as possible after a dis charge cycle.

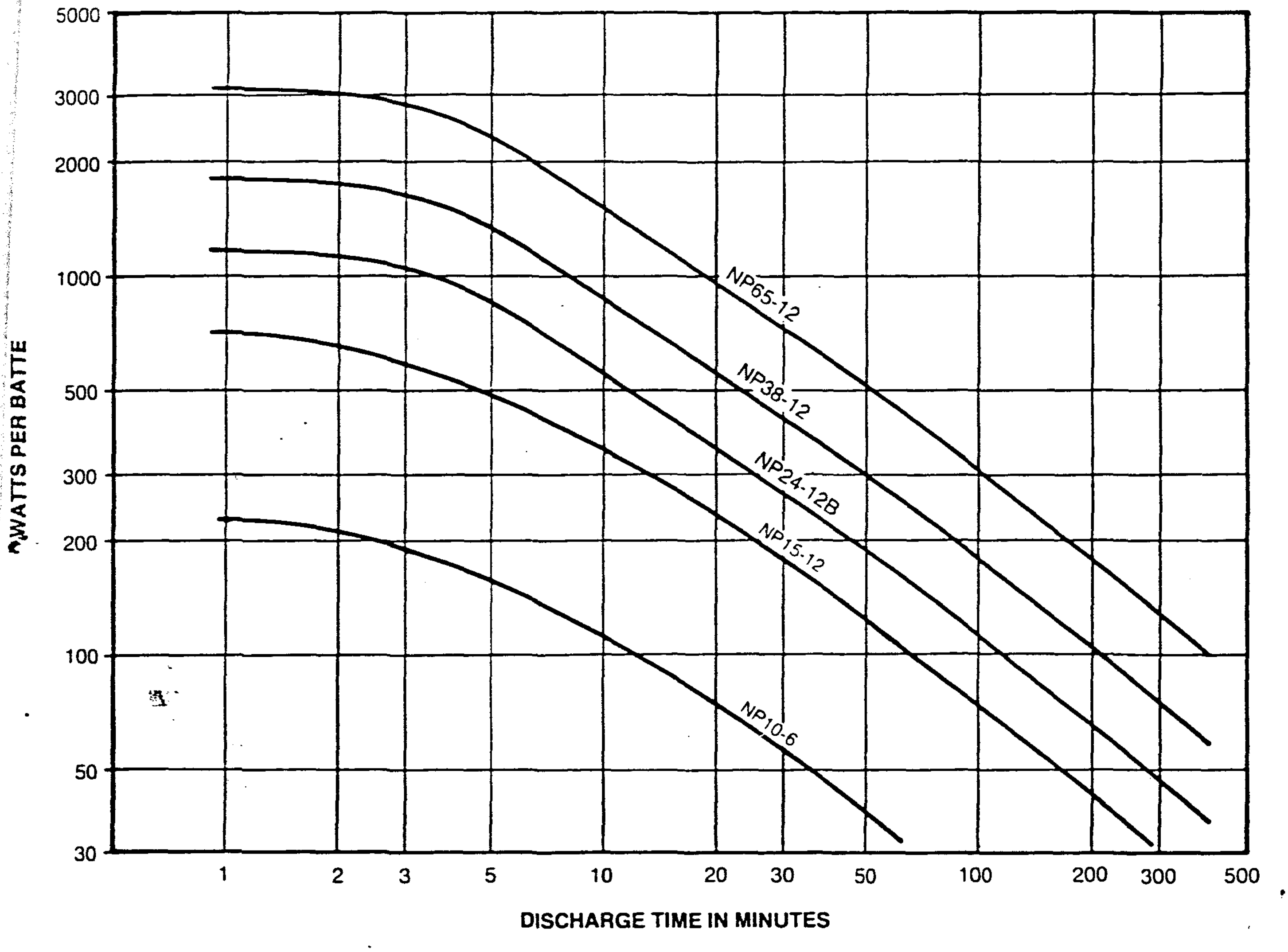
CONSTANT WATTAGE DISCHARGE

The three curves below show the constant wattage at which **one** of the batteries shown can be discharged, for the periods indicated. The wattage from a battery system will be in **multiples** of this figure, firstly for the number of batteries in series, and then for the number of batteries in parallel. This will derive the total discharge wattage for a battery system e.g. two pairs in parallel will deliver **four** times the power of one battery.

Detailed selection charts for various system nominal voltages are available.

CONSTANT LOAD DISCHARGE CURVES

(At 25°C to 1.6V.P.C.)



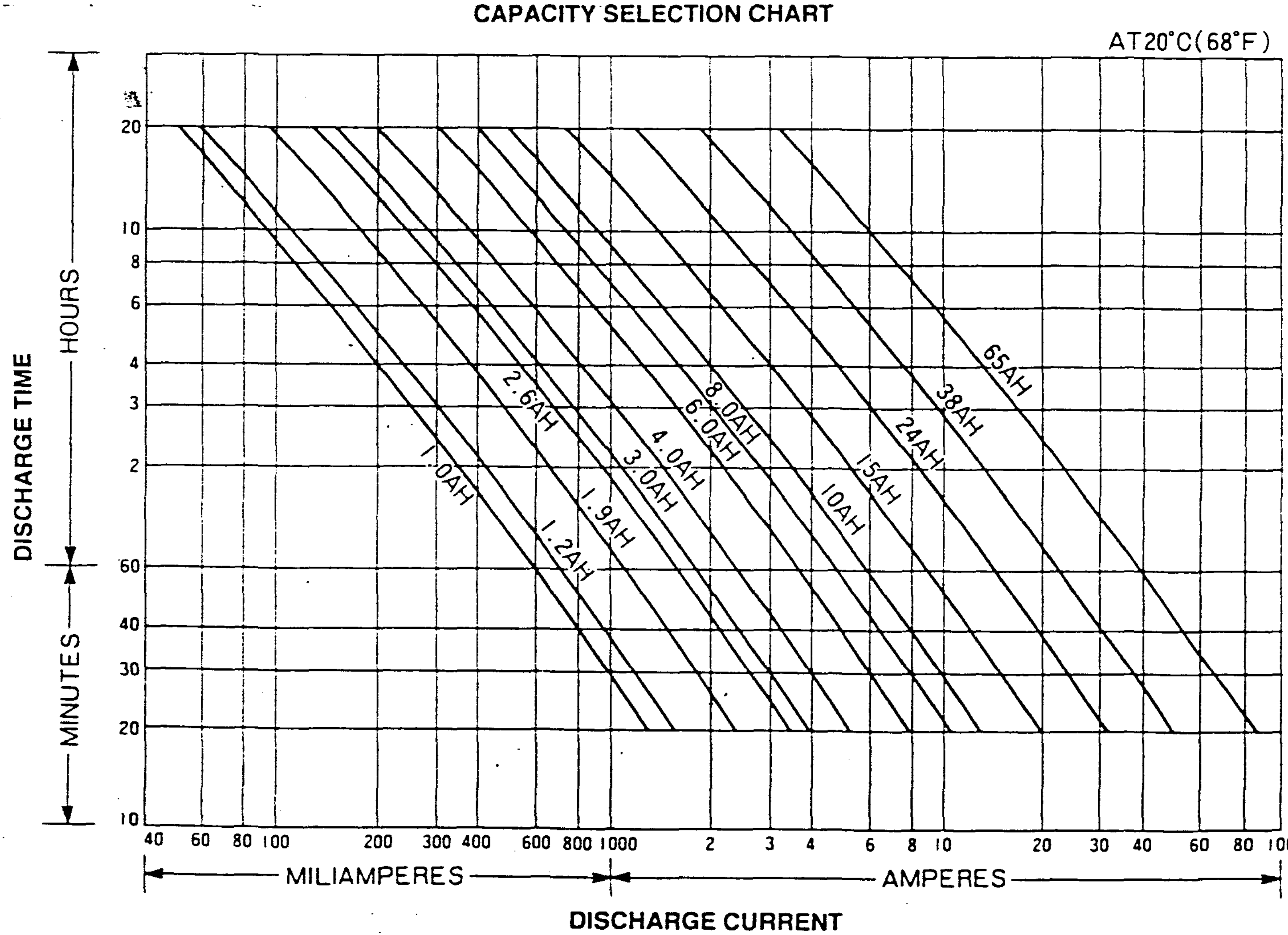
Battery Guarantee

1. Yuasa "NP" series lead acid batteries which are sold are warranted against defects in workmanship or materials for a period of 12 calendar months from date of delivery, providing installation and operation is carried out in accordance with our recommendations.
2. Batteries that have been over-discharged, left in a discharged condition, severely overcharged or abused or misused are not covered under any warranties.
3. Our obligation shall be limited to the refund of the cost, or the replacement F.O.B. our works, at our discretion, of any battery returned prepaid for examination and which is found to be defective or damaged on delivery to the buyer, to our satisfaction.
4. We accept no liability for any injury, loss, damage, incidental, contingent or consequential expenses incurred, directly or indirectly, with respect to any defective battery, or any battery misused.
5. There are no other warranties, whether expressed or implied of merchantability or suitability of application or otherwise except the warranty expressly stated herein.

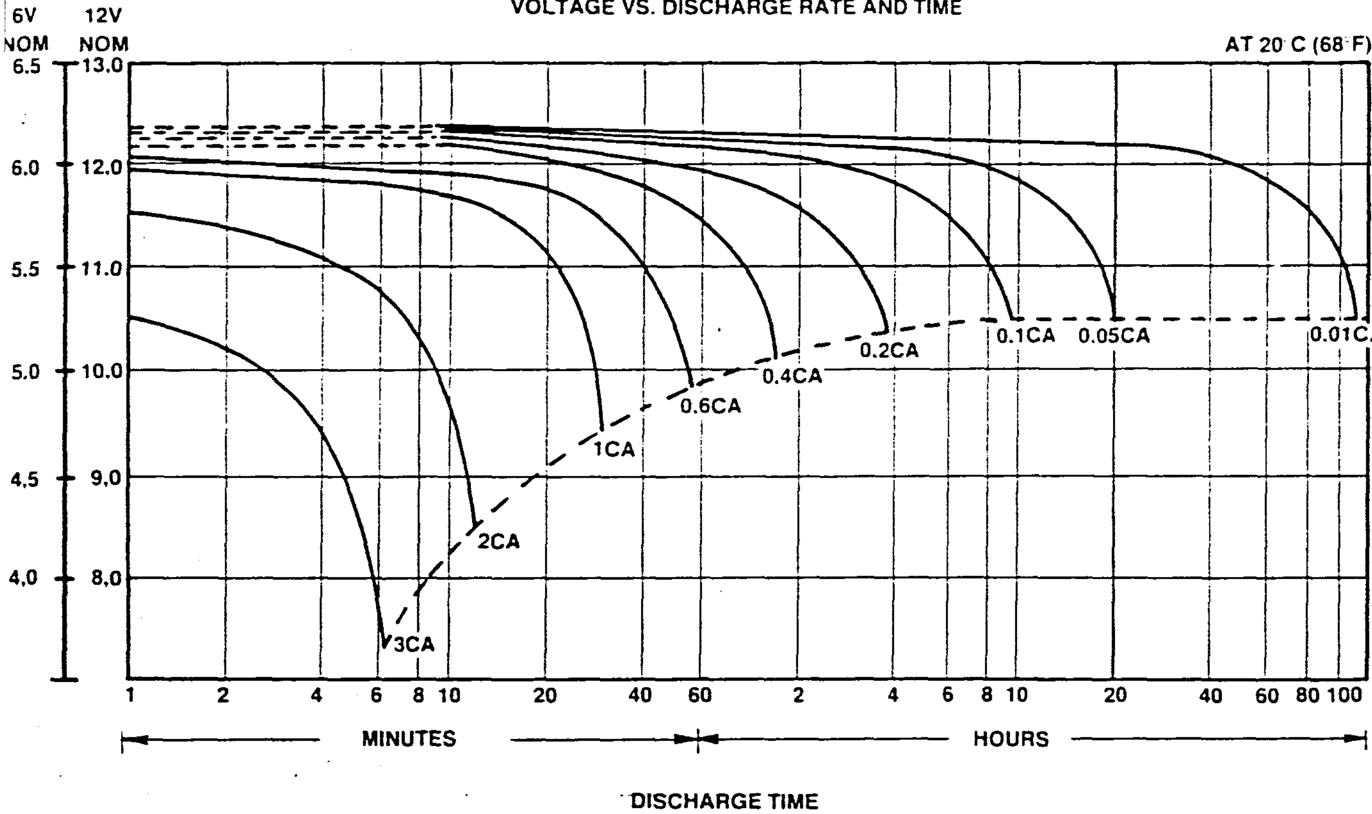
YUASA NP BATTERY SPECIFICATIONS

TYPE	CAPACITY	DIMENSIONS				WEIGHT	MAX DISCHARGE		RECHARGE
	"C" at 20 Hr Rate A.H.	L ± 1mm	W ± 1mm	Container Height ± 1mm	Overall Ht over lugs ± 3mm	Approx. Kg	Standard Amps	Short Duration Amps	Maximum Initial Current Amps
4 VOLT									
NP3-4	3,0	91	34	60	64	0,43	40	100	1,0
6 VOLT									
NP1-6	1,0	51	43	51	58	0,25	40	45	0,2
NP1,2-6	1,2	97	25	51	58	0,34	40	45	0,3
NP2,6-6	2,6	134	34	60	67	0,60	40	100	0,7
NP4-6	4,0	70	47	102	109	0,90	40	120	1,0
NP6-6	6,0	151	34	96	103	1,25	40	180	1,5
NP10-6	10,0	151	50	96	103	2,20	40	300	2,5
12 VOLT									
NP1,2-12	1,2	97	48	51	58	0,59	40	45	0,3
NP1,9-12	1,9	178	34	60	67	0,90	40	75	0,5
NP2,6-12	2,6	134	67	60	67	1,10	40	100	0,7
NP6-12	6,0	151	65	96	103	2,40	40	180	1,5
NP15-12	15,0	181	76	167	167	5,00	100	400	4,0
NP24-12B	24,0	166	175	125	125	7,70	150	500	6,0
NP38-12	38,0	198	166	170	170	13,80	200	500	9,5
NP65-12	65,0	350	166	175	175	22,70	500	800	16,5

CAPACITY SELECTION CHART



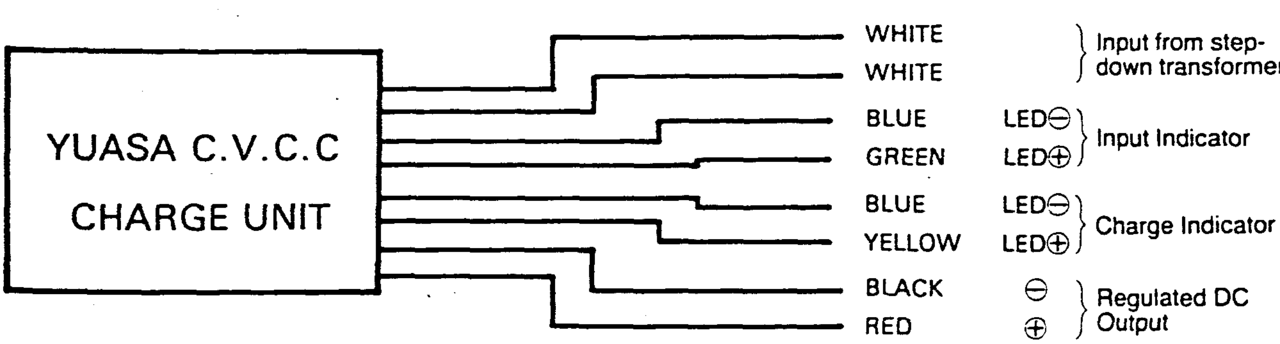
DISCHARGE CURVES
VOLTAGE VS. DISCHARGE RATE AND TIME



/CC CHARGER MODULES

illustrated these require an external 20W step down nsformer. These Yuasa charger modules provide regulated CVC output of 800ma and are reverse polarity and short circuit proof. LED connector leads indicating "mains on" and "charging on" are provided as standard.

