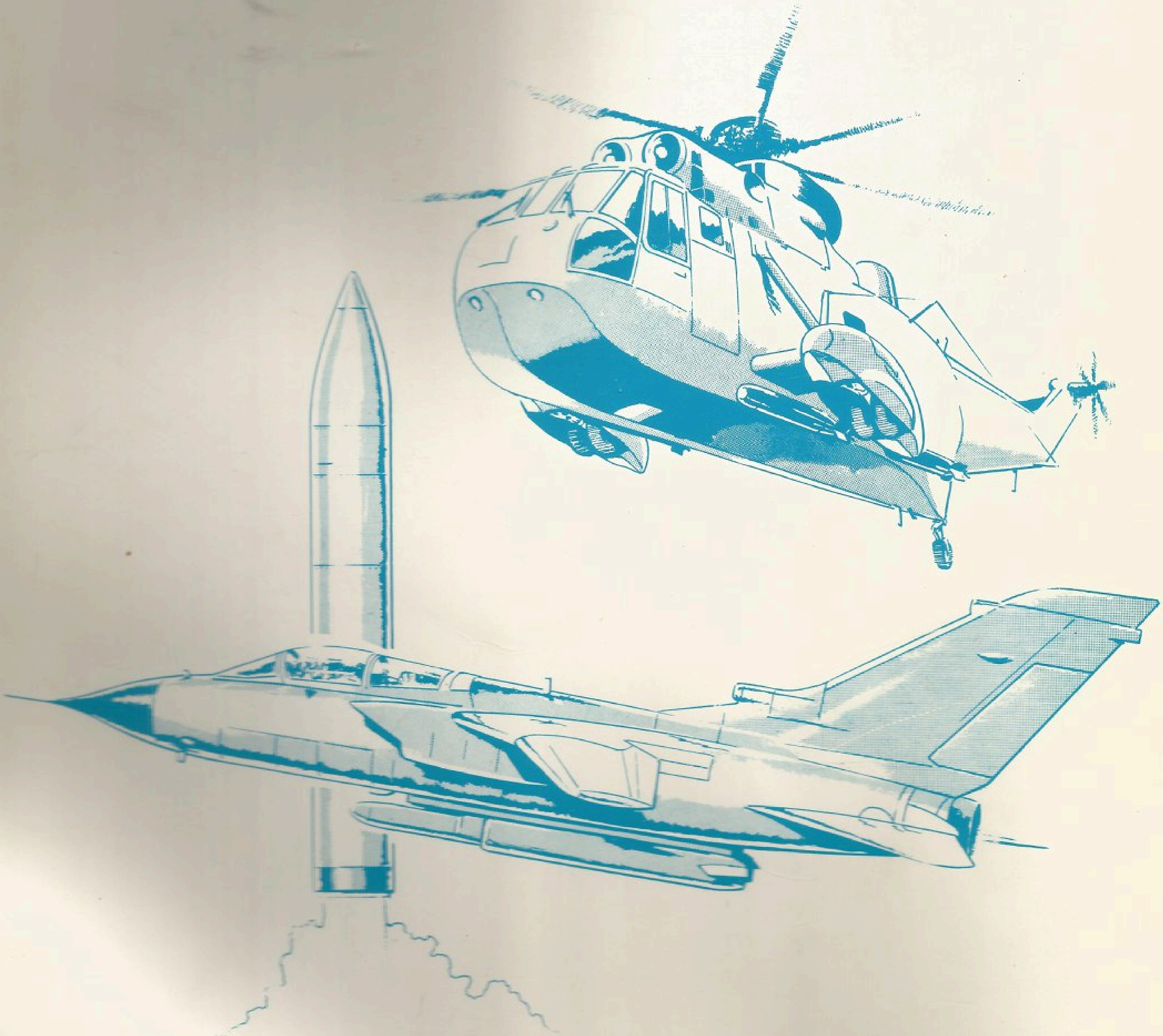
ML Radio Frequency Attenuating Connector
-design and applications



ML AVIATION COMPANY LIMITED

ML AVIATION COMPANY LTD
WHITE WALTHAM AERODROME, MAIDENHEAD,
BERKSHIRE, ENGLAND.
Tel: 062882 - 3361 Telex: 847568 Cables: 'EMELAIR' White Waltham

ML

ML EXPERIENCE AND EXPERTISE

The ML Aviation Company Limited has over 30 years specialized experience in the design and manufacture of cartridge operated devices and in the manufacture of aircraft weapon carriage and ejection/release equipment.

