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AN IMPROVED SUSCEPTIBILITY TEST FOR THE EMC TESTING OF
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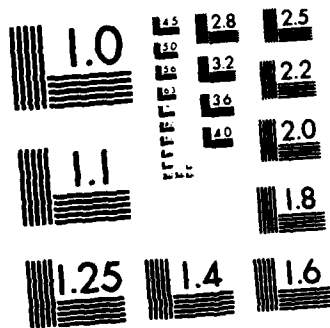
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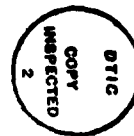
AN IMPROVED SUSCEPTIBILITY TEST FOR THE EMC TESTING
OF AEROSPACE EQUIPMENT

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N. J. Carter

SUMMARY

This Memorandum describes a revised conducted susceptibility EMC test for avionic equipment. The test covers the frequency range 50 kHz to 400 MHz and can be used in conjunction with existing EMC tests. Its implementation is described in a form suitable for direct incorporation in project requirements.



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1 INTRODUCTION

This Memorandum describes a conducted susceptibility test method developed by the EMC Section of RAE Flight Systems Department. It is intended to supplement present radiated susceptibility tests, and is part of a programme to overcome some of the shortcomings of EMC standards MIL-STD-462¹ and BS.3G.100². Criticism has long been levelled at existing EMC qualification tests by A&AEE, Boscombe Down, because they provide no information that can be used to assess the safety margins of the system when it is installed and operated in the aircraft during clearance trials. A discussion of the background to this development may be found in Ref 3.

The test described in this Memorandum will be incorporated in new project specifications and the procedures outlined in this Memorandum are those to be used in such cases.

2 PURPOSE

The purpose of this test is to confirm that rf signals in the range 50 kHz to 400 MHz, when coupled on to a test sample's interconnecting cable looms and power supply lines, will not cause either degradation of performance or malfunction. In addition it will provide an amplitude/frequency malfunction signature for the system which, when compared with the levels of current on the looms (or cables) as caused by onboard and external transmitting sources and measured during clearance trials, will assist in the establishment of adequate safety margins.

3 APPLICABILITY

Cable looms which connect the test sample to other equipments in the aircraft system (including primary power lines) or those interconnecting units of the test sample are subject to this test. Cable looms can be tested as a whole or individual wires can be tested. The looms or individual wires to be tested will be defined in the equipment test plan but some basic ground rules are:-

- (a) All looms will be tested as a whole, connector by connector (see section 5.3.3(a) below); if primary power lines use the same connector as control and signal lines they shall also be included in the test.
- (b) Primary power lines shall in addition be tested individually, injecting and monitoring on each line in turn. (If the power lines are in a loom containing other lines they will have to be separated from the loom for this part of the test.)
- (c) On flight safety critical equipment (including sub-systems responsible for the control and/or initiation of electro-explosive devices) individual wires will be selected for testing in addition to (a) and (b) above. These wires shall be those which a study of the equipment suggests may be the most sensitive, and should be defined in the equipment test plan.

4 APPARATUS

- (a) Current injection probes: AIL 93686-1** 50 kHz to 2 MHz
 ERA 36* 2 MHz to 200 MHz
 ERA 37* 200 MHz to 400 MHz.
- (b) Calibration jig for the current injection probes*.
- (c) Current monitoring probes: AIL 91550-1** 50 kHz to 2 MHz
 AIL 94111-1** 2 MHz to 400 MHz.
- (d) Signal source - 50 kHz to 400 MHz.
- (e) 200 W power amplifier - 50 kHz to 400 MHz.

This amplifier must be capable of supplying the full rated power into the current injection probes (which have a high VSWR) with a harmonic content of less than 10%.

- (f) Spectrum analyser - 50 kHz to 400 MHz (or rf voltmeter).
- (g) Directional coupler - 50 kHz to 400 MHz (eg Amplifier Research DC2000).

No other injection or monitoring probes may be used for the purposes of (a) or (c) without the express permission of Head FS(F) Department, RAE Farnborough.

5 TEST PROCEDURE5.1 General

The test procedure has two main elements:

- (i) Calibration of the current injection probes, which *must* be done prior to each equipment test or series of consecutive tests.
- (ii) The equipment test.

5.2 Calibration procedure for injection probe

The following calibration procedure shall be performed prior to the test or series of tests using the same test equipment layout and injection probes as will be used for the test. The injection probe shall be calibrated in the calibration jig as shown in Fig 1. Figs 2 to 4 show constructional details of the calibration jig (courtesy of ERA Technology Limited). This calibration jig shall be terminated in a 50 Ω , 50 W rf coaxial load at one end and a 50 Ω spectrum analyser or rf voltmeter at the other. A 50W power attenuator will be required to protect the spectrum analyser. The VSWR of the terminations at both ends of the calibration jig shall be less than 1.2:1 over the frequency range of the test. The injection probe is fed with power from the signal source via the power amplifier. The limits specified for this test method are in terms of the current induced in the calibration jig. Two levels are used:

- (a) An accept/reject level up to which the performance of the test sample should not be affected.

* These current injection probes and calibration jig have been developed for RAE under an MOD(PE) extramural research contract and are available from ERA Technology Limited.