MODULE WIRING DIAGRAM



available from:—

SAFTEC SALES
P.O. BOX 72
SALT RIVER, CAPE 7925

PERFORMANCE CHARACTERISTICS

While overcoming certain problems associated with the traditional lead-acid cell, the Gates cell has retained the advantages which have made the traditional lead-acid cell the workhorse of the battery industry.

One advantage is the high voltage (2 volts) of the lead-acid system relative to other battery systems. This means that fewer cells are required to build a battery of the desired voltage.

Another advantage is the low cost and availability of the active materials used in a lead-acid battery.

In addition, the lead-acid system does not have many of the problems associated with other systems such as cell reversal, memory, lack of state-of-charge indication and thermal runaway. The Gates cell may be used in a variety of applications — cyclic, standby, or a combination of both. To assist in the application of the cell, this section describes some of the performance capabilities.

High Discharge Current

The cell can be discharged at very high currents while maintaining reasonable capacity at a usable voltage. This characteristic is achieved because of the large surface area and proximity of the plates to each other resulting from the use of thin, pure lead plates in a spirally wound construction.

Typical maximum current capabilities of the cell are as follows:

2V 2.5Ah D - 130A @ 135W peak power transfer
2V 5.0Ah X - 200A @ 200W peak power transfer
2V 25Ah BC - 600A @ 600W peak power transfer

Low Temperature Characteristics

Exceptional low temperature characteristics are maintained through the use of a separator system which minimizes the resistance and diffusion effects. This results in efficient utilization of active materials and excellent voltage regulation.

Because the cell operates as a "starved" electrolyte system, there is only enough electrolyte to maintain the rated capacity of the cell. With this minimal amount of electrolyte, the cell will not be damaged at temperatures as low as -65° C, even if stored at that temperature in a discharged state.

Capacity available at low temperatures is a function of both the temperature and discharge current. For various discharge rates and temperature curves, refer to Section 5.

Position Flexibility

With the starved electrolyte system, the sulfuric acid is absorbed within the cell plates and the glass mat separator. The cell is virtually dry with no loose electrolyte allowing it to be charged, discharged, or stored in any position without electrolyte leakage.

Sealed Design

One of the most important features of the Gates cell is its sealed operation. This mode of operation is possible because the cell is able to use the oxygen cycle during overcharge.

The oxygen, which is evolved at the positive electrode when the cell is overcharged, is recombined at the negative electrode. Hydrogen evolution is minimized by balancing the materials in the electrodes so the positive electrode will become fully-charged and start evolving oxygen before the negative electrode is completely charged. A self-resealing valve is provided as a safety feature in case of misapplication or abuse of the cell.

It is important to distinguish between a sealed cell, such as the Gates cell, and the so-called "maintenance-free" cell made by several manufacturers. In a "maintenance-free" system, the cell is vented to allow escape of gases formed from the decomposition of the water in the electrolyte during overcharge. Thus, water is lost from the cell when the cell is overcharged. Since no water can be added to the cell, life is dependent on the initial amount of water in the cell.

The sealed Gates cell is truly maintenance-free in that no water need be added to the cell during its operation. The life of the cell is not dependent on the initial concentration of water in the cell as with other so-called maintenance-free systems.

Shock and Vibration Characteristics

The spirally-wound plate element is compressed within the polypropylene liner, minimizing plate movement in high shock or vibration applications. Movement in a vertical direction is also limited by the polypropylene top design. Overall, the cell has excellent shock and vibration characteristics.

Float Life Characteristics

As noted previously, the life expectancy of the Gates cell is not limited by loss of electrolyte, due to the sealed design. Instead, life expectancy is determined by long-term corrosion at the positive plate. The corrosion effect on cell capacity is minimal until the cell approaches end-of-life, which is defined as the cell providing less than 80% of its rated capacity.

Major factors determining float life are temperature and float voltage, as discussed further in Section 9.

Cycle Life Characteristics

The life of the cell in a cyclic application will be a function of the following variables: depth-of-discharge, temperature and charging rate. Cycle life can vary from 200 to greater than 2,000 cycles, dependent upon the depth-of-discharge, as shown on the life curves in Section 9.

Fast Charging Characteristics

Efficient, fast-charging can be accomplished using a constant voltage type charger. With initial charge current capability in the 5C range, the cell can be recharged in less than one hour.

Further specifics on fast-charging are given in Section 7.

Storage Characteristics

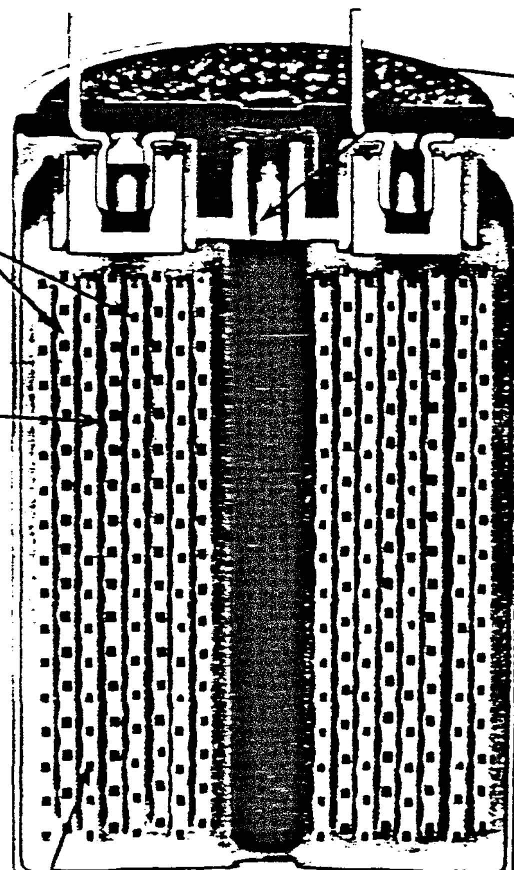
The Gates cell may be stored for three years at room temperature and recharged with no loss in cell reliability or performance capabilities.

Storage time is essentially a function of temperature. A curve showing the time-temperature relationship is in Section 6.

Construction features.

POSITIVE AND NEGATIVE PLATES
spirally-wound to yield high discharge capacity, even at high rates.

HIGHLY RETENTIVE SEPARATOR
that retains essentially all of the electrolyte.



SAFETY VENT
that allows for very abusive overcharge or charger failure without cell rupture.

ENCLOSED IN A RUGGED METAL CAN
No acid or acid vapor is vented from the cell. Gas is recombined directly with the plate materials at up to the C/3 rate of overcharge. The metal can protects the cell from physical damage.

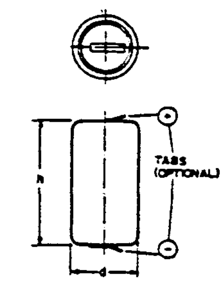
PURE LEAD GRIDS
give excellent corrosion resistance and low internal impedance.

P-34A

TADIRAN HIGH ENERGY LITHIUM CELLS

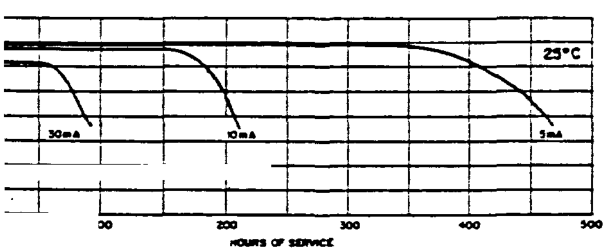
PRELIMINARY

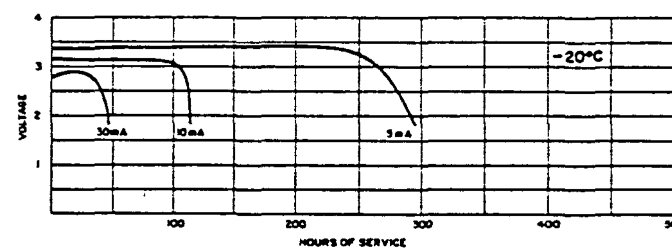
Type	TL-2100	TL-2200	TL-2300
Size	"AA"	"C"	"D"
Nominal Voltage (V)	3.4	3.4	3.4
Rated Capacity (Ah)*	2.0 (@ 5 mA)	6.0 (@ 10 mA)	9.0 (@ 15 mA)
Weight (gr.)	16.5 ± 0.5	47 ± 2	94 ± 3
Volume (cm^3)	7.31	24.12	47.39
Height (mm ± 0.4)	47.5	47.6	58.2
Diameter (mm ± 0.25)	14.0	25.4	32.2



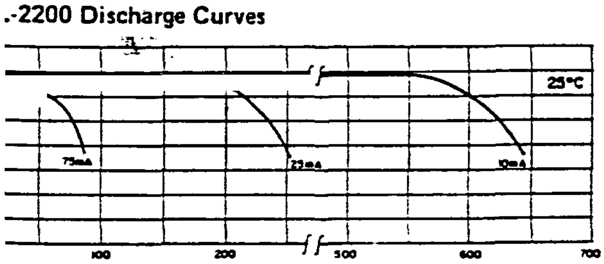
*Obtained to 3.0V cutoff point at 25°C

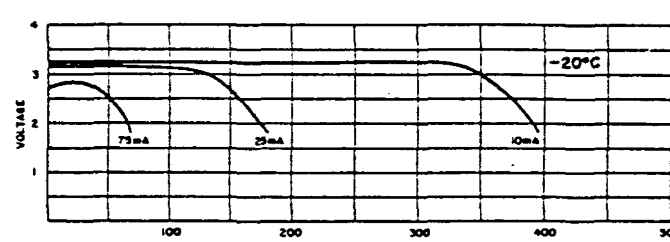
TL-2100 Discharge Curves



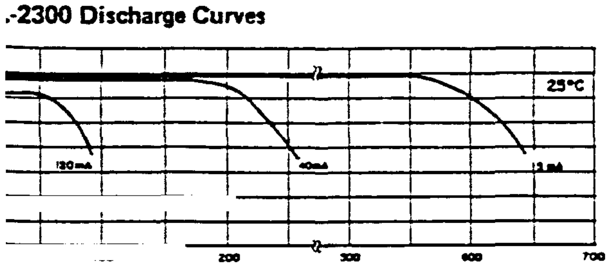


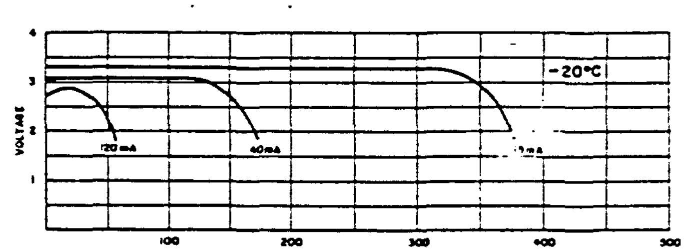
TL-2200 Discharge Curves





TL-2300 Discharge Curves

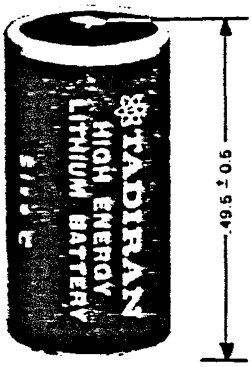




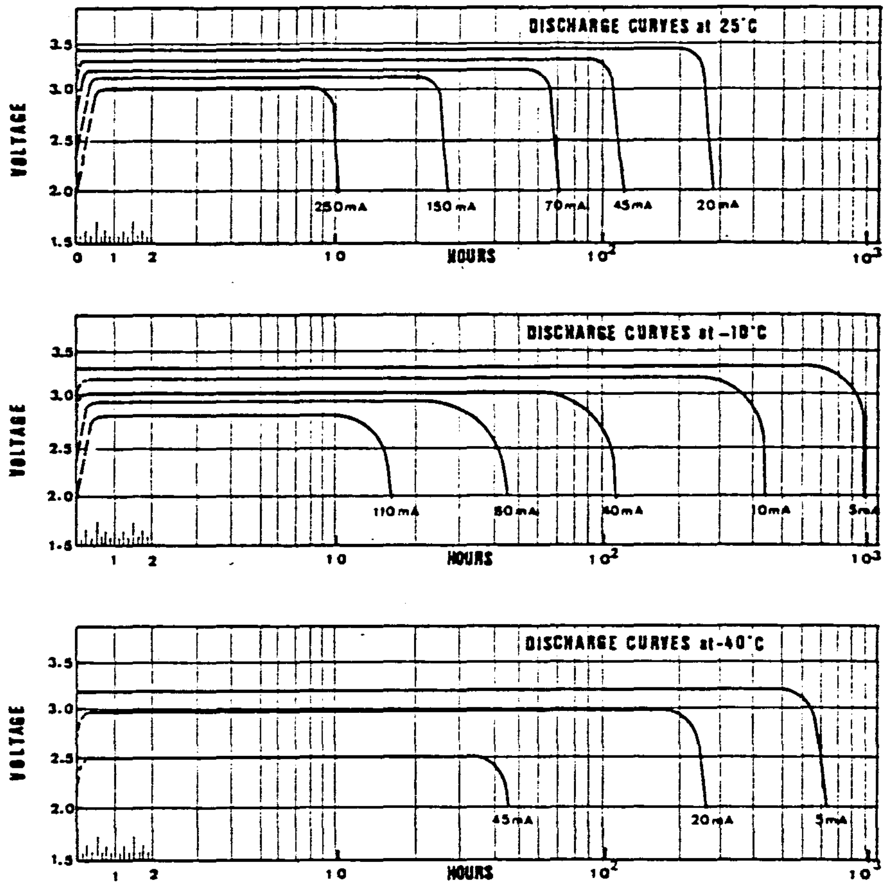
TADIRAN
ISRAEL ELECTRONICS INDUSTRIES LTD
3 HASHALOM ROAD, P.O.B. 648, TEL AVIV 61000, ISRAEL. TELEX: 33537

TL-2200
"C" IEC-R-14

Open Circuit Voltage	3.7 V
Nominal Voltage	3.4 V
Rated Capacity to 2.5 V (45 mA at R.T.)	5 Ah
Weight (max)	52 gr
Volume	26 cc

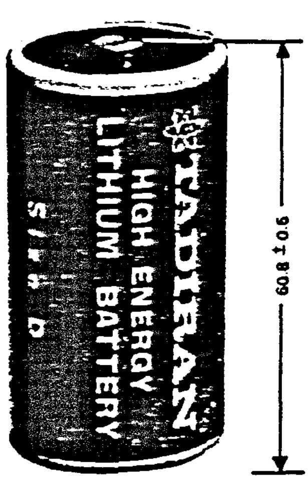


Solder tabs optional (see back page)



TL-2300
"D" IEC-R-20

Open Circuit Voltage	3.7 V
Nominal Voltage	3.4 V
Rated Capacity to 2.5 V (60 mA at R.T.)	10 Ah
Weight (max)	100 gr
Volume	51 cc