The Company, in conjunction with the UK Ministry of Defence and the Royal Aircraft Establishment, is supported by a complete research, manufacture and testing facility and offers a wide range of weapon carriers and ejector release units, which are internationally recognized as being the lightest and most reliable units in the world. ML weapon carriage systems have been selected against international competition for use with the following aircraft:

Alpha-Jet	**Hunter**
Buccaneer	**Jaguar**
Canberra	**Javelin**
CF104	**Lightning**
Draken	**Mirage**
F104G	**Nimrod**
FST-2	**Phantom**
Gnat	**Scimitar**
Harrier	**Sea Vixen**
Hawk	**Strikemaster**

ML Aviation is a UK Ministry of Defence approved Design Authority for power cartridges and carries out progressive research programmes on the design of British power cartridges in conjunction with the UK Research and Development Establishment and the Propellant, Explosives and Rocket Motor Establishment.

The Company is a Design Authority for systems incorporated in a UK/US missile application.

Research and development studies for major government projects in the fields of electrical, electronic and mechanical engineering are also carried out by the Company.

ML Aviation is fully approved by the Ministry of Defence Quality Control to DEF Stan 05-21 and our equipment is designed and manufactured to the high standards demanded by the UK Royal Aircraft Establishment and similar agencies. We can also comply with US MIL Specifications.