** Available from Eaton-Ailtech Limited, Crowthorne, Berks.

(b) A test level which is higher than the accept/reject level, up to which the equipment is tested to enable a malfunction signature to be obtained for the line or cable loom under test. The test sample must be capable of being tested to this higher level without suffering permanent damage.

The test signal supplied to the injection probe shall be increased until the voltmeter or spectrum analyser indicates that the accept/reject level of current shown in Fig 5 is flowing in the calibration jig. The forward power flow to the probe shall be recorded. The power shall be increased until the test level current shown in Fig 5 is reached, and the forward power flow again recorded. These measurements are to be made over the frequency range 50 kHz to 400 MHz at sufficient intervals to ensure that amplitude variations are less than 1 dB between each measurement point.

The calibration curves shall be shown in the test report. The forward powers to the current injection probes to give the two levels of current shall become the 'accept/reject level' and the 'test level' respectively, for the equipment test.

5.3 The equipment test

5.3.1 Test layout

(a) The test layout shall be as shown in Fig 6; it is in accordance with normal EMC practices as specified in MIL-STD-461A/462 except where stated below.

(b) The test sample shall be bonded to the ground plane in a manner representative of that used in service, including anti-vibration mountings, if used, with representative bonding jumpers of the correct length/width ratio.

(c) The interconnecting cable looms shall be constructed and terminated in the same manner as on the aircraft with special attention being given to cable type, lead lengths, screening, screen terminations, and division of cable looms.

(d) The power and interconnecting cable looms shall be the same length as on the aircraft if known; if not known they shall be 2 ± 0.1 m long.

(e) All cable looms shall be supported on 50mm high insulated stand-offs (this is to represent capacitance effects between the cable loom and the airframe).

(f) Primary power lines shall be terminated with line impedance stabilising networks (LISN) as defined in BS.3G.100: Part 4: section 2 1980² (details are shown in Fig 7, note the uprated wattage requirements of the damping resistors). A capacitor of at least 8 μ F shall be connected between the supply terminal and ground of each LISN. The measurement port of the LISN shall be terminated in a 50 Ω , 50 W, rf coaxial load with a VSWR of less than 1.2:1 over the frequency range of the test.

(g) Where possible the test sample shall not have to rely on simulated loads or test sets, as any departure from the final aircraft installation decreases the usefulness of the test results in aiding the final aircraft clearance. If simulated loads or test sets are used they must accurately represent the impedance of the real loads over the frequency range of the test.

5.3.2 Test limits

The test sample shall not be susceptible to cw or modulated signals at or below the accept/reject level (as defined in section 5.2) at any frequency in the range 50 kHz to 400 MHz. The modulation used shall be defined in the equipment test plane. When using modulated signals the amplitude shall be that indicated by the peak detector of an rfi receiver (*ie* true peak/ $\sqrt{2}$).

The test sample shall be subjected to increasing power up to the test level as defined in section 5.2 and Fig 5 or until malfunction, whichever is the sooner, in order to establish malfunction thresholds above the accept/reject level. The test sample shall be designed to withstand the test level without suffering damage.

(Note - because of the wide range of circuit impedances and resonances, it is impractical to define the test limits in terms of the current flow in the loom or wire under test. Instead the limits are in terms of the forward power to the injection probe which gives defined currents in the calibration jig.)

5.3.3 Test method

(a) This test may be applied to whole cable looms or individual conductors, those to be tested being defined in the equipment test plan. As a minimum requirement, the injection probe shall be connected around the complete cable loom and subsequently around any branches of that loom. In all cases the current monitor probe shall be connected around the complete cable loom 50 mm from the connector (see (c) below).

(b) The calibration procedure described in section 5.2 shall be performed prior to the commencement of the tests.

(c) The current monitor probe, which is used to measure the current actually induced on the loom or conductor under test, shall be fitted around the loom or conductor under test such that the face of the monitor probe nearest the test sample's connector is 50 mm from that connector (Fig 6). If the overall length of the connector and backshell exceeds 50 mm, the monitor probe shall be placed as close to the connector's backshell as possible and its position noted in the test report.

(d) The current injection probe shall be fitted around the loom or conductor under test such that the separation of the adjacent faces of it and the current monitor probe is 50 mm.

(e) At each test frequency, the signal amplitude shall be gradually increased from zero until malfunction occurs or the test level is reached. Two parameters shall be recorded: the induced current in the loom or wire (50 mm from the connector under test as measured by the monitor probe) and the forward power to the injection probe. The induced current will be used to provide information to the aircraft clearance agency and the forward power shall be assessed against the accept/reject level.

(f) At frequencies where the test sample is susceptible, the signal amplitude shall be reduced until a threshold of susceptibility is determined. Check for hysteresis

in signal amplitudes by decreasing and then increasing through the susceptibility threshold. The lesser of the two shall be recorded.

(g) Typical results are shown in Figs 8 and 9.

Acknowledgment

The author acknowledges the support given in the development of this test method by his colleagues and staff from ERA Technology Limited and the advice given by A&AEE Engineering Division. Acknowledgment is also given to Westland Helicopters Limited for supporting the use of this test in their projects.