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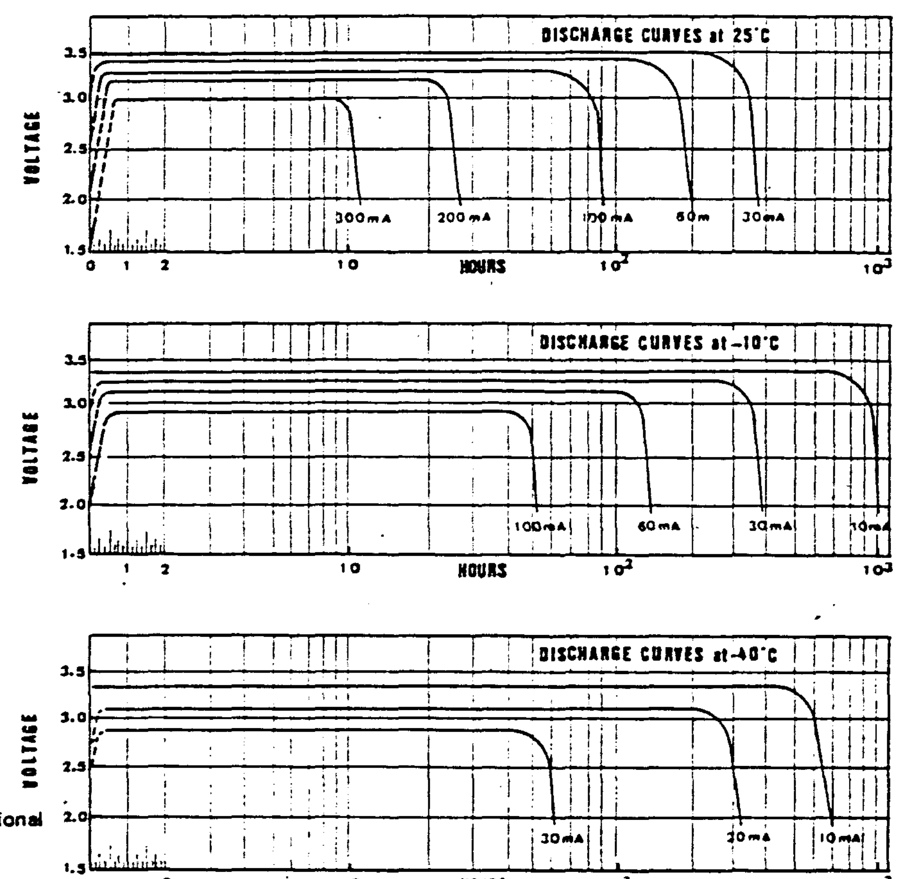
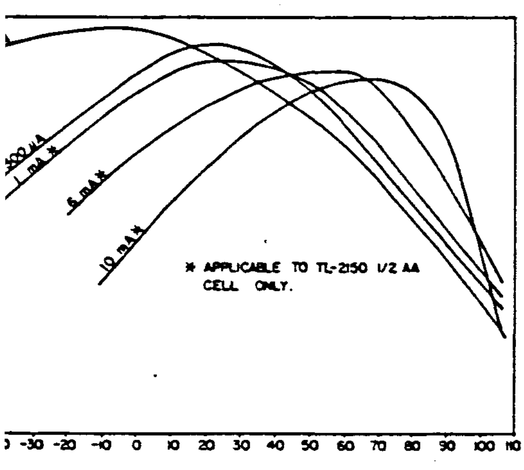


MAX CURRENT

'UM ORGANIC BATTERIES

Capacities

·23 through 3–26 show the capacity (to :he ½ AA, AA, C and D standard cells and the TEL, AEL, CEL and DEL memory backup cells as a function of discharge temperature, for various discharge currents.



3. *TL-2150 ½ AA Cell and TL-5101 TEL Cell Capacity vs. Current and Temperature.*

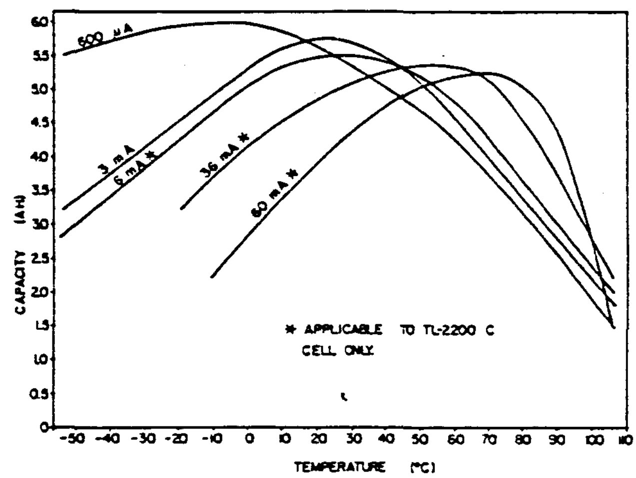
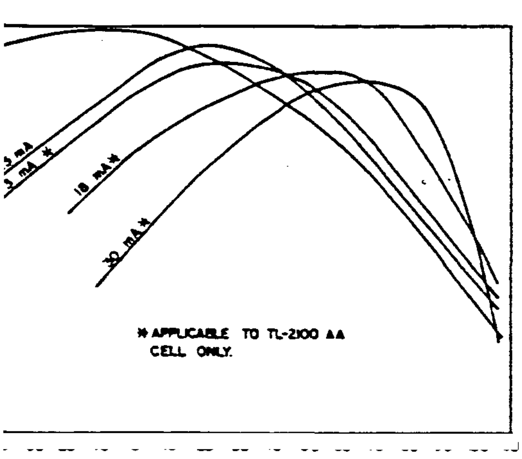


Figure 3–25. TL-2200 C Cell and TL-5105 CEL Cell Capacity vs. Current and Temperature.



'4. *TL-2100 AA Cell and TL-5104 AEL Cell Capacity vs. Current and Temperature.*

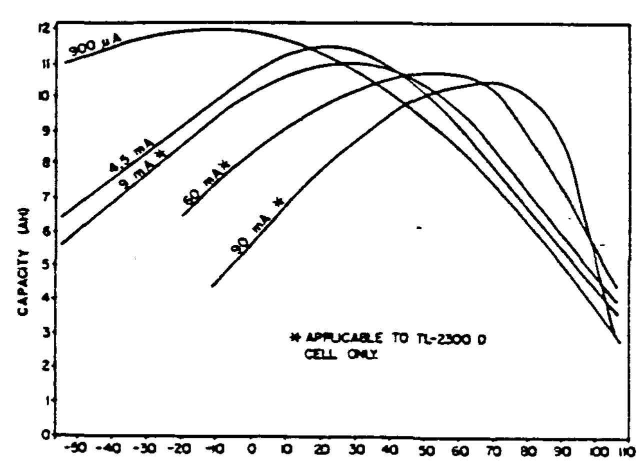


Figure 3–26. TL-2300 D Cell and TL-5106 DEL Cell Capacity vs. Current and Temperature.

CHAPTER 4

ENVIRONMENTAL TESTING

4.1 GENERAL

TADIRAN™ lithium inorganic cells have undergone intensive environmental testing to the following rigorous standards and specifications:

U.S. Army Electronics Command SCS-459
Military Specification for Dry Batteries MIL-B-18D,
Military Standard for Environmental Test Methods MIL-STD-810C.

Various groups of cells were used for each of the tests. The cells in each group were selected at random from production batches following final inspection:

Mechanical Vibration (4.2),
Mechanical Shock (4.3),
Combined Mechanical Shock and Vibration (4.4),
Thermal Shock (4.5),
Pressure Test (4.6),
Altitude Test (4.7),
Impact Test (4.8),

The following test results prove that TADIRAN™ lithium inorganic cells comply with the specified environmental requirements.

4.2 MECHANICAL VIBRATION TEST

4.2.1 Applicable Documents: MIL-B-18D, MIL-STD-810C, SCS-459.

4.2.2 Cells Tested: AA, C and D size.

4.2.3 Test Description

a. **Vibration:** Harmonic with an amplitude of 0.03 inch.
b. **Frequency:** Initial 10 Hz increasing at a rate of 1 Hz/min up to 55 Hz. Then, decreasing to 10 Hz at the same rate.
c. **Test duration:** 95 minutes per test.
d. **Procedure:** The test was repeated three times on each of the two axes shown in Figure 4–1. At the conclusion of the vibration cycles, the cells were discharged and various other observations made.

4.2.4 Observations: No change in cell voltage: no delay in reaching plateau voltage; no substantial reduction in cell capacity; no cell leakage; no changes in cell construction as detected by X-ray photography; no change in cell weight.

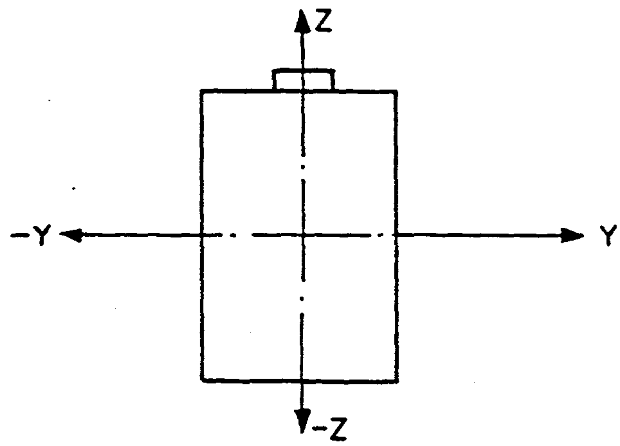


Figure 4–1. Mechanical Vibration and Shock Test Axes

4.3 MECHANICAL SHOCK TEST

4.3.1 Applicable Documents: MIL-B-18D, MIL-STD-810C, SCS-459.

4.3.2 Cells Tested: AA, C and D size.

4.3.3 Test Description.

a. **Shock applied:** A half-sine pulse of 150 G peak acceleration, for 6 ms.
b. **Procedure:** Mechanical shocks were applied three times on each of the two axes shown in Figure 4–1. At the conclusion of the shock test, the cells were discharged and various other observations made.

4.3.4 Observations: No change observed in cell voltage; no delay in reaching plateau voltage; no substantial drop in cell capacity; no cell leakage; no changes in cell construction as detected by X-ray photography, no change in cell weight.

4.4 COMBINED MECHANICAL SHOCK AND VIBRATION TEST

4.4.1 Applicable Documents: None (test not required by MIL specifications).

4.4.2 Cells Tested: AA, C and D size.

4.4.3 Test Description: The cells were subjected to mechanical vibration tests as in paragraph 4.2.3, followed immediately by mechanical shock tests as in paragraph 4.3.3.

4.4.4 Observations: No change in cell voltage; no delay in reaching plateau voltage; no substantial drop in cell capacity; no cell leakage; no changes in cell construction as detected by X-ray photography; no change in cell weight.

4.5 THERMAL SHOCK TEST

4.5.1 Applicable Documents: MIL-STD-810C.

4.5.2 Cells Tested: AA and D size.

4.5.3 Test Description: The cells were submitted to temperature cycling as shown in Figure 4–2 (four cycles). They were then discharged at nominal rates after stabilizing at +25°C. The cell voltage was recorded during the discharge and various observations made.

4.5.4 Observations: No change in cell voltage; no delay in reaching plateau voltage; no substantial reduction in capacity; no cell leakage observed.

4.6 PRESSURE TEST

4.6.1 Applicable Documents: MIL-STD-810C.

4.6.2 Cells Tested: D size.

4.6.3 Test Temperature: +25°C.

4.6.4 Test Description: The cell weight was determined to an accuracy of 0.001 grams before and after the test. Cell dimensions were measured before and after test. The cells were placed in a pressure chamber at 4 atm for 12 hours. The open circuit voltage was measured during the test. The cells were removed from the chamber and discharged at 60 mA, to determine the voltage under load and the capacity.

4.6.5 Observations: No leakage observed; no change in weight; no change in cell dimensions; no reduction in cell capacity; no change observed in open-circuit voltage (3.68 to 3.71 V).

4.7 ALTITUDE TEST

4.7.1 Applicable Document: SCS-459.

4.7.2 Cells Tested: D size.

4.7.3 Test Temperature: +25°C.

4.7.4 Test Description: The cells were weighed before and after the test. The cell dimensions were measured before and after the test. The cells were placed in a vacuum chamber and subjected to a pressure equivalent to that at 50,000 feet altitude. The open circuit voltages were measured during the test. The cells were removed from the charger and discharged at 60 mA, to determine the voltage under load and the capacity.

4.7.5 Observations: No change in cell weight; no change in cell dimensions; no reduction in cell capacity; no leakage observed; no change in open-circuit voltage (3.68 to 3.71 V).

4.8 IMPACT TEST

4.8.1 Applicable Document: MIL-STD-810C

4.8.2 Cells Tested: ½ AA and AA size.

4.8.3 Test Temperature: +25°C.

4.8.4 Test Description: The cells were subjected to an impact of 14,000 G on each of the axes, as shown in Figure 4–3.

4.8.5 Observations: No visual defects were detected; no reduction in cell capacity; no electrolyte leakage; open-circuit voltage: 3.68 to 3.70 V; voltage under load: 3.4 V.

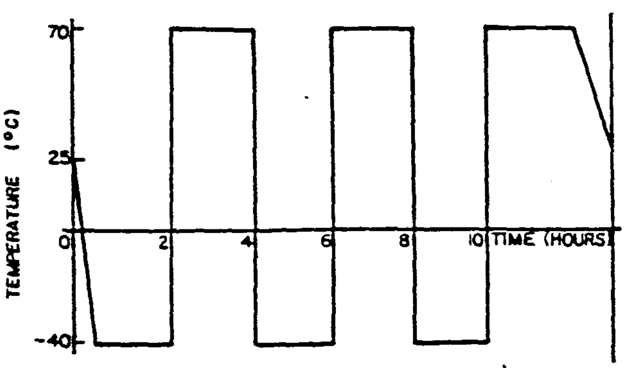


Figure 4–2. Thermal Cycling Curve

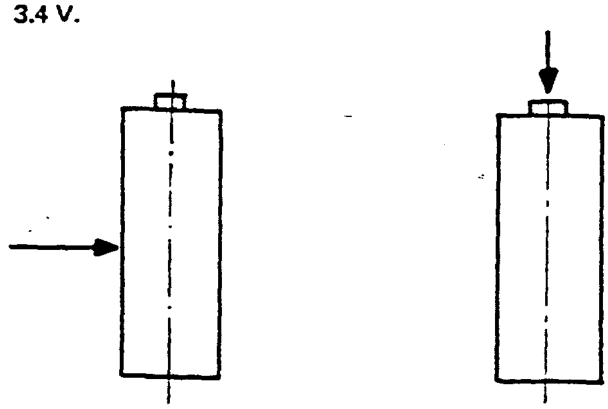


Figure 4–3. Impact Test Axes

114 Terrace Road, Sebenza Township, Edenvale
P.O. Box 411, Edenvale 1610. Telex 4-20865 SA
Telephone 609-8732

INDUSTRIAL URETHANES

KPA/prg

17th June, 1985

Somchem (Pty) Ltd.,
P.O. Box 187,
SOMERSET WEST.
7130

Att: Mr. van Niekerk

Dear Sir,

Further to our recent telephone conversation concerning the DURAUTO FIB/L - DURANATE system, please find enclosed a summary of the basic processing parameters.

As already indicated, the products were originally supplied by Reac Chemicals, but are now manufactured and distributed by ourselves. The availability is thus assured and you should encounter no problems in this respect in the future.

Yours faithfully,
INDUSTRIAL URETHANES (PTY) LTD

K.P. ARKLE
TECHNICAL PRODUCT MANAGER

PRELIMINARY DATA SHEET:

DURAUTO FIB/L

DURAUTO FIB/L is a blend of polyether polyols, catalysts and modifiers which, when reacted with Duranate under the correct processing conditions produces a flexible, resilient, integral skin polyurethane foam.

PROCESSING DETAILS:

Weight Mixing Ratio	:	100 parts Durauto FIB/L 28 parts Duranate.
Cream Time at 20°C	:	15 secs.
Free Rise Density	:	100kg/m³ (approx).

17th June, 1985

APPENDIX 7

NATIONAL ELECTRICAL ENGINEERING RESEARCH INSTITUTE (CSIR)

CONTRACT REPORT E/85/247

TITLE: RF SUSCEPTIBILITY AND SHIELDING EFFECTIVENESS TESTS ON A FIRING UNIT USED TO INITIATE TWO PYROTECHNIC CHAINS.

DATE OF REPORT: 10 DECEMBER 1985

AUTHOR: MR J VOIGHT

MR H YNTEMA

APPROVED BY: MR K S G STRAUSS

NEERI, CSIR, P O BOX 395 PRETORIA 0001

4443B

RF SUSCEPTIBILITY AND SHIELDING EFFECTIVENESS TESTS ON THE FIRING UNIT USED TO INITIATE TWO PYROTECHNIC CHAINS

1. INTRODUCTION

The firing unit is that part of a system used to initiate two pyrotechnic chains. The electronic part of the system tested consists of a firing unit, a multicore cable, a squibhead (including the squib and a low-pass filter) and an electrolyte capacitor.