ML RADIO FREQUENCY ATTENUATING CONNECTOR DESIGN AND APPLICATIONS

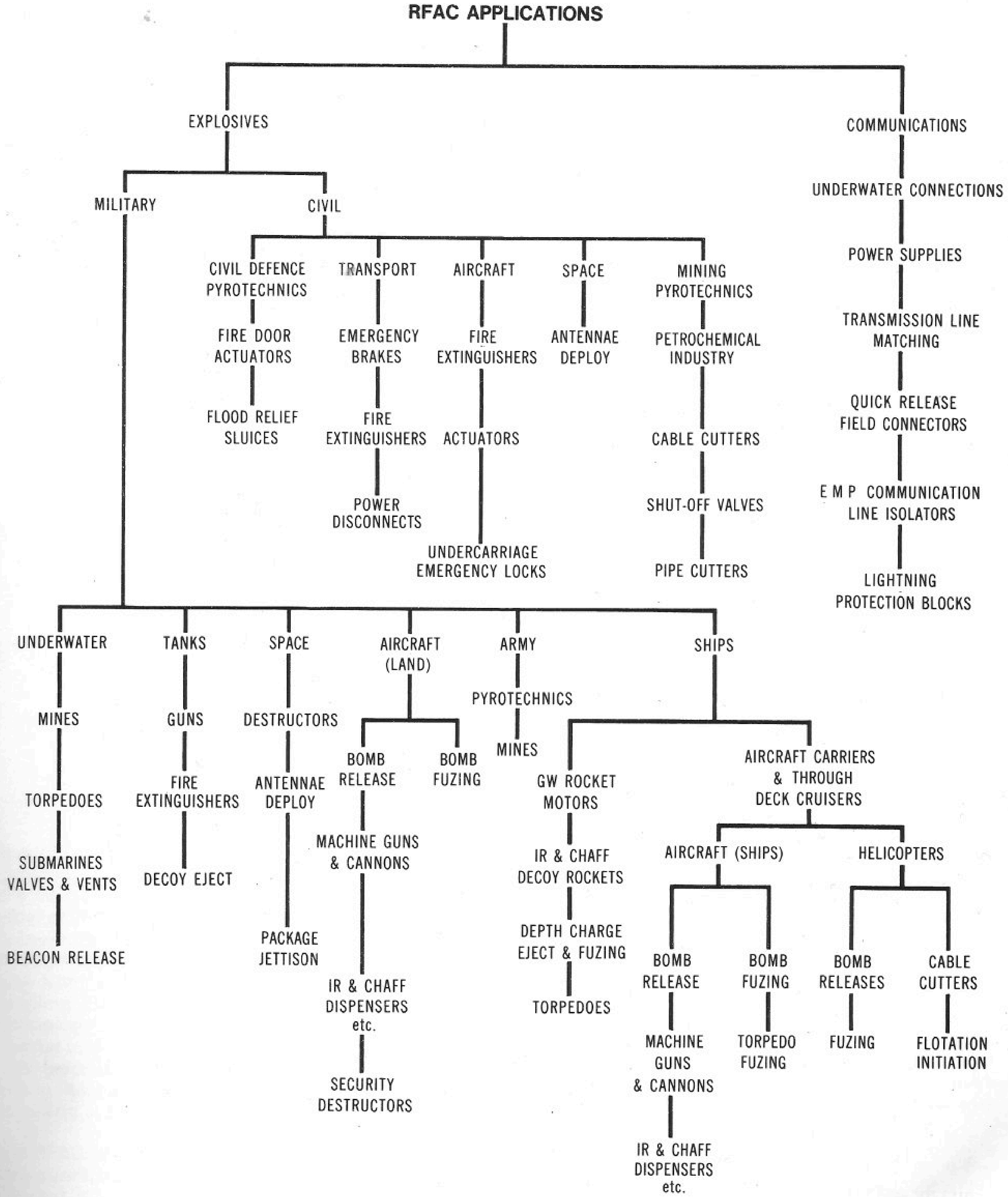
INTRODUCTION

The purpose of this document is to familiarize potential customers and agencies with the application of the ML Radio Frequency Attenuating Connector (RFAC).

It also highlights the use of RFACs in the Aerospace industry and similar areas requiring high degrees of safety and reliability coupled with protection from severe EMI hazards; and further, to show its superiority over conventional filtering systems.

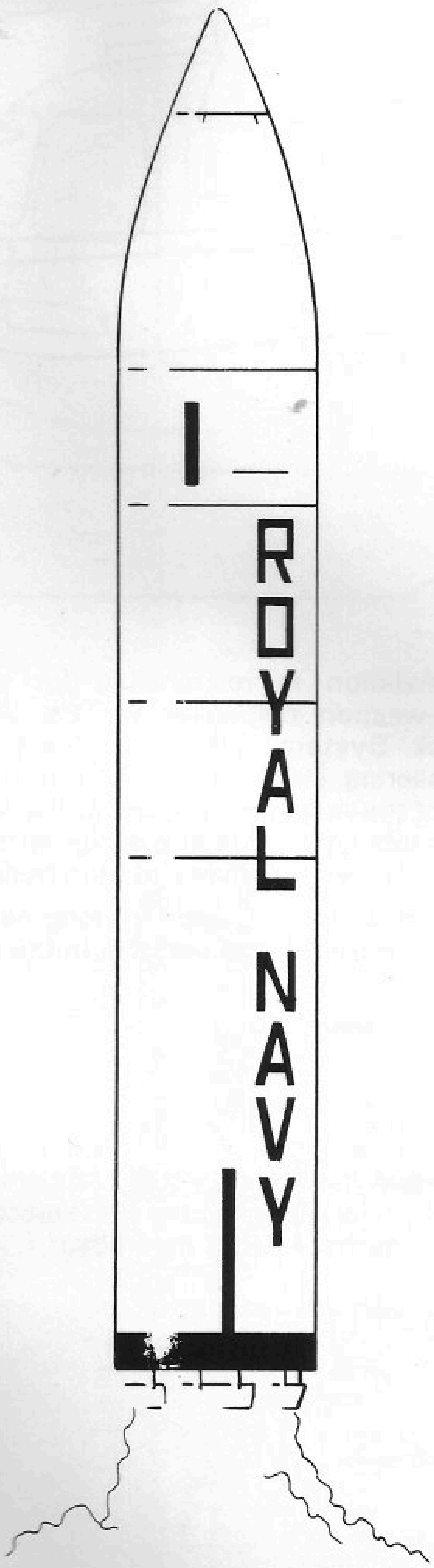
WW1504

APPLICATIONS OF THE RFAC



MISSILE SYSTEMS

The RFAC is successfully employed in a major UK missile system to provide complete isolation of explosive and pyrotechnic devices from EMI and electrostatic hazards in both the 'hand-held' and installed modes.