Table 1

DETAILS OF THE INDUCTOR SHOWN IN FIG 7a
(FROM UNPUBLISHED WORK BY ERA TECHNOLOGY LIMITED)

Current rating (A)	Inductance (μ H)	Inside diameter (mm)	Length (mm)	Number of turns	Conductor cross section (mm)
10	5	25.4	32	20	1.6 diameter
100	5	50	115	18	6 diameter
500	5	90	178	11	12.5*12.5 square

REFERENCES

- | <u>No.</u> | <u>Author</u> | <u>Title, etc</u> |
|------------|---------------|--|
| 1 | - | MIL-STD-462 Electromagnetic interference characteristics,
measurement of.
Department of Defence (USA) |
| 2 | - | General requirements for equipment for use in aircraft: electrical
equipment: electromagnetic interference at radio and audio
frequencies.
British Standards Institution, BS.3G.100: Part 4: section 2, 1980. |
| 3 | N.J. Carter | The EMC testing of aircraft equipment.
AGARD Lecture Series 116, August/September 1981 |

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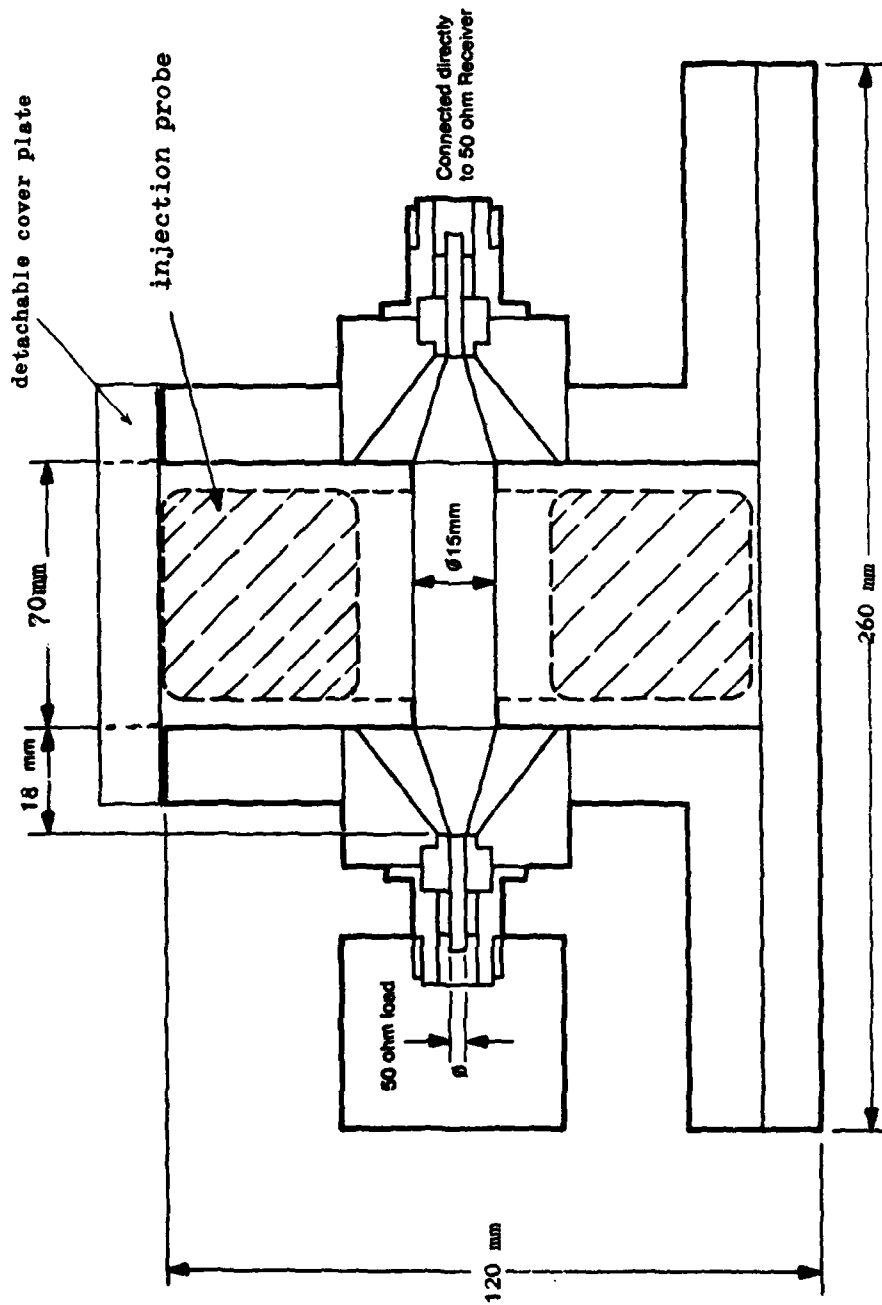