In order to reduce the possibility of malfunctioning of the system in RF fields, NEERI was asked to carry out RF susceptibility tests based on the requirements of Kentron document KE 347.

The investigation consisted of the following:

PART 1

RF susceptibility tests over the frequency range 60 Hz to 10 GHz. The system was subjected to specified RF fields to conclude whether:

1. The resulting induced RF current through the squib is below the maximum no-fire current;

2. The system functions satisfactory at all test frequencies.

PART 2

Relative RF shielding effectiveness measurements on the system against magnetic and electric fields over the frequency range 60 Hz to 10 GHz.

PART 3

Recommendations pertaining to the reduction of the RF susceptibility of the firing unit, as well as suggestions for improving the shielding of this unit.

2. MEASUREMENTS AND TESTS CONDUCTED

2.1 Test Procedures

The firing unit systems was either completely or partly placed in a defined RF field outside the shielded enclosure as shown in Figs 1 to 4. The measuring equipment was used inside the shielded enclosure, so that it would not be influenced by the irradiating RF field.

All measurements and test on the system were done with the squib replaced by a squib-simulating resistor (SSR), which was supplied as a squib substitute. Measurements and tests were done at the test frequencies shown in the graphs. If it was noticed that the system was more vulnerable in a certain frequency band, the frequency intervals were decreased. While subjected to RF fields, the resulting induced voltage across the squib was measured. At the same time, the firing unit was tested for correct functioning.

After the measurements and tests had been conducted, the SSR was replaced by a real squib. Measurements and tests were then repeated for the frequencies for which the system was shown to be vulnerable.

Susceptibility and shielding effectiveness tests were done with the indicated four different arrangements (Figs 1 to 4) of the firing unit system in order to evaluate the individual sub-systems.

2.2 RF Fields Used

The RF fields covered the frequency range 60 Hz to 10 GHz. The magnetic fields covered the frequency range 60 Hz to 500 kHz, while the electric fields covered the frequency range 10 kHz to 10 GHz. MIL-STD-RS01 was used to specify the magnetic field strengths, while MIL-STD-RS03 was used to specify the electric field strengths. Above-mentioned MIL-STDs are summarized in the Kentron document KE 347.

Because of the limited capabilities of available equipment, the arrangements of the system could not be subjected to the 200 V/m field strength required by the MIL-STD. In graph 1 the RS01 required magnetic field strengths, together with the magnetic field strengths used, are shown. In graph 2 the RS03 required electric field strengths, together with the electric field strengths used, are shown. Where the required field strengths could not be generated, the measured values had to be scaled up. The calculations for this is shown in the Appendix.

3. RESULTS OF SUSCEPTIBILITY TESTS

3.1 RF Susceptibility of Squib

Graph 3 indicates the scaled up current through the SSR for the different measuring arrangements, while subjected to magnetic fields. Graph 4 is similar to graph 3, but for electric fields.

In the handbook supplied with the system, it is specified (page 8) that the -

"Safe measuring current" 50 mA

Therefore, with the present 5 mA DC test current through the squib, the induced RF current should not exceed 45 mA.

45 mA = 93 dBuA (dB above 1 uA).

From graphs 3 and 4 it can be concluded that RF fields with the levels required by the MIL-STD-461, will not induce currents large enough to cause ignition of the squib.

Appendix 1.2 demonstrates how the current through the SSR was calculated from the measured voltages.

3.2 System performance in RF fields

Under the conditions indicated in Table 1, it was noted that it was not possible to activate the system with the hand cranked generator as required. While turning the generator, the "Squib Fault" LED illuminated.

Only electric fields resulted in malfunctioning. The electric fields had to be reduced from 12 V/m to 2 V/m before the system could be operated, whereas MIL-STD-RS03 demands 200 V/m.

TABLE 1: Malfunctioning conditions

Arrangement	I	II	III	IV
Frequency MHz	300 - 10 000	No malfunc.	50 - 100	400 - 600

This shows that a firing unit without cover, whether silver sprayed or not, will malfunction at frequencies in the range 300 to 1 000 MHz.

Although arrangement III did not malfunction in the frequency range 300 - 1 000 MHz (because of cover), leakage via the multicore cable caused malfunctioning in the frequency range 50 - 100 MHz.

4. RESULTS OF SHIELDING EFFECTIVENESS MEASUREMENTS

4.1 Shielding effectiveness of conductive silver spray

For magnetic fields in the frequency range 60 Hz - 500 kHz, the shielding effectiveness is increased by 20 - 40 dB. This can be seen by comparing the results of Arrangement I with that of Arrangement IV in graph 3.

For electric fields at frequencies above 150 MHz, the conductive silver spray results in an additional 10 - 30 dB shielding. Below 150 MHz the silver spray does not improve the shielding effectiveness against electric fields. This can be seen by comparing the results of Arrangement I with that of Arrangement IV in graph 4.

4.2 Shielding effectiveness of cover of "Firing unit"

Magnetic fields are reduced by 5 - 30 dB in the frequency range 60 Hz - 500 kHz. Above 10 kHz, a magnetic field shielding of 30 dB is obtained. Below 1 kHz, magnetic fields are reduced by 5 dB. This can be seen by comparing the results of Arrangement I with that of Arrangement II in graph 3.

An electric field shielding of 20 dB is obtained above 10 MHz. Below 1 MHz the shielding effectivenss could not be measured because the RF voltage across the SSR was too low to measure. Graph 4, the results of Arrangement I, can be compared with that of Arrangement II, to obtain the shielding effectiveness.

5. RECOMMENDATIONS (Part 3)

5.1 Prevention of malfunctioning of system

The reason for the malfunctioning of the system at high RF levels was found to relate to the low signal levels at which the op amps were operated. Consequently, three modifications were implemented to reduce the susceptibility of the op amps in the "Squib Fault" sensing circuit and the relative improvements were established.

5.1.1 Decoupling of the inputs of the operational amplifiers

A recommended practice would be to decouple the inputs to the op amps as shown in Figure 5.

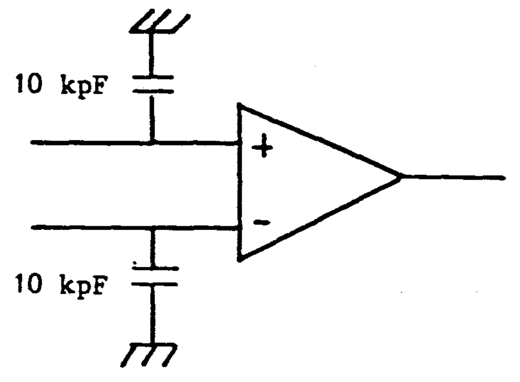


Fig. 5: op amp decoupling

This idea could not be applied, as the input pins and the nearest ground conductor are too far apart. The resulting loop formed by the decoupling capacitor would act as a receiving antenna and introduce noise to the op amp inputs. The capacitors (ceramic) were therefore placed at the input of the op amp as shown in Figure 6.

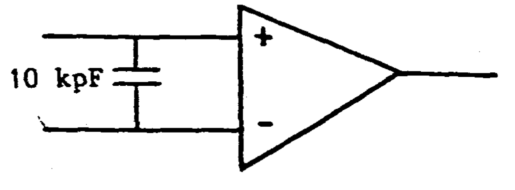


Fig. 6: op amp decoupling

This resulted in an improvement of the system's immunity to RF fields, but it still malfunctioned at certain frequencies.

5.1.2 Shielding of op amps

A further improvement was obtained by shielding the op amp IC on top and beneath the PC board with copper tape. The copper shields were grounded. As a more permanent solution, the use of an additional copper layer on the PC board to serve as a ground plane, is suggested. If circuit-compatible metal can op amps are available, these should be used.

5.1.3 Reduced sensitivity of "Squib Fault" sensing circuit

The sensing circuit is shown in Figure 7.

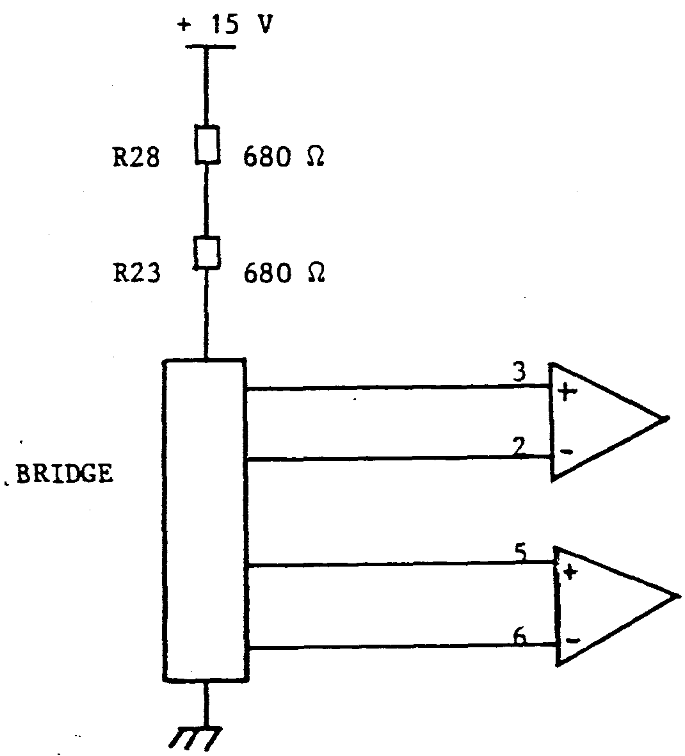


Fig. 7: "Squib Fault" sensing circuit

The sensing input voltages to the 2 op amps were found to be at a very low level, as shown in Table 2 (before correction). Therefore, a small RF voltage could easily disturb the balance. By increasing the current through the bridge (and the SSR) the voltages were increased as shown in Table 2 (after correction). The current was increased by reducing series resistances R28 and R23 (1 360 Ω) to 150 Ω.

TABLE 2: Input voltage to op amp

R (SQUIB)	Before correction		After correction	
	V_{2-3}	V_{5-6}	V_{2-3}	V_{5-6}
2 Ω	+ 17 mV	+ 5 mV	+ 130 mV	+ 35 mV
0 Ω	-	- 2 mV	-	- 7 mV
∞	- 300 mV	-	- 1 000 mV	-

In graph 4 it was shown that the maximum induced RF current through the SSR would be 70 dB µA

70 dB µA = 3 mA.

The measuring current after correction would be

0,5 [15/(150 + 0,5 x 47)] = 43 mA

The maximum measuring current that would flow through the SSR when subjected to RF fields would then be

$43\ mA_{DC} + 3\ mA_{RF} = 46\ mA.$

This current is still below 50 mA, the "safe measuring current", but possible degradation effects on the squib should be taken into account.

5.2 Shielding of multicore cable

It was noticed that the braids of the interconnecting cables form an integral part of the equipment shield. In order to preserve the continuity of the shield, a permanent and reliable low-resistance between mating connector shells is essential. Measurements would be required to establish whether all connectors, old and new, always fulfil this requirement.

5.3 Static charge on "Firing unit"

Under certain conditions a static charge could build up on the enclosure of the "Firing unit" relative to the internal electronic ground. An electric discharge could then take place between the body of the "Firing unit" and the circuit ground or between the shield of the cable and the internal conductors. This discharge could potentially ignite the squib. To prevent a discharge, a 1 MΩ resistance should be used between the body of the "Firing unit" and circuit ground.

5.4 Polyurethane - Silver sprayed unit

The 10 to 30 dB additional shielding offered by the silver spray is not in accordance with the maximum potential shielding qualities of the product. This is probably due to the degradation of the total shield by the cable harness, cracks in the layer of spray and the undefined contact between the conductive spray and the metal of the box. Unless precautions are taken, the conductive layer can easily be damaged and penetrated during transportation, storage and handling.

It is recommended that the design should make provision for a semi-permanent, factory fitted, RF tight lid and that the mounting method be adapted accordingly.

6. CONCLUSIONS

6.1 When the "Firing unit" with its cover and wiring loom is subjected to RF fields, as required by MIL-STD-RS01 and RS03, the induced RF voltages were far below the values required to ignite the squib.

6.2 The conductive silver spray is not considered a reliable solution and thought should be given to use the present lid of the box as a permanent shield.

6.3 After implementation of the above recommendations, malfunctioning of the system could not be introduced by irradiation with the specified RF fields.

6.4 As there was some concern over the validity of the results obtained with the SSR, the manufacturers provided samples of the actual squib for comparative tests. Measurements at certain selected spot frequencies confirmed that differences in the measurement results obtained with squibs and the SSR were insignificant.

J Voigt
Project Team Member
EM Measurements & Testing
NATIONAL ELECTRICAL ENGINEERING RESEARCH INSTITUTE

H Yntema
Project Team Member
EM Measurements & Testing

JHJF/KSGS/JV/HY/BMW
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APPENDIX

1.1 Upscaling

MIL-STD-461 specifies a field E1 which would result in an induced measured voltage V1 across the SSR simulating resistor. Measurements were done in an RF field E2 which resulted in a measured voltage, V2.

$$V_1 = V_2 . \times E_1/E_2$$

$$V_1(\text{dB}\mu\text{V}) = V_2(\text{dB }\mu\text{V}) + 20 \log E_1/E_2 \text{ (dB)}.$$

1.2 Current through SSR

The measured impedance of the supplied SSR-simulating resistor as a function of frequency is given in the table below.

Table: Impedance vs frequency

f(MHz)	/Z/ ∠DEG (Ω)
< 1	1,5 ∠0°
1	2 ∠10°
20	8 ∠77°
50	20 ∠85°
100	42 ∠88°
150	47 ∠86°
200	54 ∠87°
400	130 ∠89°
600	200 ∠89°
800	125 ∠89°
1 000	110 ∠88°

The current through the resistor is then calculated from:

$$/I/ = \frac{/V/_2}{/Z/}$$

where V_2 is the measured voltage across the resistor while subjected to RF fields.