Reasons for usage in the missile are:

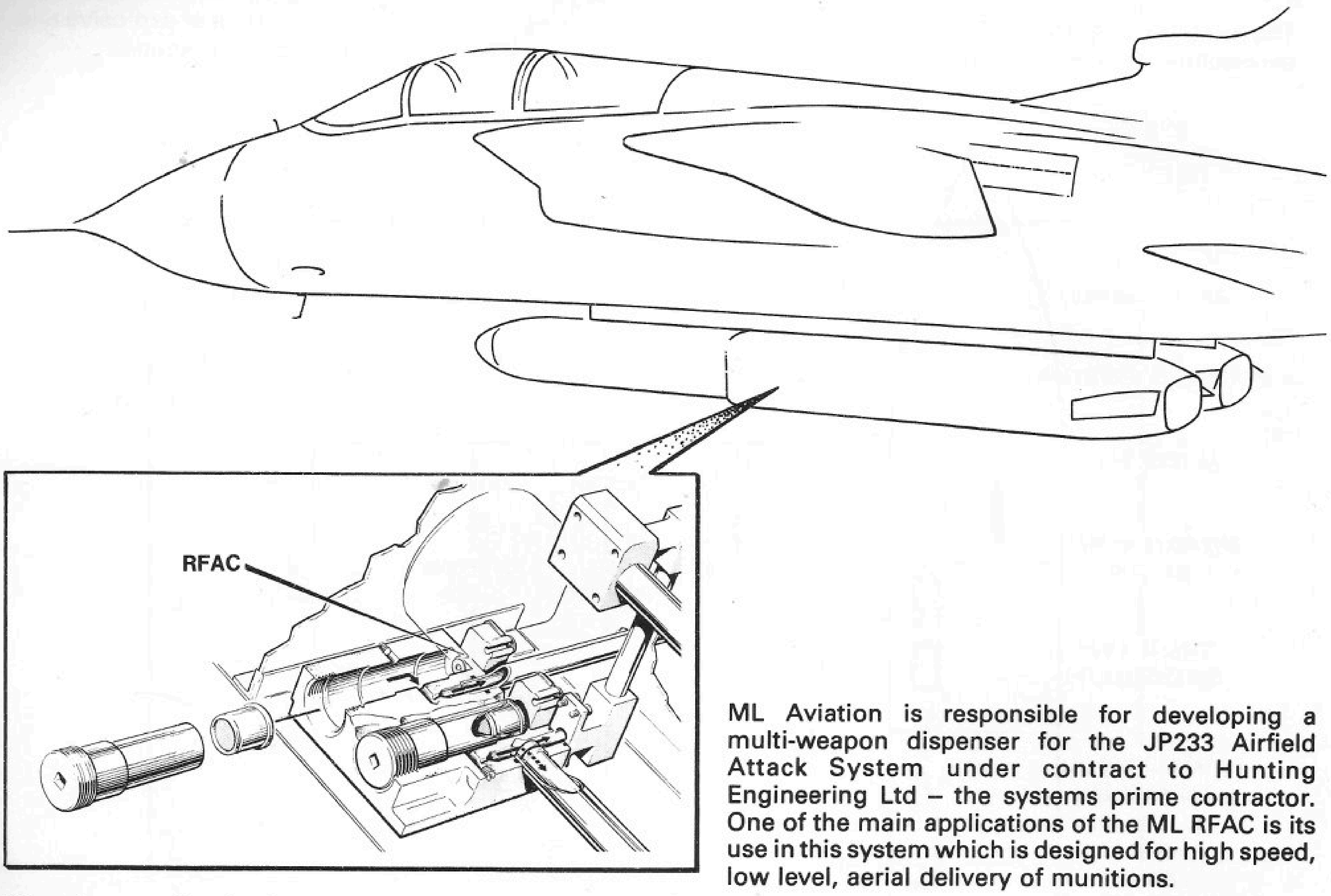
(1) Electromagnetic Compatibility with subsystems.
(2) Protection against electromagnetic pulse.
(3) Protection against extreme RF environment.
(4) Protection from electrostatic discharges.
(5) Protection from lightning.
(6) Radiation hardened.
(7) Good power budget.
(8) Computer sequenced.

The RFACs involved in the above have all undergone full Design Type Approval testing to the requirements of the Ministry of Defence Ordnance Board and the following tests have been successfully completed:

Transport vibration, drop test, shock test, pressure test, acceleration, electrostatic life trials, safety tests and high temperature storage.

The mechanical/electrical concept of the RFAC design has been fully researched to measure the effects of gap and axial mis-alignment between the mating faces of the primary and secondary. A separate document is available on this subject.