Fig 1 Injection probe calibration jig

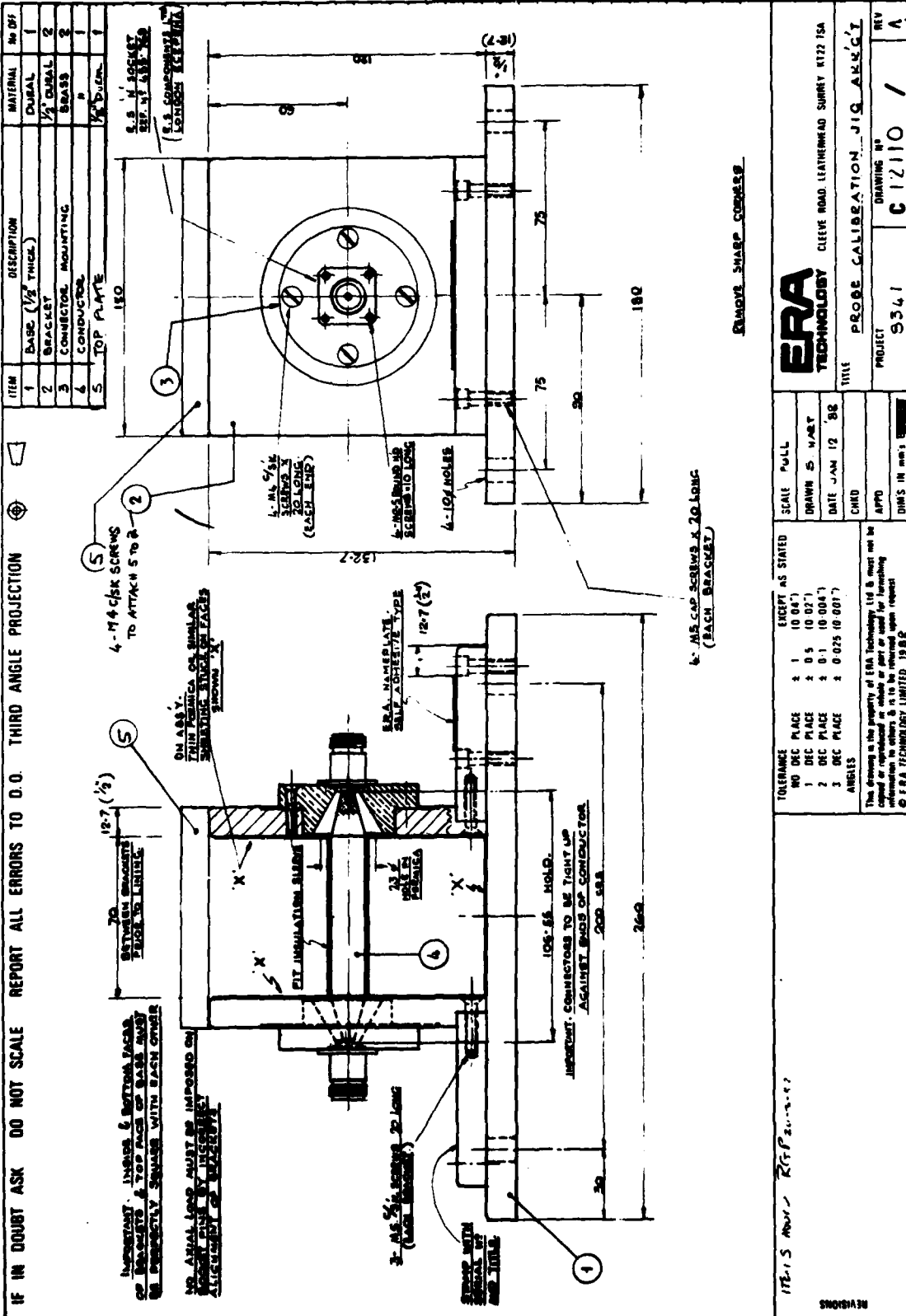


Fig 2 Constructional details of the calibration jig

Fig 4

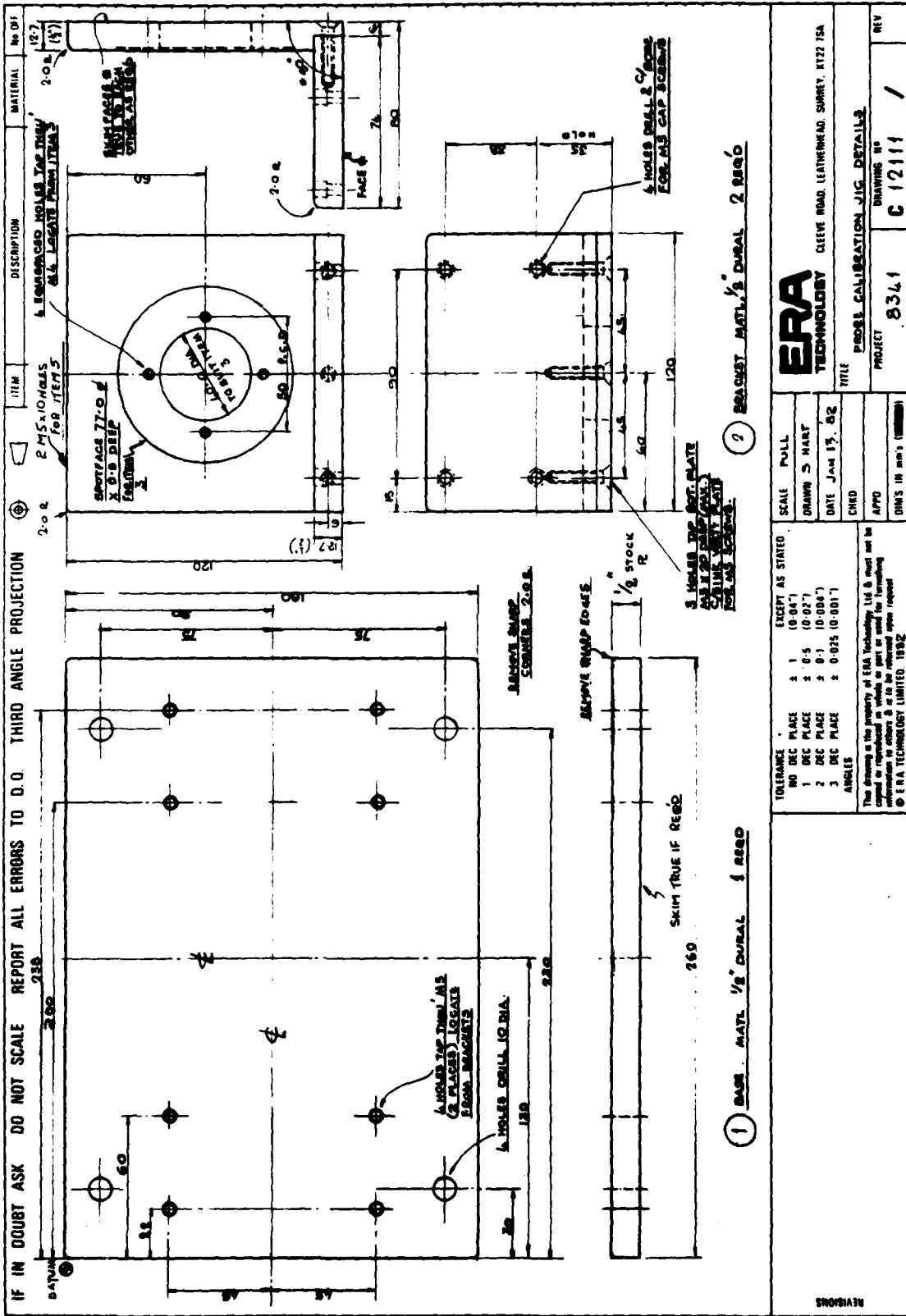


Fig 4 Constructional details of the calibration jig (concluded)