ARRANGEMENTS

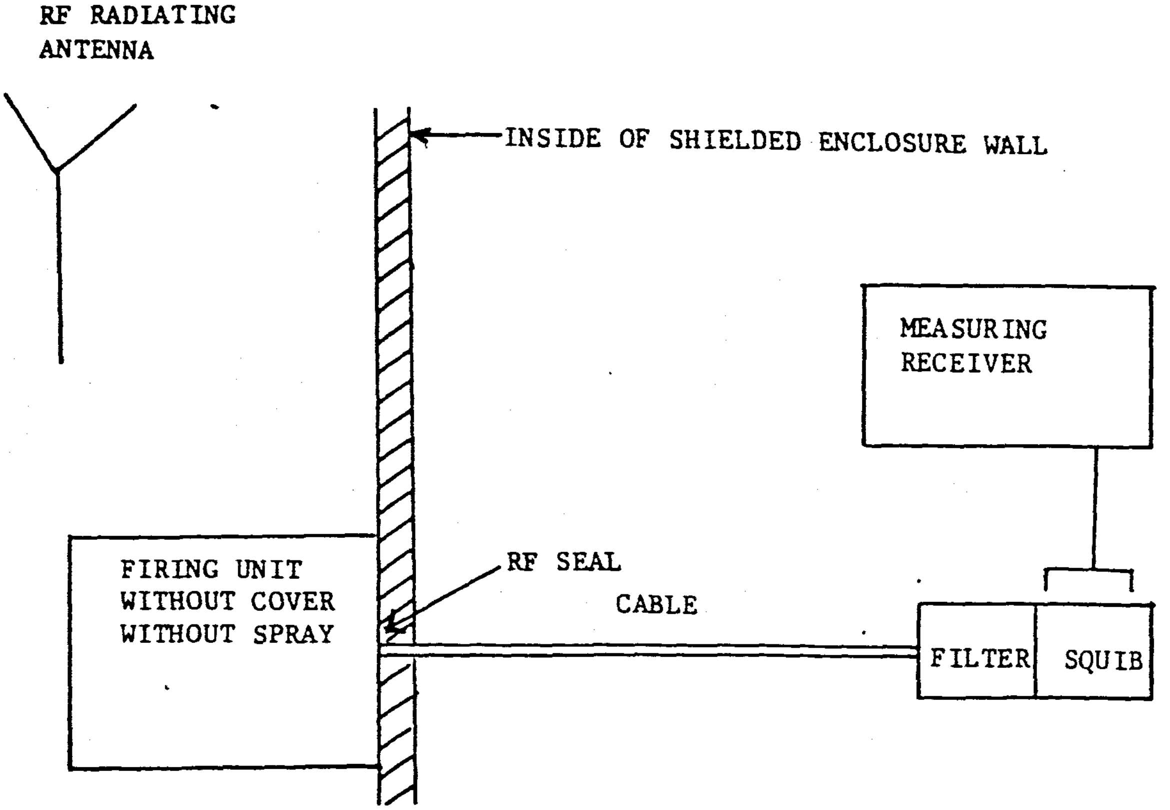


Fig. 1: Arrangement I

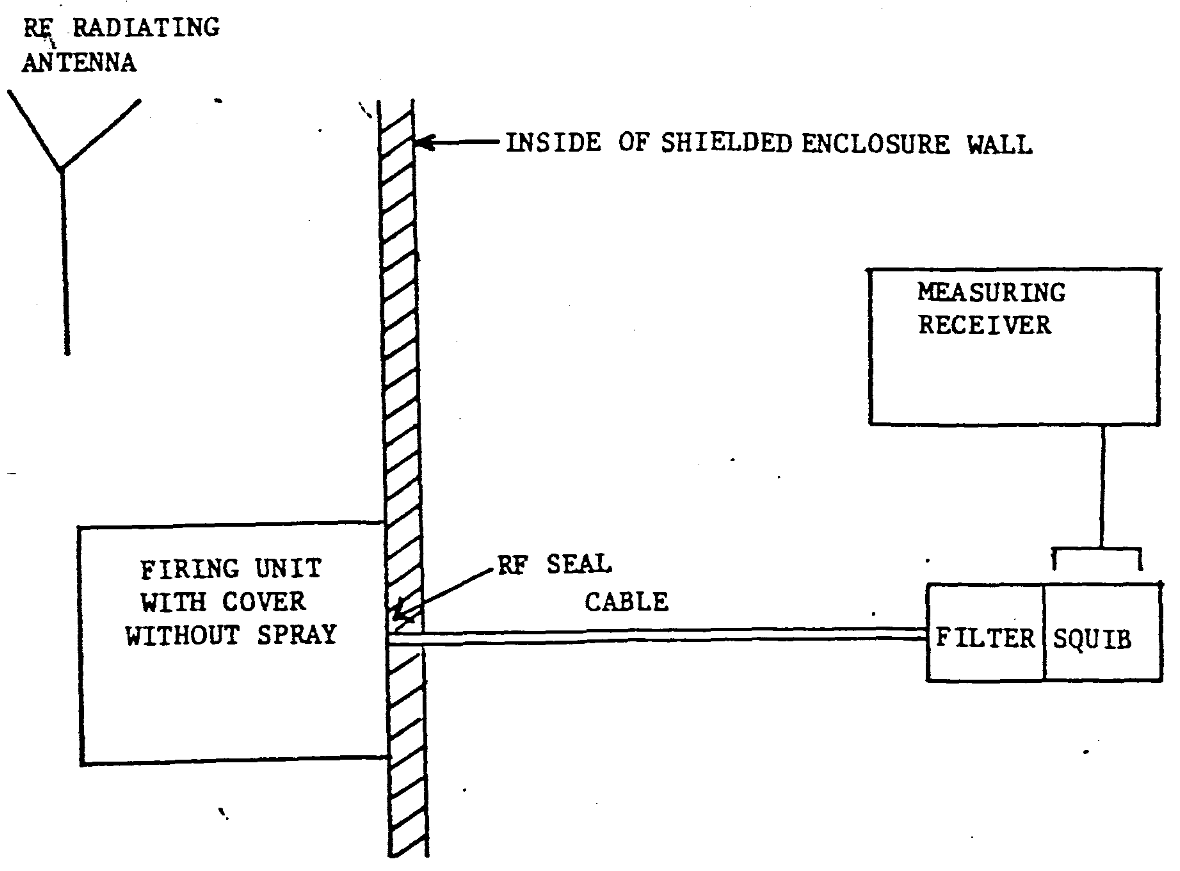


Fig. 2: Arrangement II

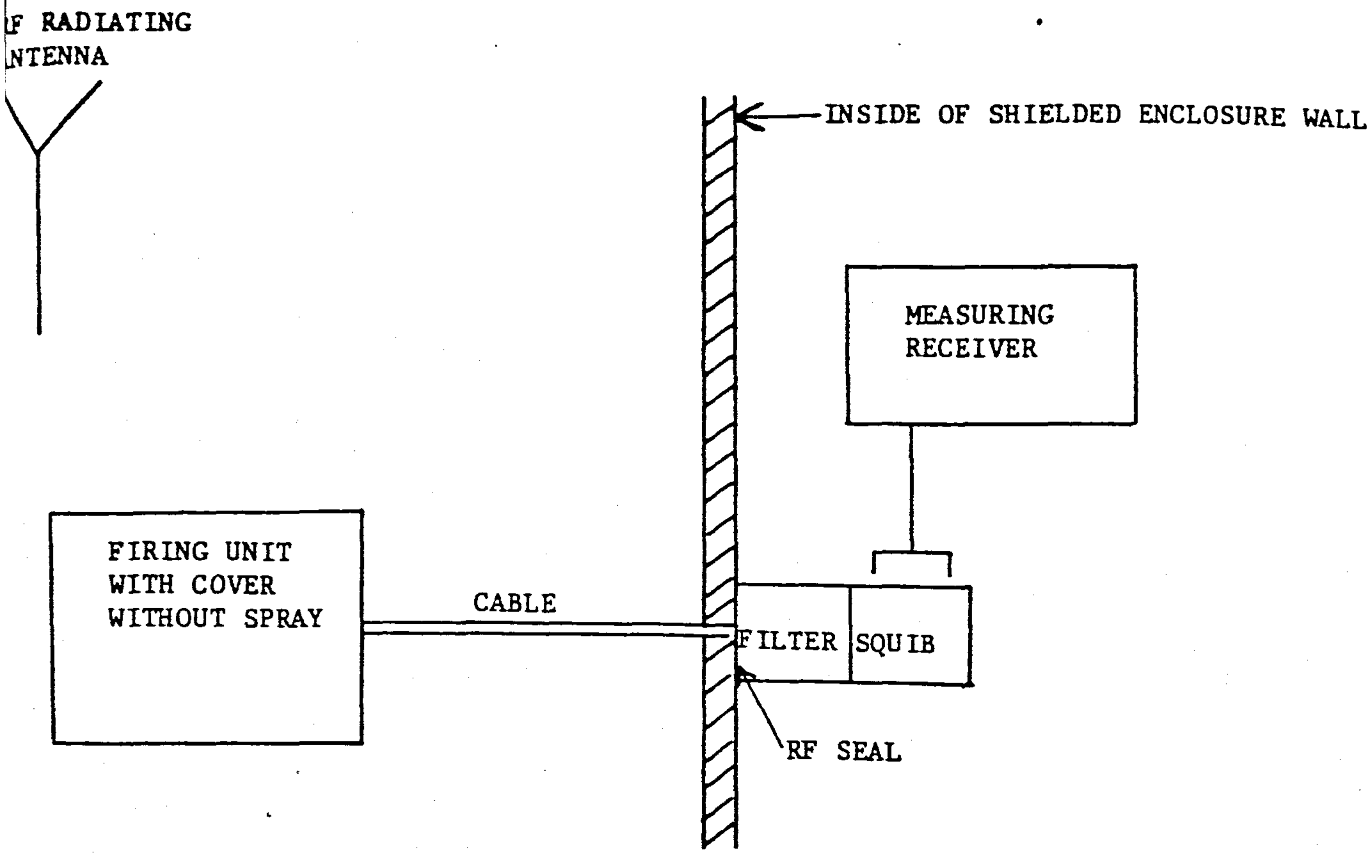


Fig. 3: Arrangement III

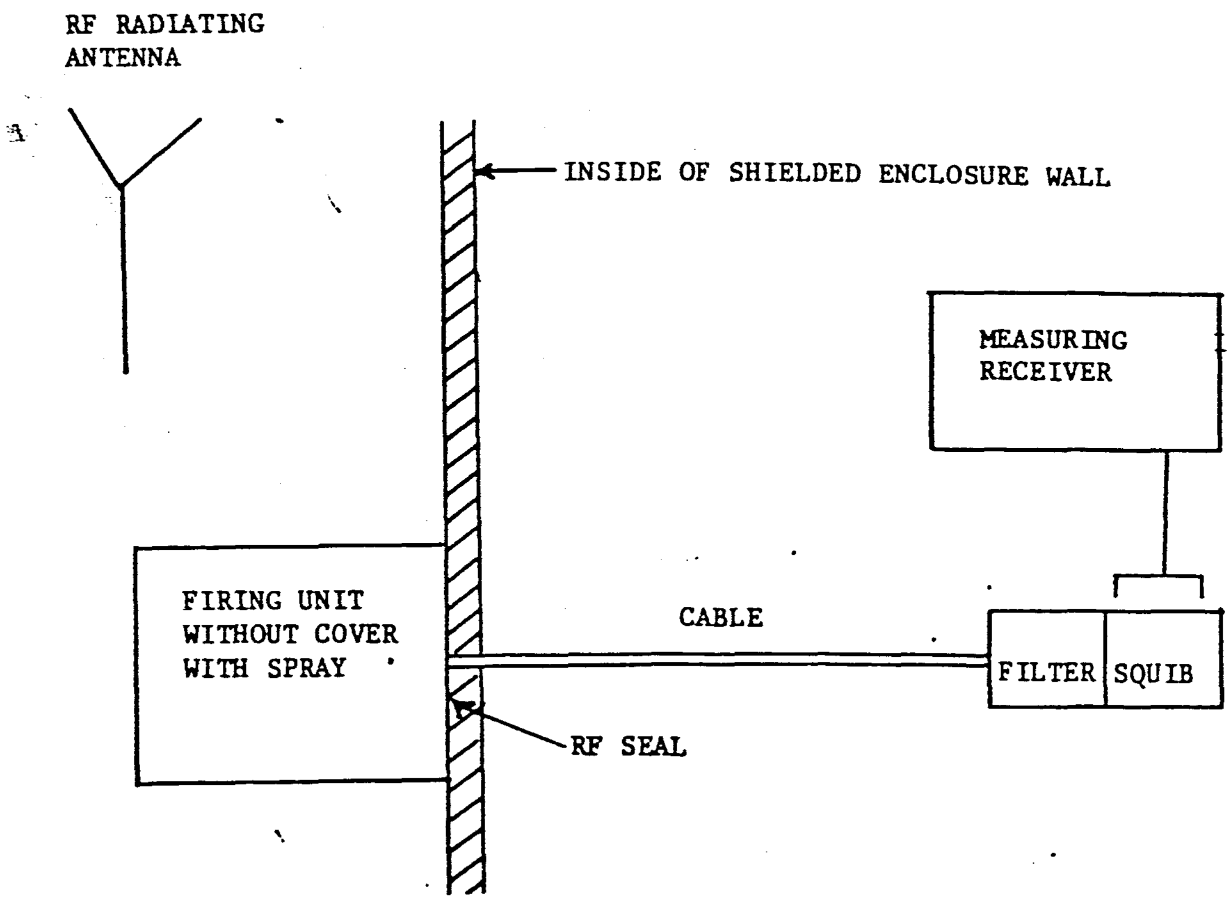
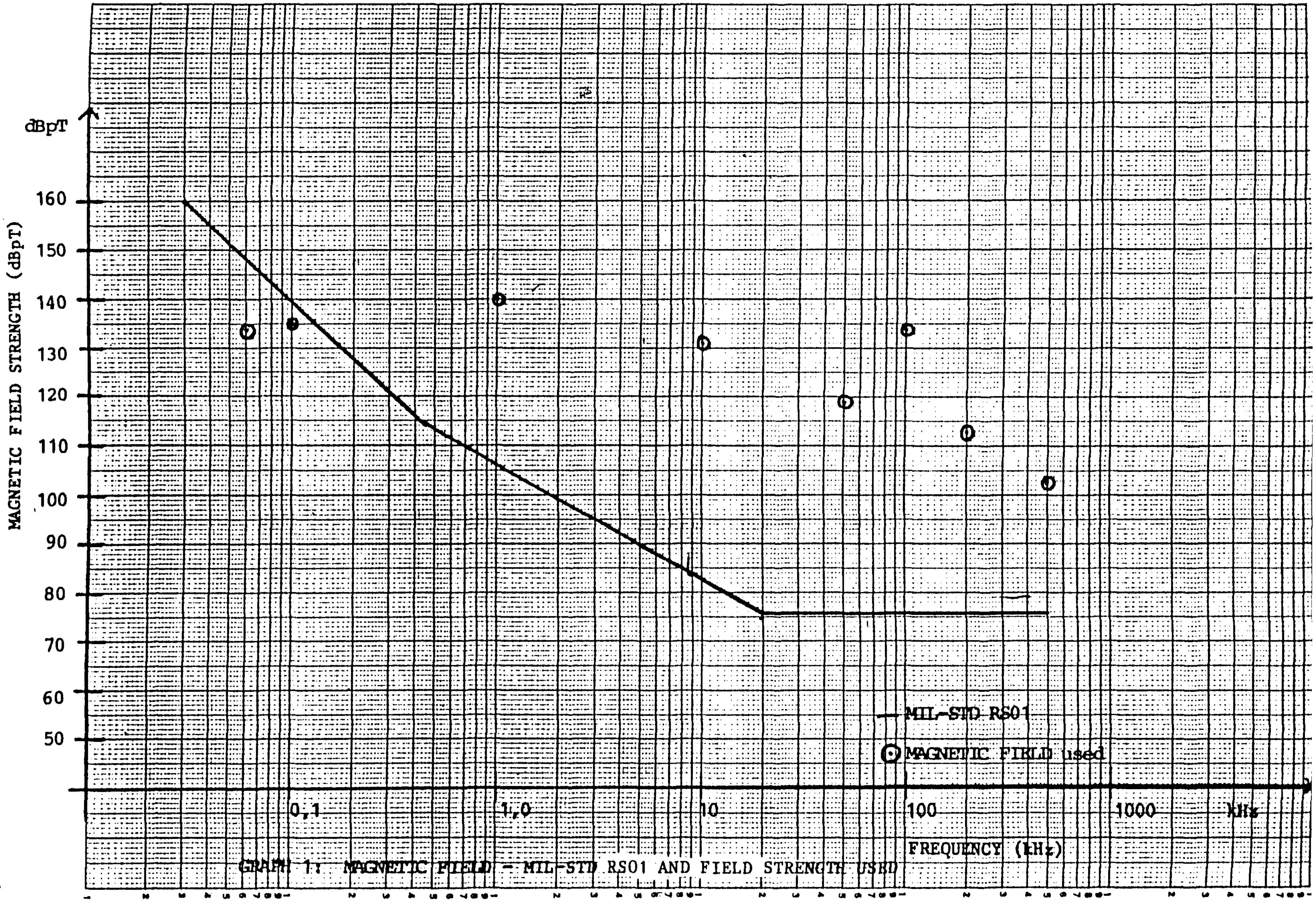
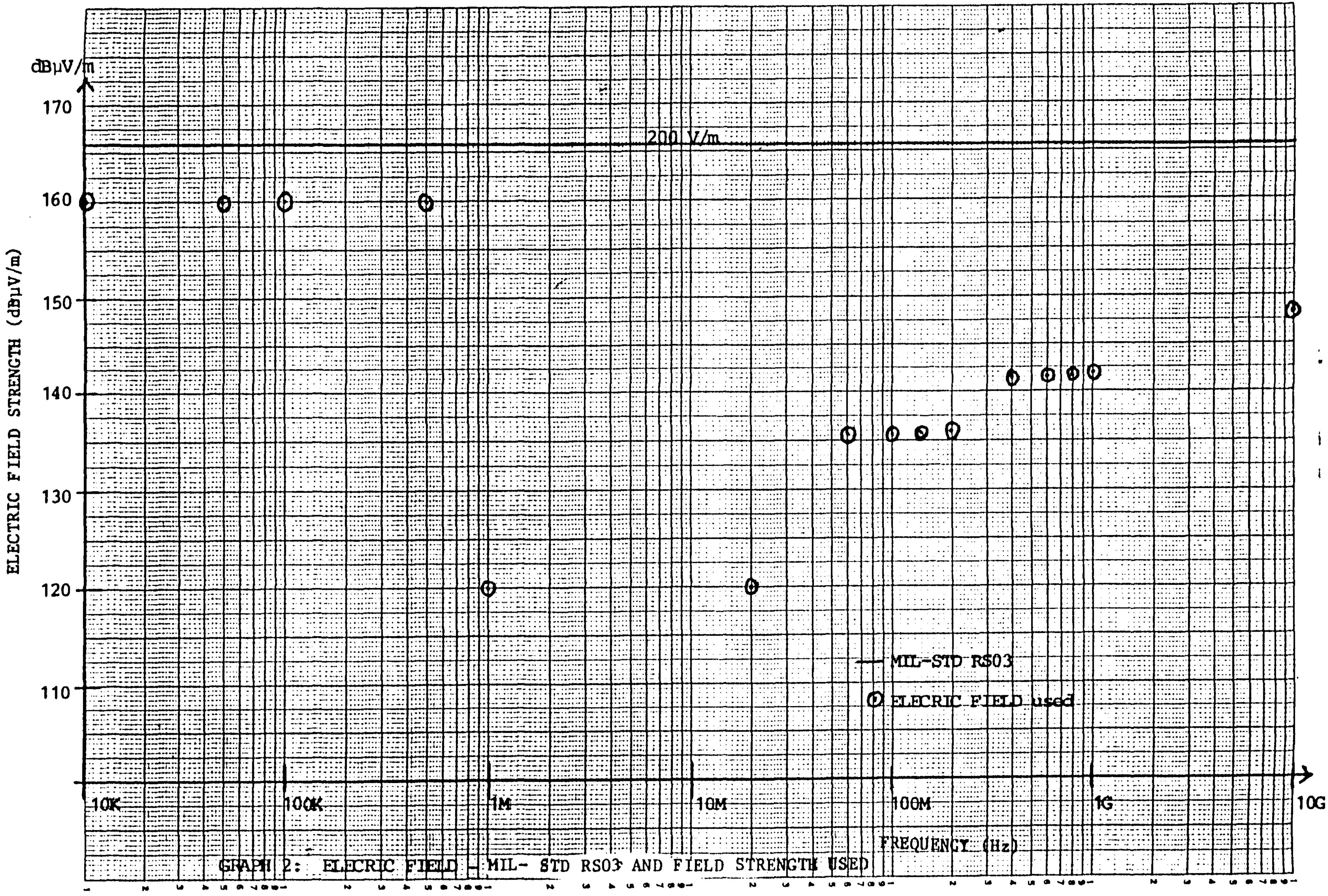