AIRCRAFT WEAPON SYSTEMS



ML Aviation is responsible for developing a multi-weapon dispenser for the JP233 Airfield Attack System under contract to Hunting Engineering Ltd – the systems prime contractor. One of the main applications of the ML RFAC is its use in this system which is designed for high speed, low level, aerial delivery of munitions.

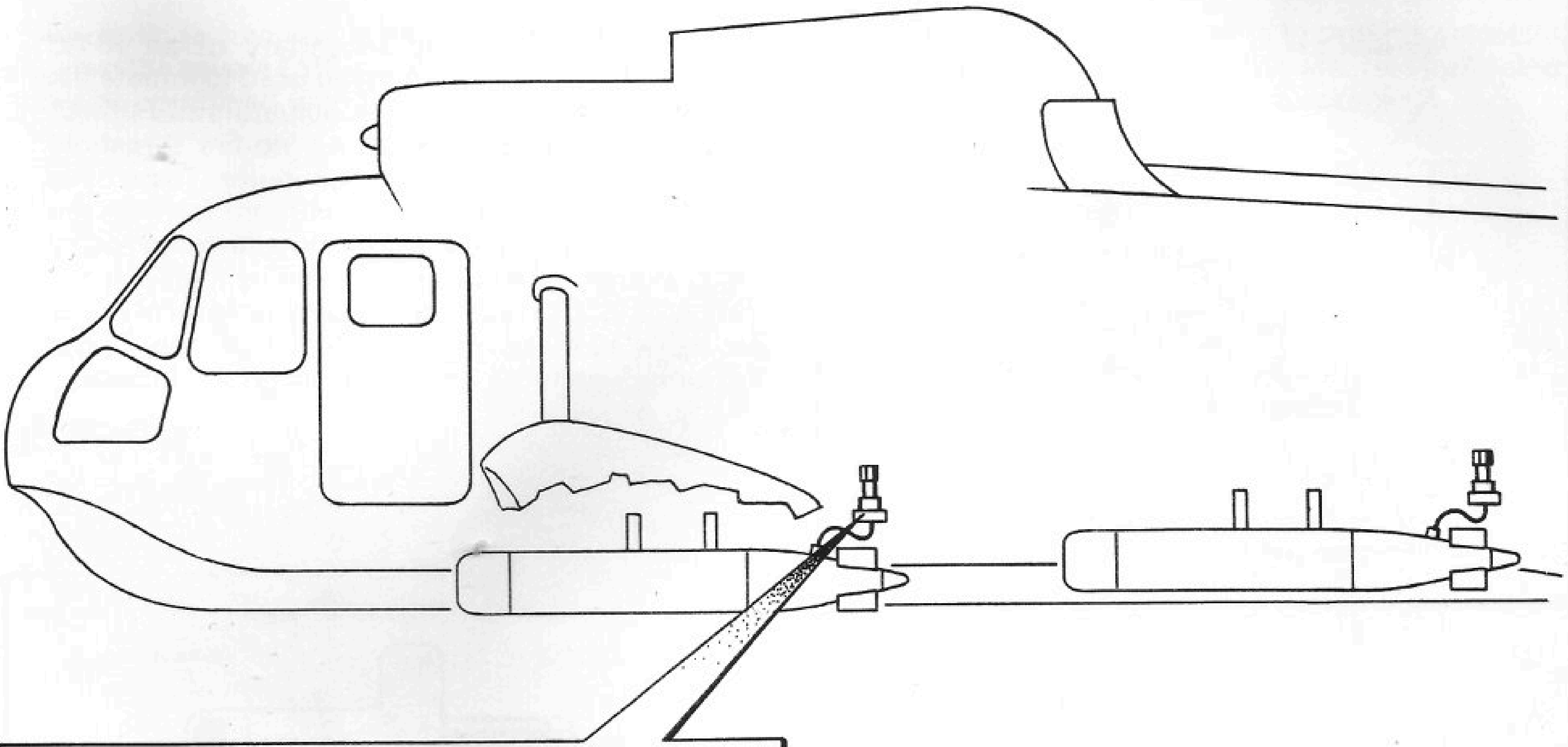
The primary objective is to destroy enemy airfields and prevent them from being used for long periods, but the system is also effective against hardened structures, concentrations of troops and vehicles in the open and key points in road and rail networks.