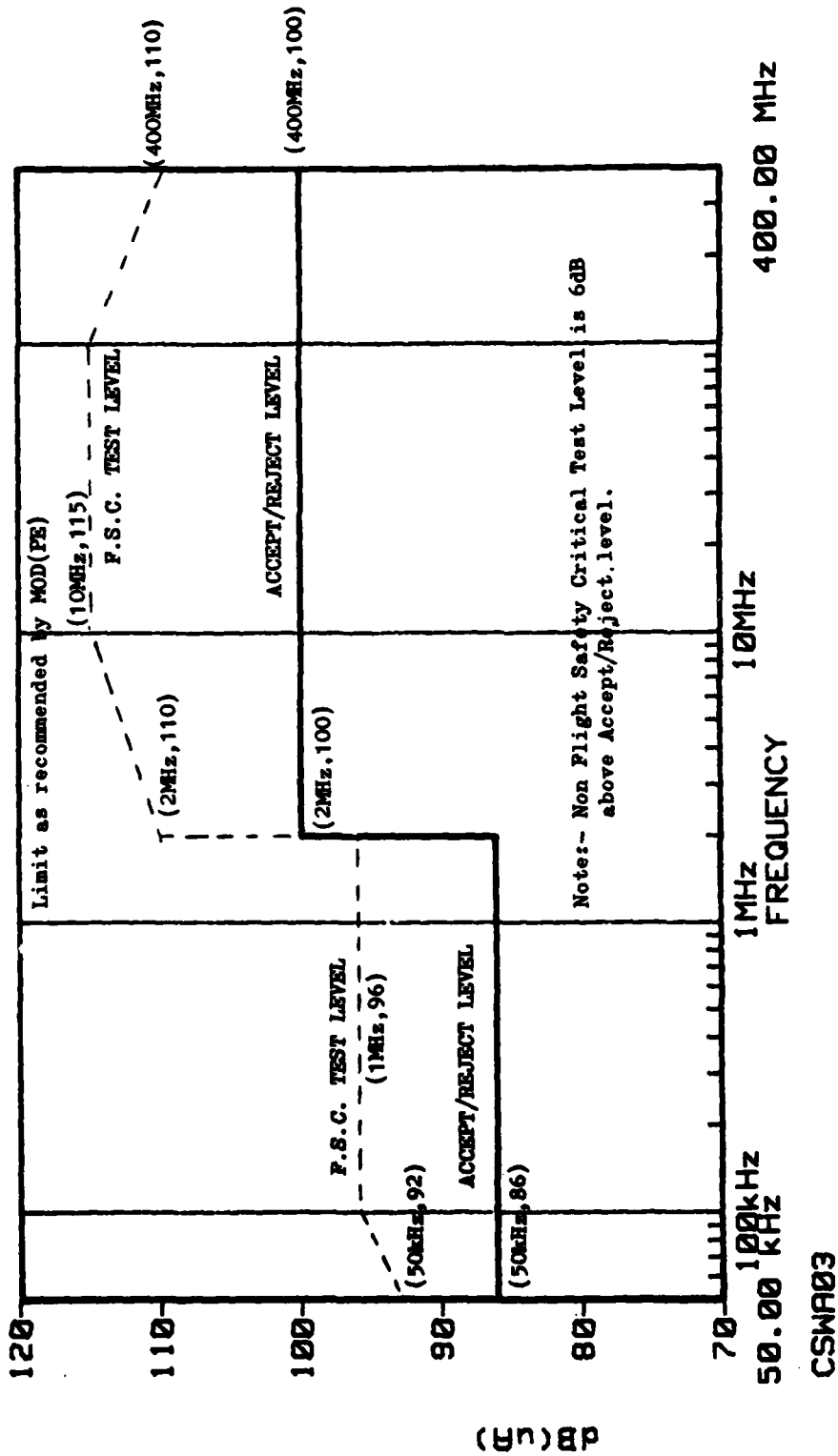


Fig 5

Fig 5 Limits in terms of current that must be induced in the calibration jig