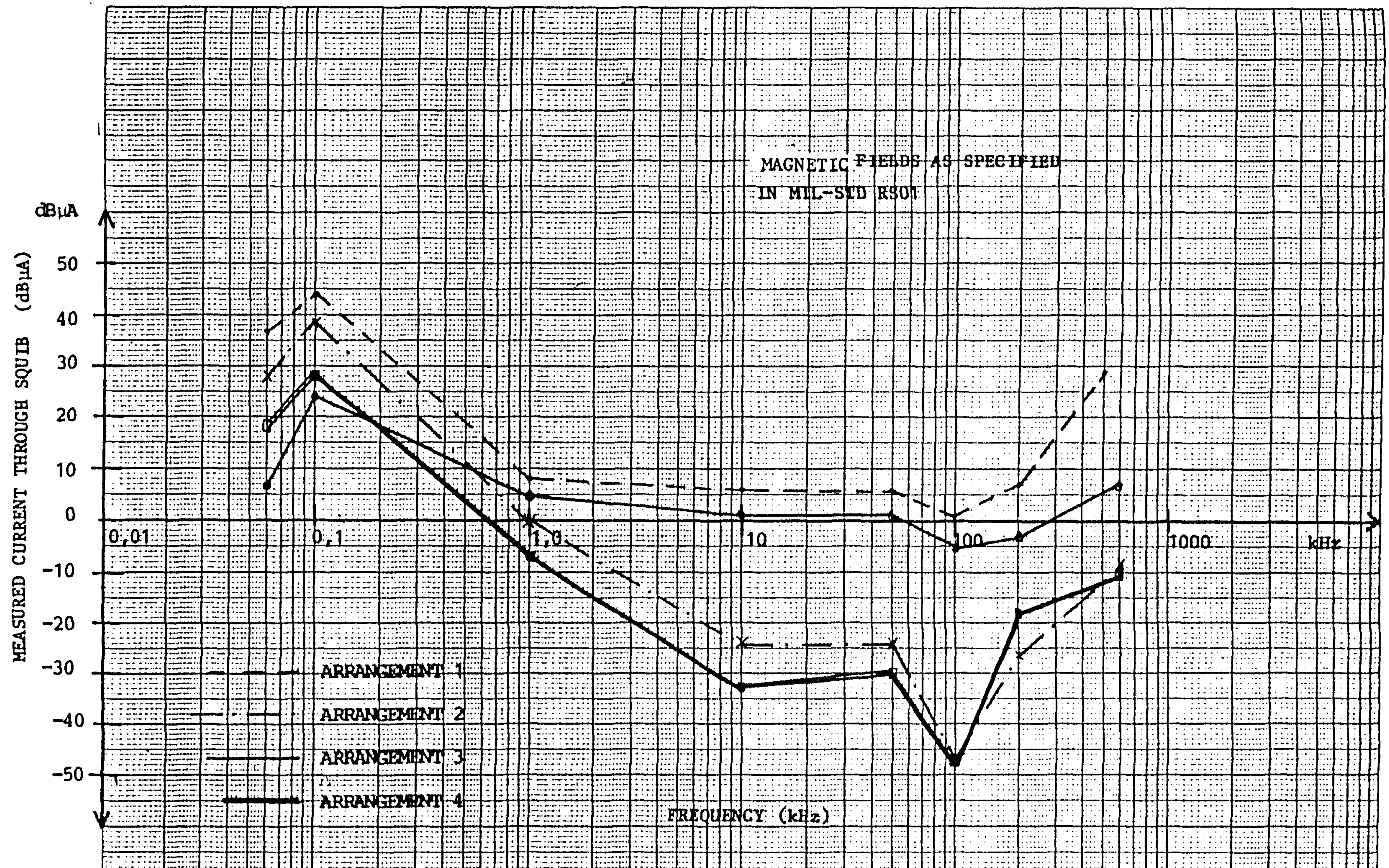
Fig. 4: Arrangement IV



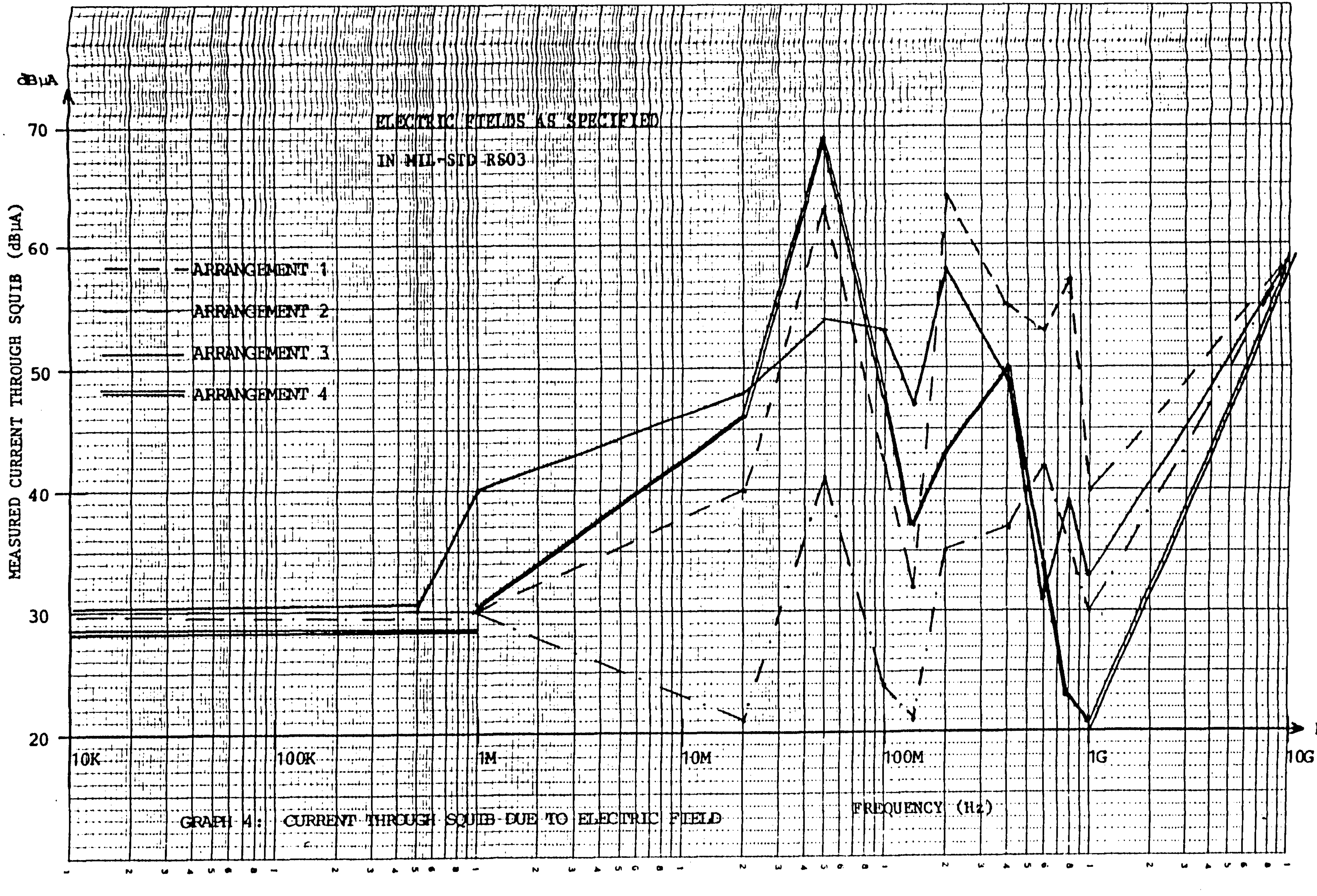
GRAPH 1: MAGNETIC FIELD – MIL-STD RS01 AND FIELD STRENGTH USED



GRAPH 2: ELECRIC FIELD - MIL- STD RS03 AND FIELD STRENGTH USED



GRAPH 3: CURRENT THROUGH SQUIB DUE TO MAGNETIC FIELD



GRAPH 4: CURRENT THROUGH SQUIB DUE TO ELECTRIC FIELD

APPENDIX 8

PROCEDURES FOR FUNCTIONAL TESTING OF THE FIRING UNIT

A testing jig, illustrated in Figure 1, is used to simulate the interlock circuitry, the SAD capacitor and the rocket motor fuzehead of the Firing System. This jig is used in conjunction with a Storage Oscilloscope, a Digital Multimeter and a Decade Resistance Box for functional testing of the Firing Unit.

1. THE DISCONNECTED CABLE TEST

This test ensures that if the firing cable is disconnected from the launch pack, the firing unit will inform the operator of the error.

(a) Equipment required

None

(b) Setting up

(i) Ensure that all cables are disconnected from the Firing Unit.
(ii) Ensure that the SAFE/ARM switch is on SAFE.

(c) The Test

(i) Switch the Firing Unit on and crank the hand-crank generator
(ii) Record in the table below which LED's come on and which do not.

FIG. 1 - FUNCTIONAL TEST JIG

	LED on	LED off
Fuzehead fault		
Interlock fault		
Discharged		
Ready		

If the previous table does not agree with the one below, the firing unit shall be rejected

	LED on	LED off
Fuzehead fault	X	
Interlock fault		X
Discharged	X	
Ready		X

2. THE INTERNAL RESISTANCE TEST

This test verifies various short circuits and discharge resistors. The circuitry ensures that inadvertent firing cannot occur.

(a) Equipment required

(i) A digital multimeter of input impedance 1 megohm or greater

(ii) The test jig, figure 1.

(b) Setting Up

(i) Connect the test jig to the Firing Unit

(ii) Connect the ohmmeter to terminals D and F, positive on F

(iii) Ensure the SAFE/ARM switch is on SAFE

(iv) Set the multimeter to read a maximum of 2 kilo-ohm

(c) The Test

Part One

(i) Record the resistance between terminals D and F, after the meter has stabilised, in line one of the table below.

Part Two

(i) Set the multimeter to read a maximum of 200 ohm

(iii) Connect the ohmmeter to terminals B and D, positive on B

(iv) Ensure that the internal fuzehead/external fuzehead switch is in the external position and the ON/OFF switch is in the OFF position.

(v) Record the resistance, as indicated on the ohmmeter, in line two of the table below. Switch the SAFE/ARM switch to ARM.

Record the resistance, as indicated on the ohmmeter, in line three of the table below.

Part Three

(vi) Set the multimeter to read a maximum of 2 megohm

(vii) Connect the ohmmeter to terminals D and E, positive on E.

(viii) Record the resistance, as indicated on the ohmmeter in line four of the table below.

RESISTANCE	Min Value	Value measured	Max value
Line one	200 ohm		250 ohm
Line two	Zero ohm		5 ohm
Line three	90 ohms		115 ohm
Line four	850 kilo-ohm		1,2 megohm

If the values measured are not between the minimum and maximum values specified above, the firing unit shall be rejected.

3. THE IMPEDANCE MEASURING CIRCUITRY

This test verifies the fuzehead resistance range acceptable to the firing unit.

(a) Equipment required

(i) A Decade resistor box with a minimum range of zero ohm to 10 ohm in 0,1 ohm steps; 1% tolerance

(ii) The test jig as shown in figure 1.

(b) Setting up

(i) Connect the test jig to the Firing Unit.

(ii) Ensure the FAULT/GO switch is in the "GO" position.

(iii) Ensure the "Fault/Go" switch is on the "External" position.

(iv) Connect the decade box to terminals B and D of the test jig.

(c) <u>The Test</u>

<u>Caution</u>

Do <u>not</u> press the FIRE button at any time during this test.

(i) Set the decade box to zero ohm.

(ii) Switch the Firing Unit ON, the SAFE/ARM switch on SAFE and crank the hand-crank generator.

(iii) Record on the table below which LED's illuminated.

(iv) Repeat the test with the decade box set at 0,4 ; 1,2 ; 2,0 ; 3,0 ; 4,0 ; 6,5 and 8,0 ohm respectively.

RESISTANCE in ohm	FUZEHEAD FAULT LED	INTERLOCK FAULT LED	DISCHARGED LED	READY LED
0				
0,4				
1,2				
2,0				
3,0				
4,0				
6,5				
8,0				

If the table above does not agree with the table below, the unit shall be rejected.