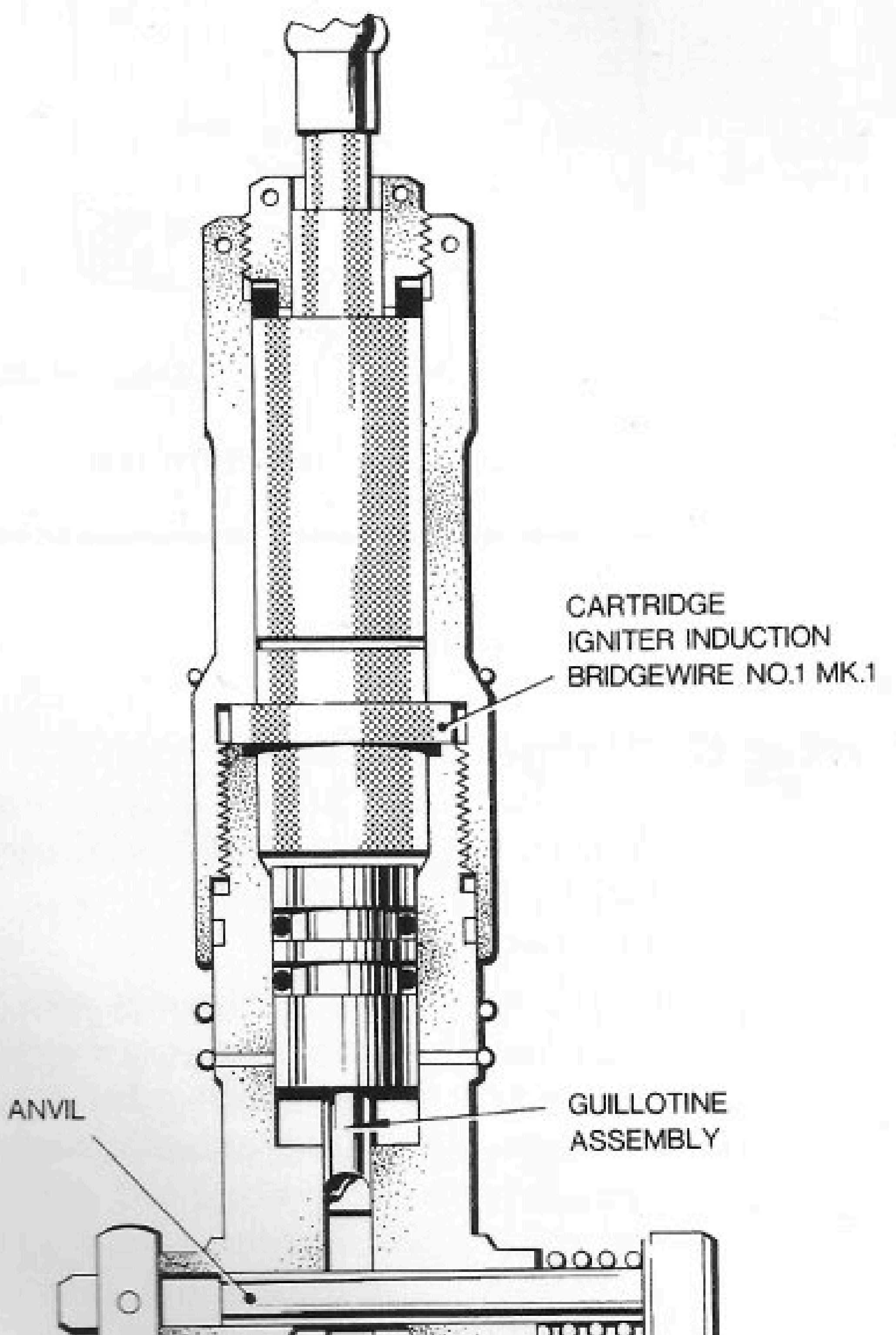
The RFAC employed in the JP233 provides protection against the following:

(1) Electromagnetic interference (EMI)
(2) Electronic counter measures (ECM)
(3) Lightning

The RFAC also provides an optimized aircraft power budget distribution method by virtue of its unique matching ability. This would be impossible using conventional methods. The reliability of connection to the ejection cartridges during the long stockpile-to-target sequence cannot be achieved by normal contact methods.