Fig 6

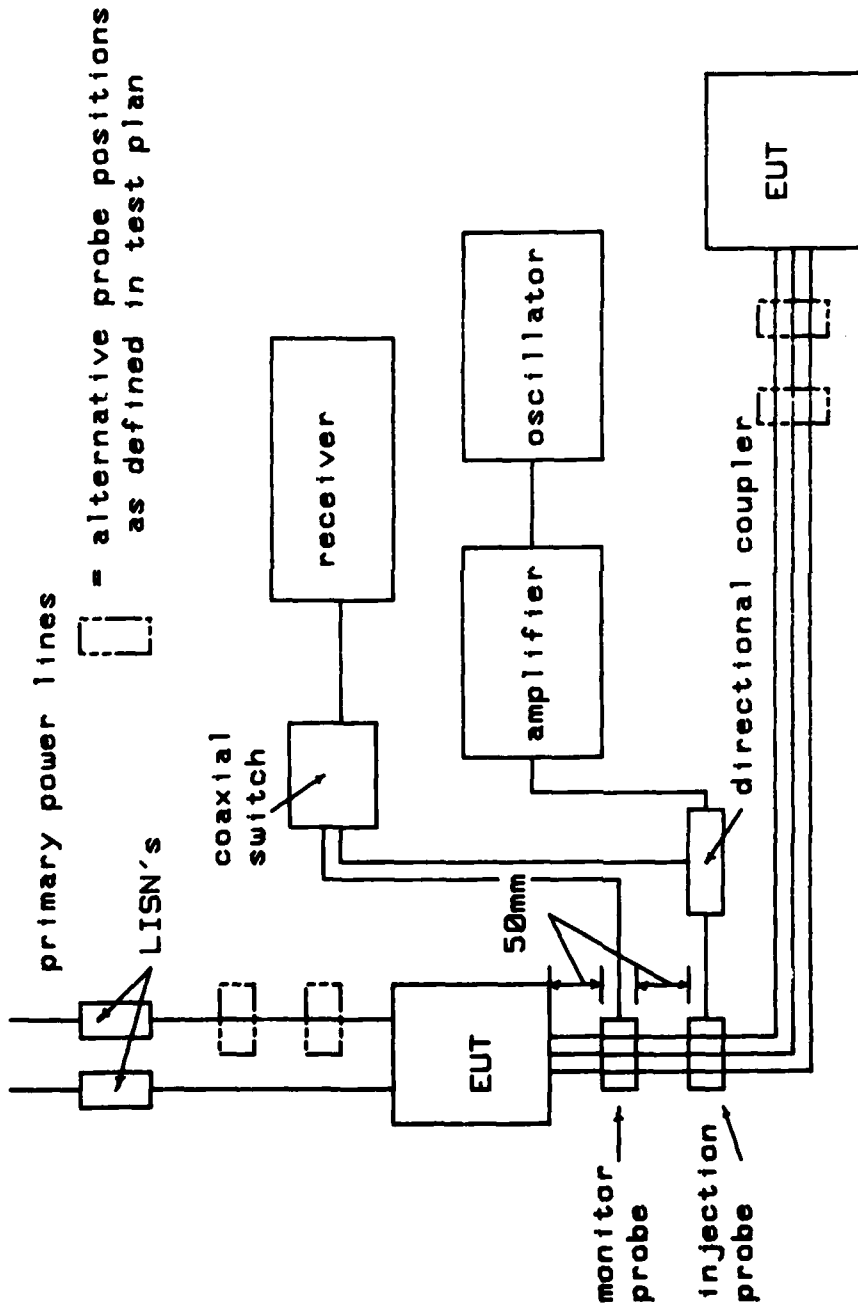
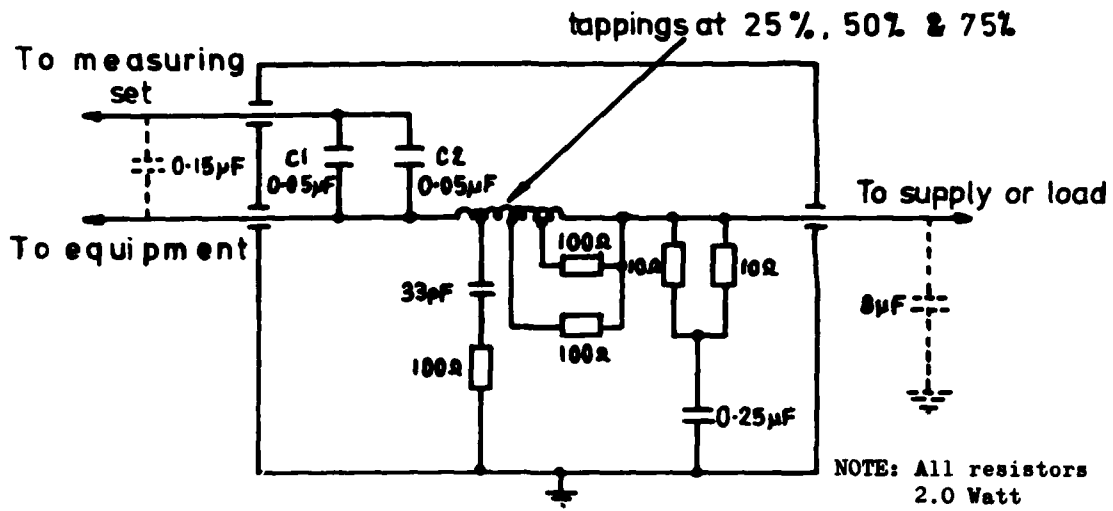
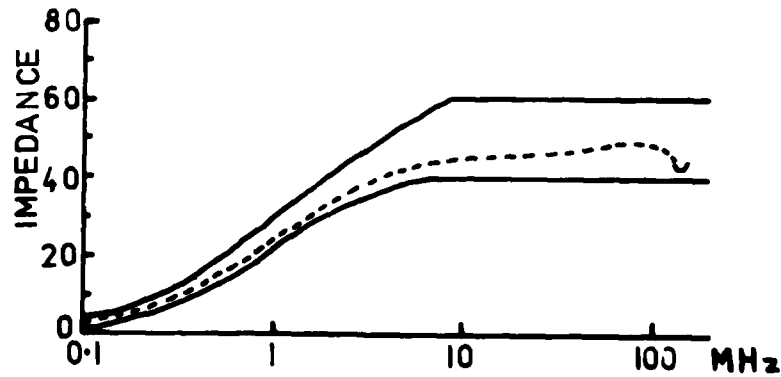