RESISTANCE in ohm	FUZEHEAD FAULT LED	INTERLOCK FAULT LED	DISCHARGED LED	READY LED
0	on	off	on	off
0,4	on	off	on	off
1,2	off	off	off	on
2,0	off	off	off	on
3,0	off	off	off	on
4,0	off	off	off	on
6,5	on	off	on	off
8,0	on	off	on	off

4. <u>THE INTERLOCK CIRCUITRY</u>

This test verifies that if any interlock fault occurs before or during system operation, (such as a door being inadvertently shut) system operation will be automatically aborted.

(a) <u>Equipment required</u>

(i) A storage oscilloscope, Tektronix type number 466 or similar.

(ii) A digital multimeter of input impedance 1 megohm or greater.

(iii) The test jig, figure 1

(b) Setting up

(i) Connect the test jig to the Firing Unit

(ii) Connect the digital voltmeter to terminals D and F, positive on F

(iii) Connect the oscilloscope to terminals A and D, positive on A.

(iv) Ensure the FAULT/GO switch is in the GO position

(v) Ensure the FUZEHEAD RESISTOR switch is on the INTERNAL position.

(vi) Ensure the SAFE/ARM switch is on SAFE.

(vii) Adjust the multimeter to read a maximum of 2,0V D.C.

(viii) Set the oscilloscope into the storage mode. Adjust the vertical sensitivity to 20 mV per division and the horizontal deflection to 1 ms per division.

(c) The Test

(i) Switch the Unit on. Crank the hand-crank till the READY LED illuminates. Record this in the table below.

(ii) Switch the FAULT/GO switch to FAULT. Record which LED illuminates.

(iii) Crank the hand-crank and record which LED's illuminate.

(iv) ARM the firing pack and depress the FIRE button within 2 minutes of (iii). Record the peak voltages on the oscilloscope and voltmeter.

NOTE: If the firing unit is working correctly, these voltages will be very small.

TEST NO	READY LED	INTERLOCK ERROR LED	DISCHARGED LED
(i)			
(ii)			
(iii)			

	Oscilloscope Voltage	Voltmeter Voltage
(iv)		

If the above table disagrees with the one below, the unit is rejected.

TEST NO	READY LED	INTERLOCK ERROR LED	DISCHARGED LED
(i)	on	off	off
(ii)	off	off	on
(iii)	off	on	on

	Oscilloscope Voltage	Voltmeter Voltage
(iv)	Less than 0,1 volt	Less than 2 volt

5. ENERGY TRANSFERRED TO THE LOAD

This test ensures that the energy outputs of the firing unit are sufficient to deploy the system.

(a) Equipment required

(i) A storage oscilloscope, Tektronix type number 466 or similar.

(ii) A digital multimeter of input impedance 1 megaohm or greater.

(iii) The test jig, figure 1.

(b) Setting up

(i) Connect the instruments as in 4b.

(ii) Connect the instruments as in 4b.

(iii) Adjust the multimeter to read a maximum of 200V D.C.

(iv) Set the oscilloscope into the storage mode Adjust the vertical sensitivity to 2 V per division and the horizontal deflection to 2 ms per division.

(v) Ensure that the FAULT/GO switch is on GO.

(vi) Ensure that the INTERNAL FUZEHEAD/EXTERNAL FUZEHEAD switch in on INTERNAL FUZEHEAD.

(vii) Switch the SAFE/ARM switch to SAFE.

(c) The Test

(i) Switch the Firing Unit on. Crank the hand-crank generator till the READY LED comes on.

(ii) Switch the SAFE/ARM switch to ARM and press the FIRE button. Record the oscilloscope peak voltage and time duration of the pulse and the voltmeter voltage in the table below.

(iii) Return the SAFE/ARM switch to SAFE. Record which LED momentarily illuminates.

(iv) Crank the hand-crank generator till the READY LED glows, then crank the hand-crank a further ten times.

(v) Switch the SAFE/ARM switch to ARM and press the FIRE button. Record the oscilloscope peak voltage and time duration of the pulse and the voltmeter voltage in the table below.

(vi) Return the SAFE/ARM switch to SAFE. Record which LED momentarily illuminates.

(vii) Crank the hand-crank generator till the READY LED glows. Wait 30 minutes ± 5 minutes.

(viii) Switch the SAFE/ARM switch to ARM and press the FIRE button. Record the oscilloscope peak voltage and time duration of the pulse and the voltmeter voltage in the table below.

(ix) Return the ON/OFF switch to OFF. Record which LED momentarily illuminates.

TEST	WHICH LED ILLUMINATED	OSCILLOSCOPE PEAK VOLTAGE	OSCILLOSCOPE PULSE TIME	VOLTMETER VOLTAGE
(ii)				
(iii)				
(v)				
(vi)				
(viii)				
(ix)				

If the above table does not agree with the table below, test VII to IX shall be repeated twice. This is to ensure correct formation of all electrolytes within the firing unit. If the above table still does not comply with the one below, the Firing Unit shall be rejected.

TEST	WHICH LED ILLUMINATED	OSCILLOSCOPE PEAK VOLTAGE	OSCILLOSCOPE PULSE TIME	VOLTMETER VOLTAGE
(ii)		Not less than 3 V	Not less than 2 milliseconds before the measured voltage drops below 3 V	Not less than 65 V
(iii)	Discharged LED			
(v)		Not greater than 8 V		Not greater than 90 V
(vi)	Discharged LED			
(viii)		Not less than 3 V	Not less than 2 milliseconds before the measured voltage drops below 3V	Not less than 60 V
(ix)	Discharged LED			

APPENDIX 9

THE DEVELOPMENT PROCESS

A project or programme is born when:

(a) Armscor is approached by the SADF with a staff requirement for a weapon system that is required either to meet a new threat or to comply with a change in military doctrine.

(b) A technology funded by an affiliate has reached maturity and can form the basis for a new weapon concept for which there exists a need in the SADF without having been defined in the form of a staff requirement.

In the latter case, a concerted marketing effort by the affiliate often preceeds the receipt of a RFP from Armscor.

Before development can start, the staff requirement has to be translated into a high level technical requirement describing the primary functions the system must be able to execute under certain constraints (operational or service environment). This document usually evolves through close interaction between the designated main contractor, Armscor and the SADF project officer.

Depending on whether this specification permits the use of well established technology, techniques and proven weapon concepts, there will or will not be a requirement for a Conceptual Phase. If this spec. calls for novel ideas and new technology, the latter applies. Often the project study and conceptual phase are not separable.

CONCEPTUAL PHASE (3 months to 8 months)

This is the phase in which the weapon system or other materiel is envisioned, problems considered, and technically feasible solutions developed. Before entering this phase there must be a need for the materiel that will eventually evolve. Serious consideration is always given to use of improvement of existing materiel before proposing a new system.

This phase involves much more than merely dreaming up a system. Program issues must be defined and documented. Logistics support and training must be considered. Costs and schedules are projected, and an outline development plan, including the system specification, is prepared. The system specification describes the system function together with tests to assure that functional requirements will be met.

Depending on the complexity of the weapon system concept proposed and accepted, there will or will not be a requirement for a detailed definition study. Experience however, has taught that the more time is spend on this phase, the fewer design changes and cost overruns occur at a later stage.

DEFINITION PHASE (6 months to 24 months)

During this phase several subcontractors may be tasked to develop the alternative weapon concepts into detailed system configurations with subsystem performance specifications based on:

(a) Computer modeling

(b) Laboratory type models

(c) Technology demonstrations

On the completion of the definition phase, every subcontractor submits a complete delineation of how it plans to develop, document, and test the system. Proposal documents are submitted by each prospective contractor, and every facet of the program is covered. Depending upon urgency and complexity, the time alloted for contractor response may vary from a few weeks to several months. While the System Specification explicity defined system objectives, the contractor must show that his proposal meets or exceeds these objectives. The basic tools for demonstrating the soundness of his approach are the Development Specifications which is the most important output of the definition phase. This document defines the functional requirements for each major configuration item. In other words, certain functions of the overall system are assigned or "Allocated" to a particular CI. These specifications, supplemented interface drawings constitute the subsystem specifications. Each development specification should be in sufficient detail to describe effectively the performance characteristics that each configuration item is to achieve when a development item is to evolve into a detail design for production. The development specification should be maintained current during development and can only be updated via ECP procedure.

A Configuration Management Plan is also prepared during this phase.

The Main outputs of this phase is therefore:

- A Development Proposal
- A Development Specification
- A Configuration Management Plan
- A Definition Report

DEVELOPMENT PHASE

Depending on the complexity of the system being developed, this phase may take up to 8 years to complete.

Typically an unguided system will take 3 to 5 years and a guided system 4 to 8 years to develop. The majority of development projects are sub-divided into four distinct phases, viz XDM ADM, EDM and Design Qualification. For a simple system the XDM and ADM phases are often combined.

In order to facilitate adequate control over the development process, a major programme would be sub-divided into projects often grouping together similar activities or activities within a single engineering discipline. These projects are once again sub-divided into elements based either on engineering discipline or phase. This work breakdown structure is depicted in Fig 1.

Apart from the matrix management principle that may or may not apply to a project, the actual control of the project falls primarily under two people, each with a unique responsibility, viz

a. The programme/project managers who takes responsibility for the managerial aspects with reference to cost and schedule and enlists the support of a planner and contracts administrator to execute his functions.

b. The systems engineer who carries the responsibility for overall technical conformance of the product with reference to performance, configuration, reliability and maintainability.

Like the skeleton and the flesh constitutes the body, these two inter-dependant functions constitute the project management.

XDM PHASE

The prime inputs for this phase is the Development Specification and Configuration Management Plan generated during Definition. The main objectives are:

a. To prove that the prescribed subsystem performance can be attained at unit level.

b. Evaluate the influence of environmental conditions on the individual subsystems performance.

c. Detail functional, electrical and mechanical interfaces between CI's.

d. Identify critical items, do FMECA on such items and place under configuration control.

e. Draw up and implement quality plan, do reliability allocation.

f. Do initial projection tests in the case of a projected weapon (rocket or missile).

g. Detailed stress analysis on all structural components.

h. Design reviews on all CI's.

The Main Outputs are

- Design and test reports
- Design drawings
- Revised development specification
- Hardware as required

Assorted other documents typical of this phase are listed in Appendix A.

The (objectives of) and (procedure for) the design reviews are detailed in Appendix B.

ADM PHASE

Early in this phase, the development specification, which has been undergoing a process of evolution, is finalised and deviations can only be negotiated through the systems engineer who would assess the implication of any such change in subsystem performance on the overall system.

During this phase the main emphasis is placed on:

1. In depth evaluation of individual subsystem performance under environmental extremes.

2. Integration of subsystems and evaluation of system performance.

Considerable time is spent on definition of interfaces.

In support of these activities, much attention is given to:

1. Detailed FMECA's on all subsystems.

2. Sub and main system tolerance analysis.

3. Reliability testing.

4. Refining of design in order to comply with manufacturing requirements.

Once again, the outputs of this phase is primarily in the form of reports, viz

1. ADM Design and Test Reports

2. FMECA reports

3. Tolerance Analysis

4. Reliability Analysis and Predictions.

5. Preliminary Subsystem Product Specs.

6. Design Drawings on Numerical Issue

EDM PHASE

At this stage of a programme, there exists a product that meets the prime performance objectives, but which does not necessarily have the reliability, maintainability, manufacturability and lacks value engineering as well as finish. The EDM phase therefore, concentrates effort on the following aspects:

1. Industrialisation of designs that have hitherto often taken little cognisance of mass production techniques.

2. Generation of MRI listed documents on numerical issue. See Appendix A for complete information.

3. Build a pre-qualification lot of hardware on a production line evaluating the validity of assembly and inspection procedures.

4. Do a pre-qualification test on all CI's to prove conformance with technical and performance requirements.

5. Revise designs where shortcomings are identified and prove modifications.

6. Issue MRI for design qualification build. (Documents to be approved by QMG and Armscor).

7. Build qualification lot to MRI standards and present for drawing of qualification sample.

8. Execute qualification tests.

DEFINITIONS

SYSTEM

A composite of subsystems, assemblies (or sets), skills, and techniques capable of performing and/or supporting an operational (or non-operational) role. A complete system includes related facilities, items, material, services, and personnel required for its operation to the degree that it can be considered a self-sufficient item in its intended operational (or non-operational) and/or support environment.

SYSTEM SPECIFICATION

A document which states the technical and mission requirements for a system as an entity, allocates requirements to functional areas (or configuration items), and defines the interfaces, between or among the functional areas.

DEVELOPMENT SPECIFICATION

A document applicable to an item below the system level which states performance, interface and other technical requirements in sufficient detail to permit design, engineering for service use and evaluation.

PRODUCT SPECIFICATION

A document applicable to a production item below the system level which states item characteristics in a manner suitable for procurement, production and acceptance.

CONFIGURATION MANAGEMENT (CM)

A discipline applying technical and administrative direction and serveillance to:

a Identify and document the functional and physical characteristics of a configuration item.

b Control changes to those characteristics and record and report change processing and implementation status.

CONFIGURATION ITEM (CI)

An aggregation of hardware/software or any of its discrete portions, which satisfies an end-use function and is designated by configuration management. CI's may vary widely in complexity, size and type; from an aircraft, electronic, or ship system to a test meter or round of ammunition. During development and manufacture, CI's are those specification items whose functions and performance parameters must be defined (specified) and controlled to achieve the overall end-use function and performance. Any item required for logistic support and designated for separate procurement is a configuration item.

ENGINEERING CHANGE PROPOSAL (ECP)

A document recording proposal approvals for any change affecting an established baseline.

WORK BREAKDOWN STRUCTURE (WBS)

A product-oriented family tree, composed of hardware, software, services and other work tasks, which results from project engineering effort during the development and production of a defense materiel item, and which completely defines the project/program. A WBS displays and defines the produc(s) to be developed or produced and relates the elements of work to be accomplished to each other and to the end product.

CRITICAL ITEM

An item within a configuration item (CI) which, because of special engineering or logistic considerations, requires and approved specification to establish technical or inventory control at the component level.