Fig 6 Test layout

Fig 7



(a) Circuit diagram of the LISN (for constructional details see ERA report No.5076 obtainable from ERA Technology Ltd, Cleeve Road, Leatherhead, Surrey, England)



(b) Impedance/frequency characteristic of the LISN

Fig 8

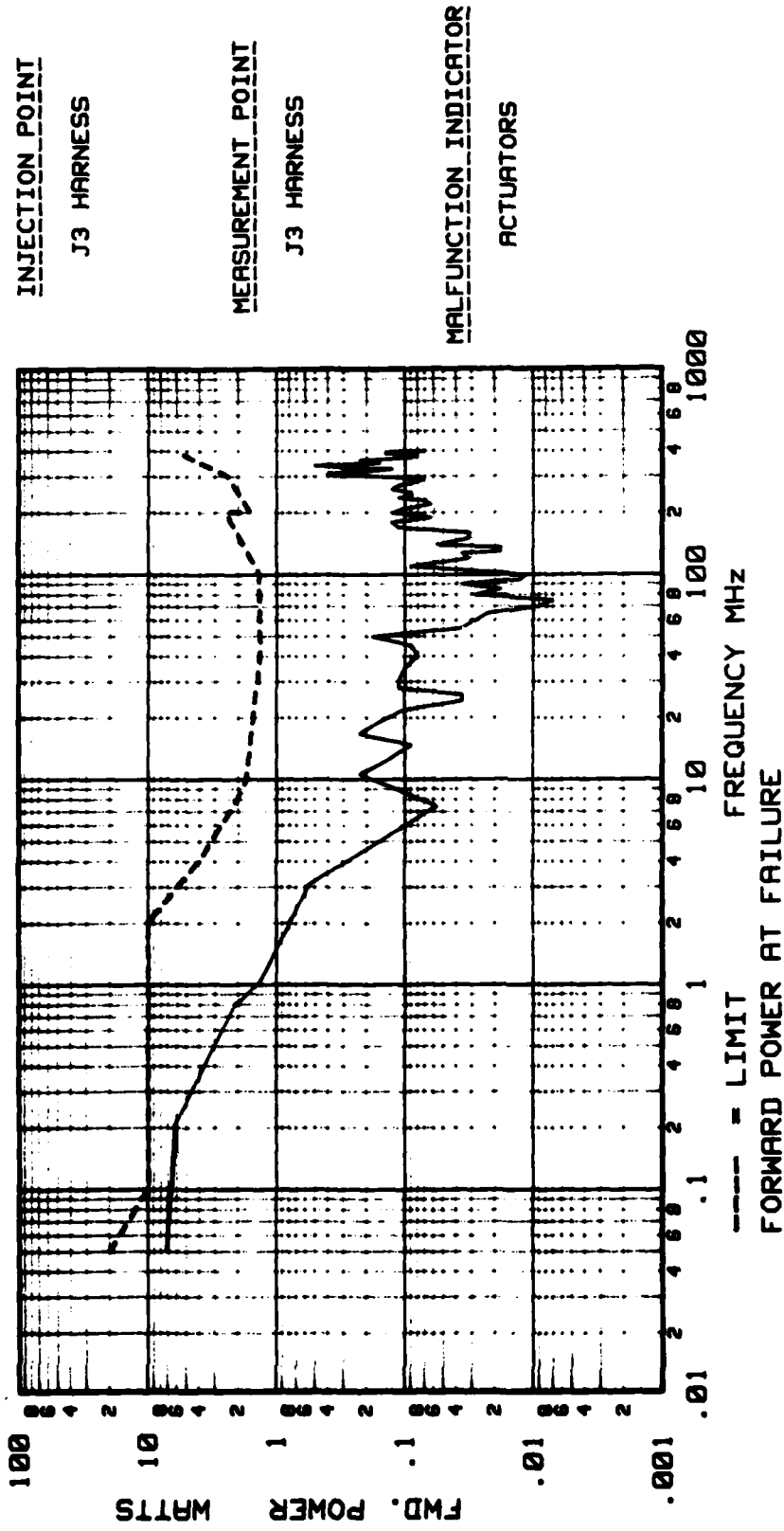


Fig 8 Typical results showing forward power to the injection probe at failure compared with the accept/reject level

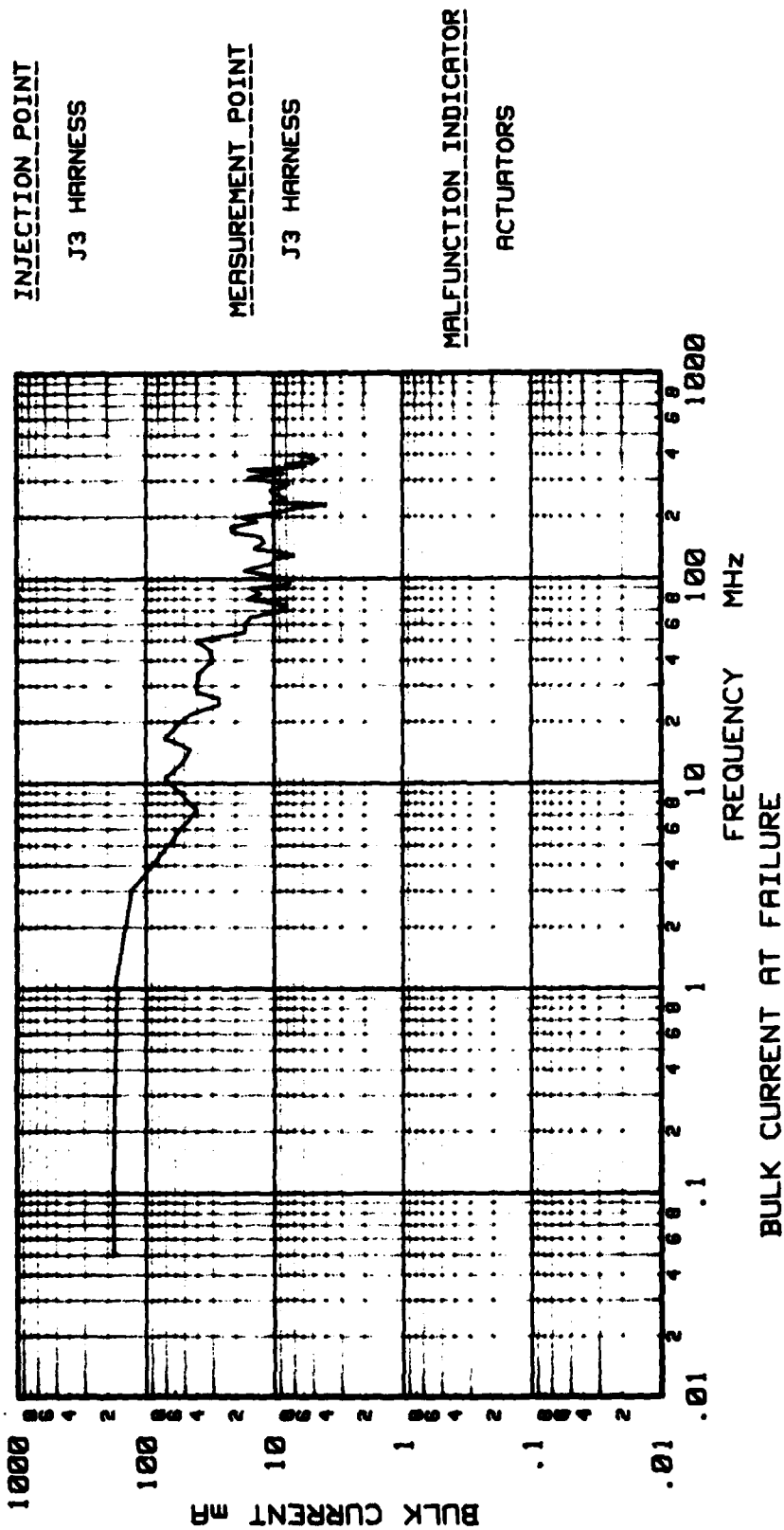


Fig 9 Typical results showing induced current in the loom under test at failure

REPORT DOCUMENTATION PAGE

Overall security classification of this page

UNCLASSIFIED

As far as possible this page should contain only unclassified information. If it is necessary to enter classified information, the box above must be marked to indicate the classification, e.g. Restricted, Confidential or Secret.

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