SCHEMATIC OF PROGRAM RESPONSIBILITY STRUCTURE

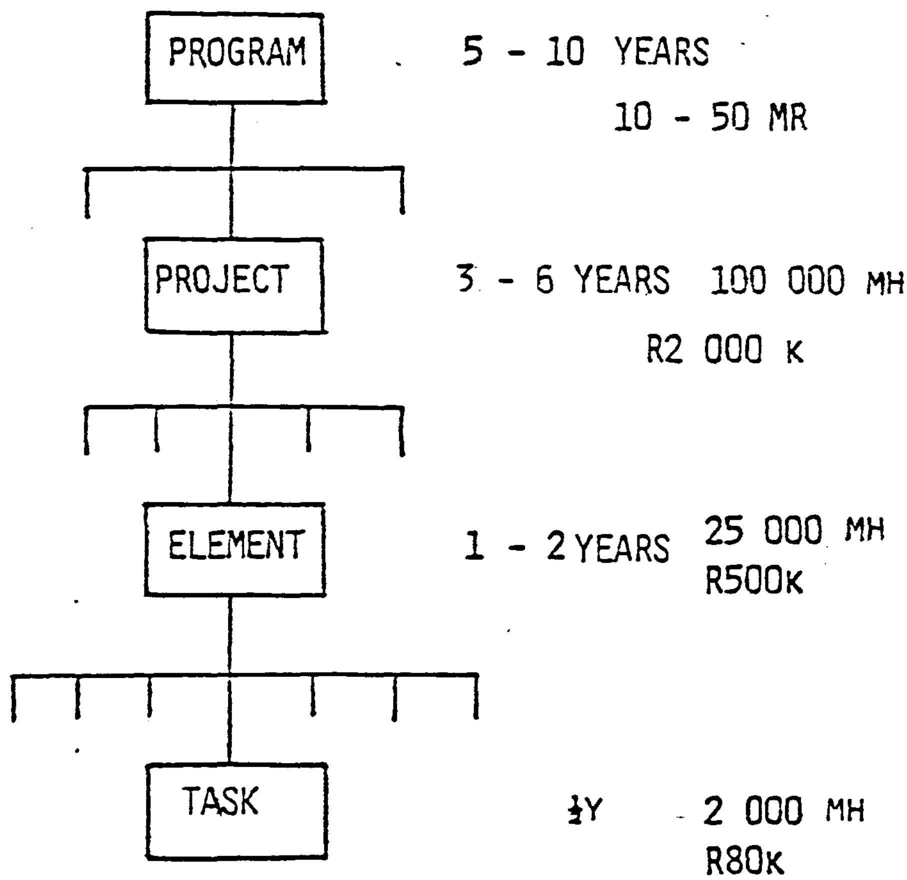


FIG. 1

APPENDIX A

DOCUMENTATION REQUIREMENT FOR DEVELOPMENT

REMARKS		DOCUMENTATION	PHASE
CONTRACTUAL BASE-LINE	26	SYSTEM SPECIFICATION	CONTRACTUAL
		DETAIL PLANNING	
		LIST OF ARMSCOR C ITEMS	
		LIST OF CUSTOMER F EQUIPMENT	
		SADF SPARE PARTS	
	36	CLASSIFICATION OF DEFECTS	
		CONTROLLED RELEASE ITEMS	
		ACCEPTANCE CRITERIA	
	02	DETAIL DRAWING (DRAFT ISSUE)	XDM
	42	PROCESS SPECIFICATION	
	67	QA REQUIREMENT (WRITTEN)	
	68	QA REQUIREMENT (DRAWN)	
PRELIMINARY DESIGN REVIEW	27	CRITICAL PARTS LIST	
	66	DEVELOPMENT DATA COLL & INDEX	
	30	DESIGN REVIEW REPORT	
	64	PROJECT NUMBERING PROJECT	
	00	HARDWARE FAMILY TREE (LEVEL 2)	
DEVELOPMENT BASE-LINE AT START OF ADM PHASE	28	FINAL CONTRACT SPEC	ADM
	62	PREL APPROVAL SUB-SYSTEM SPEC	
	88	DOCUMENT RECORD INDEX ARMSCOR C I LIST	
	36	UPDATE CLASS OF DEFECTS	
	46	CLASSIFICATION OF CHAR	
DEVELOPMENT DESIGN REVIEW		CONTROLLED RELEASE ITEMS	
		DEVELOPMENT PLAN	
	06	DOCUMENTATION PLAN	
	03	ASSEMBLY DRAWING DRAFT	
	08	ITEM LIST ISSUES	
	30	DESIGN REVIEW REPORT	
QUALIFICATION BASE-LINE	05	SCHEMATIC DRAWING	EDM
	40	PRODUCTION FLOW DIAGRAM	
	41	PRODUCT SPECIFICATION	
	49	INSPECTION INSTRUCTION	
	50	ASSEMBLY INSTRUCTION	
	54	QUALIFICATION TEST INSTRUCTION	
PRE-QUALIFICATION DESIGN REVIEW TO VERIFY DOCUMENTS ON MRI BEFORE QUALIFICATION BUILD	57	MANUFACTURING PROCESS DRAWING	
	58	PACKING, SHIPPING AND HANDLING	
	81	ACCEPTANCE TEST SPECIFICATION	
	83	QUALIFICATION TEST SPEC	
	85	MANUFACTURING SPEC	
	09	DRAWING AND DOCUMENT RELEASE NOTE	
	88	DOCUMENT RECORD INDEX	
	89	DEC AND SCHEDULE OF TEST	
	00	HARDWARE FAMILY TREE (LEVEL 6)	
	02	DETAIL DRAWING NUMERICAL	
	03	ASSEMBLY DRAWING ISSUES	
	08	ITEM LIST	
	30	DESIGN REVIEW REPORT	

REMARKS		DOCUMENTATION	PHASE
NOTE: IF THE EDM IS USED FOR QUALIFICATION THE MRI MUST BE SIGNED PRIOR TO THE COMMENCEMENT OF FABRICATION POST-QUALIFICATION DESIGN REVIEW TO VERIFY DOCUMENT ON MRI FOR PRE-PRODUCTION PURPOSES	22 33 38 30	DEVELOPMENT REPORT QUALIFICATION TEST REPORT MASTER RECORD INDEX DESIGN REVIEW REPORT	QUALIFICATION
PRODUCTION DESIGN REVIEW TO REVIEW AND UPDATE DOCUMENTS ON MRI BEFORE PRODUCTION	30 55	DESIGN REVIEW REPORT APPARATUS USER INSTRUCTION	PRODUCTION

APPENDIX B

DESIGN REVIEWS

PURPOSE

The purpose of an internal design review is as follows:

a. To confirm that the design takes adequate cognisance of the following considerations:

   (i) System requirements;

   (ii) Critical technologies;

   (iii) Production requirements;

   (iv) Operating requirements;

   (v) Maintenance requirements; and

   (vi) Lifetime requirements.

b. To ensure that alternatives have been adequately explored;

c. To confirm that the correct priorities have been assigned to the design requirements when making design decisions;

d. To ensure that the design decisions are adequately documented for future requirements;

e. To detect gross errors by calling on the cumulative experience of the review team;

f. To provide training opportunities for young designers through discussion with experienced members of the team; and

g. To define the evaluation tests to be conducted on the development models.

PROCEDURE

The internal design review is a team exercise in problem solving - not an audit prior to a design acceptance.

The documentation required for the review should be that which is necessary for the designer in the normal course of development, and must not place an additional manpower requirement on the development team.

The organisation of the design review should be the responsibility of the project or element manager.

The composition of the design review team and the agendas for the meetings shall be agreed by the System Engineer.

The general form of the design review will be as follows:

a. Information meetings at which the design data pack is distributed and the design is presented, the alternatives are named, and the main reasons for the design choice are given;

b. Team members in specialised fields evaluate the design in terms of the requirements applicable to their specific fields;

c. Design review meeting which gives the following outputs:

   (i) Recommended design changes;

   (ii) Guidelines for the evaluation programme; and

   (iii) Requirements for documentation in laboratory Blue Books;

d. A follow-up meeting to check on the implementation of these requirements, must be held <u>before</u> the evaluation programme;

e. Final wind-up meetings after the evaluation and flight tests.

XDM DESIGN REVIEW

This must be conducted at a time which satisfies the following criteria;

- The design is reasonably well defined; and
- There is sufficient time to perform urgent modifications before the evaluation tests.

ADM DESIGN REVIEW

This must be conducted before the orders for long delivery times are placed.

If possible, the ADM design should be reasonably well defined.

EDM DESIGN REVIEW

This must be conducted before the major orders for EDM build equipment are placed.

The EDM design should be reasonably well defined.

PDM DESIGN REVIEW

This must be conducted once the pre-qualification tests have been completed, in order to finalise the EDM design.

R E F E R E N C E S

A P P E N D I X 1 0

INTRODUCTION

The method of referencing is based on the Harvard System, but differs in that alphanumeric ordering of document number is used, instead of author. This is because the author of the referenced volumes is often given as the Department of Defence, and is considered confusing.

APPENDIX 10

B 57 Radio System, Volumes 1 and 2.
Barlow's Communications (Pty) Ltd, 1980

These volumes describe the design, maintainance, installation and operation of the B57 vehicle radio system.
Complete printed wiring board layouts, circuit diagrams and all pertinent information is given. The complete parts catalogue for all units and sub assemblies is included.

Considine, D M
Handbook of Applied Instrumentation
Mc Graw Hill

This handbook includes detailed description of instrumentation applicable in most industries and scientific fields.
The following chapter was of particular interest.

Nuclear Indicating Safety Approach - Nuclear Reactor Instrumentation
V.S. Underkoffler
Systems Equipment Section, Research and Development
Department, Leeds and Northrup, North Wales.

Nuclear reactor instrumentation encounters a unique variety of problems, varying from conventional instrumentation to radiation hardened systems with built in redundancy. Reliability and safety of these systems is of paramount importance.

INSPEC
Electronic Reliability Data, A guide to selected components
Institution of Electrical Engineers London and New York, 1981

This publication presents electronic component reliability data. This data is a condensation of Systems Reliability Services reliability data bank. Information is related to both field and laboratory experience, encompassing environmental, temperature, stress, packaging, quality and reliability growth factors. Information on failure modes is also presented.
A list of abstracts dealing with the above is also catalogued.

ISBN 0 408 70662 7   3rd edition   1975
Classification and Indexing in Science
B C Vickery

This book is intended primarily as a study of method, constructing systems of information retrieval and techniques of subject analysis. The contents range from the need for classification to classification in indexing. Of prime interest were the alphabetical subject index, cross referencing and indexing order.

ISBN 3-18-41 9071-4
Sealed Nickel Cadmium Batteries
Varta Batterie -AG, 1982 (Prof Dr G Lander)

This book contains scientific information concerning the design, principle and construction of sealed nickel cadmium batteries. Environmental effects, electrode and cell mechanics are also discussed. Further information is also introduced in the field of application techniques, inclusive of charging and discharging methods.

KA 3117
Standard General Requirements for Electronic/Electrical Equipment.
Armscor Pretoria, 1983

This document provides a guide for quality assurance personnel in the field of electronic/electrical engineering. Safety factors are introduced in part one, while acceptable and unacceptable design/manufacturing techniques are discussed in detail in succeeding chapters. Soldering, printed wiring boards, wiring harnesses and metal finishes are some of the subjects dealt with in detail.

MIL-B-18D, superceeded by E
Batteries, Non Rechargable, Dry
Department of Defence, Washington

MIL-C-5015
Connectors, Electrical, Circular Threaded Antype,
General Specification for
Department of Defence, Washington

MIL-E-8189H
Electronic Equipment, Missiles, Boosters and Allied Vehicles,
General Specification for
Department of Defence, Washington, 1980

This specification covers the general requirements for hardware that is required to operate at altitude, including short time exposure to space environments.
Electronic equipment is classified into 6 classes, dependant on minima and maxima of operating temperature and altitude. Many of the general requirements are cross referenced to MIL-STD-454.

MIL-E-47231 (MI)
Electrical Components, Potting of
Department of Defence, Washington, 1974

This specification covers the requirements of a polysulfide base compound for potting or sealing electrical components. Storage procedures, potting procedures and quality assurance of the finished product are discussed.

MIL-HDBK-217D
Reliability Prediction of Electronic Equipment.
Department of Defence, Washington, 1983

This handbook superceeded MIL-HDBK-217B and has since been superceeded by MIL-HDBK-217E dated 1986. Uniform methods for predicting the reliability of electronic equipment and systems are established. Two methods of prediction are detailed: - Part Stress Analysis and Parts Count. Parts Count is used in the early design phase, needing less information, while Parts Stress Analysis analyses each component and it's stress level, hence can only be completed in later design phases.

MIL-HDBK-338
Electronic Reliability Handbook
Department of Defence, Washington, 1984

This databook consists of 1063 pages encompassing 2 volumes. It contains detailed, up to date information concerning practical, pertinent guidelines for use by design and allied personnel. The object is to produce and deploy reliable and maintainable electronic systems at minimum life cycle cost. Consequently the major sections of this handbook concern reliability and maintainability analysis. Different methods of quantitising these analysis are introduced, with the expressed object of optimising system effectiveness.

MIL-R-11 1A
Resistors, Fixed, composition, Insulated, General Specification for
Department of Defence, Washington

MIL-R-10509 F
General Specification for Resistors, Fixed, Film (High Stability)
Department of Defence, Washington, 1981

This specification covers the general requirements for high-stability, film, fixed resistors of 0,1; 0,25; 0,5 and 1,0 percent resistance tolerance, which are relatively stable with respect to time, temperature and humidity. The method of indicating the actual resistance is described. Data pertaining to the resistance temperature characteristic, derating factors, power ratings and maximum percentage change in resistance is shown.

MIL-STD-454E
Standard General Requirements for Electronic Equipment.
Department of Defence, Washington, 1976

This standard is the technical baseline for the fundamental design and construction requirements of electronic equipment for the Department of Defence. Topics such as safety (personnel hazard), flammable materials, workmanship, dissimilar metals, electronic components, welding, micro electronic device, electomagnetic interference control and human engineering are discussed.

MIL-STD-461 B
Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference
Department of Defence Washington, 1980

The objective of this publication is to set standards relating to the emission of and susceptibility to Electromagnetic Interference of any piece of equipment. This ensures the effectiveness of systems in a complex electromagnetic environment. Permissable levels of both electric and magnetic fields are tailored to the frequency range under consideration and the environment in which it is installed. They are classified according to conducted, radiated, emissitted, susceptibility and any unique requirements.

MIL-STD-785B
Reliability Program for Systems and Equipment, Development and Production.
Department of Defence, Washington, 1980

This standard provides general requirements and specific tasks for reliability programs during the development, production and initial deployment of systems and equipment. Methods for task tailoring is provided, based on the equipment and its operating environment. The methods introduced include reliability modelling and predictions, failure modes, effects, and criticality analysis, stress screening and production reliability.

MIL-STD-810D
Environmental Test Methods and Engineering Guidelines.
Department of Defence Washington, 1983

This standard provides guidelines for tailoring environmental testing to suit the system being designed and the environment in which it is expected to function. The application of environmental testing early in the development phase is encouraged, to disclose design deficiencies and verify corrective action. This testing also assesses equipment suitability to its intended operational environment.

MIL-STD-1275A(AT)
Characteristics of 28 Volt DC Electrical Systems in Military Vehicles
Department of Defence, Washington 1981

Conformance to this standard provides for greater compatibility between power supply and utilisation equipment. Power characteristics will be confined to definitive limits, and these limits are used as output data for power supplies and input data for utilising equipment.
Information concerning test methods and characteristics of those tests is also discussed.

MIL-STD-1472C
Human Engineering Design Criteria for Military System, Equipment and Facilities.
Department of Defence Washington, 1981

The purpose of this standard is to present human engineering design criteria, principles and practices to achieve mission success through integration of the human into the system.
This achieves efficiency, reliability and safety of the system during training, operation and maintenance, making it easy for the operator to use the system effectively.

It must be noted, however, that the physical structures and sizes of the human moles are American Dimensions. South African dimension are generally larger.

MIL-STD-1629 A
Procedures for Performing A Failure Mode, Effect and Criticality Analysis
Department of Defence Washington, 1984

The objective of the Failure Mode, Effect and Criticality Analysis (FMECA) is the early identification all possible catastrophic and critical failure properties of a piece of equipment, so they can be minimised or eliminated. This publication describes the application of this design tool to the item under analysis.

MIL-S-3950
Switch, Toggle, Environmentally Sealed, General Specification for
Department of Defence, Washington

MIL-W-22759D
Wire, Electric, Fluoropolymer-Insulated Copper or Copper Alloy.
Department of Defence, Washington, 1980

This specification covers fluoropolymer-insulated single conductor electric wires. The wire may be tin, silver or nickel coated conductors of copper or copper alloy and the fluoropolymer may be used alone or in combination will other insulating materials. Various tests and characteristics of the wire are examined, so helping to determine suitability for various applications.

QR - 844 - B
Guidelines for Performing Failure Modes and Effects Analysis on Missile, Rocket and Laser Weapon Systems and Support Systems.
U S Army Missile Command, 1979

This document establishes a uniform procedure for conducting and documenting a systematic, critical examination of all potential failure modes and failure mechanism of a design. This analysis determines those items contributing most to system unreliability and operational safety hazards.

RDH 376
Reliability Design Handbook
R T Anderson IIT Research Institute Chicago, 1979

This book is principally for designers of military equipment, to help the engineer design reliability into the equipment during its basic design stage. It includes theoretical and cost considerations, also covering considerations such as component selection, derating, redundancy and environmental design evaluation. Basic design safety criteria in also introduced.

SABS 0111-1980 (ISBN 0-626-05582-2)
Code of Practice for Engineering Drawing
South African Bureau of Standards

This code of practice covers mechanical engineering drawing and includes the preparation of drawings of mechanical parts in the fields of mechanical, civil and electrical engineering, but does not include architectural and building construction drawing.

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