HELICOPTER APPLICATION



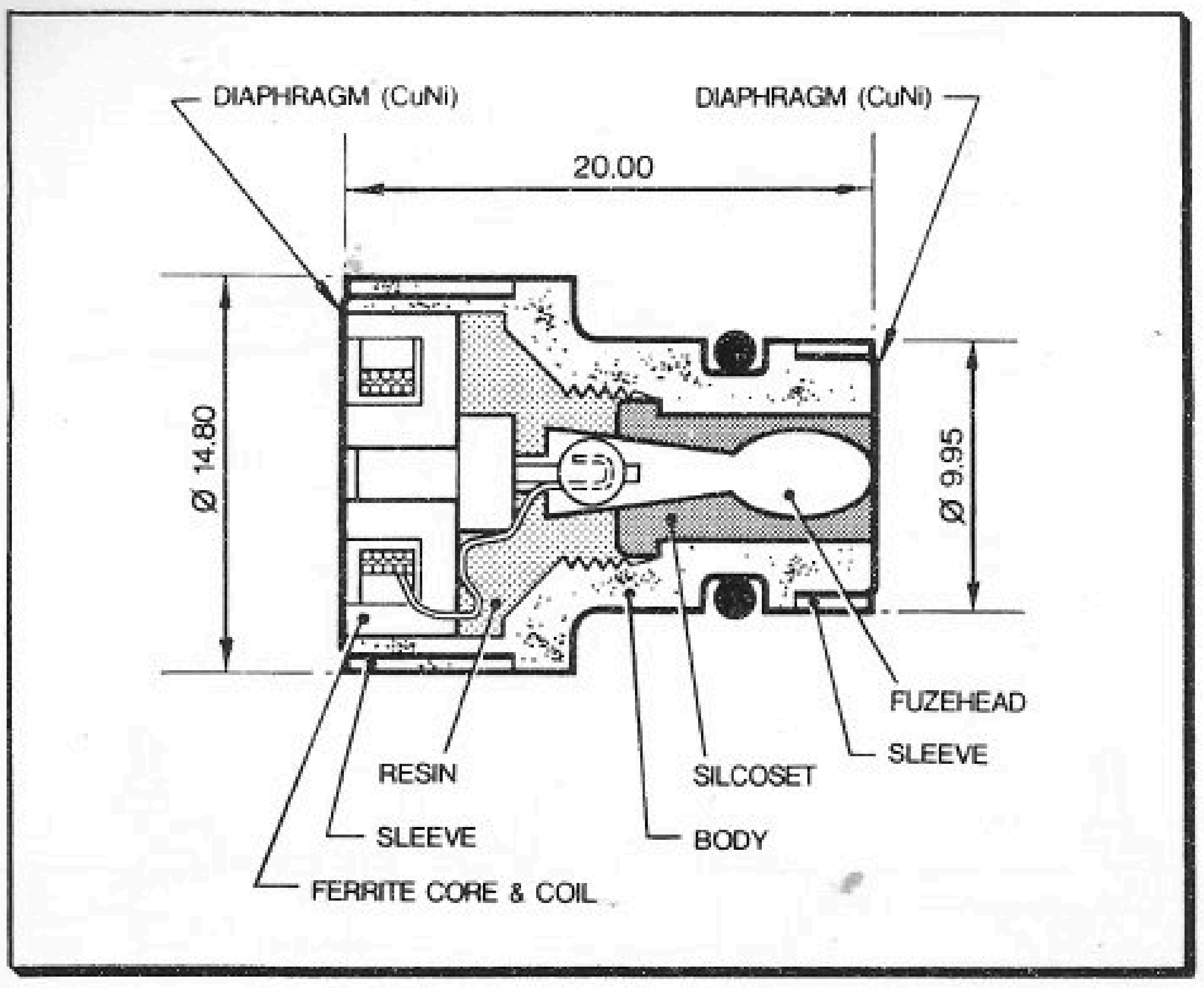


Cutter, Weapon Lanyard No 1 Mk 1

The Cutter, Weapon Lanyard No 1 Mk 1 is fitted to the aircraft structure for emergency jettison of stores. The unit contains an explosive cartridge actuated by an RFAC igniter, induction, bridgewire No 1 Mk 1. The RFAC provides the reliable RF proof connection to the igniter and matches the limited helicopter 28V d.c. supply efficiently to the low resistance twin bridgewire. The guillotine assembly consists of a body, a piston incorporating a knife edge, and a sleeve which screws onto the body. Seals are provided to prevent ingress of moisture at the interface between the RFAC primary and the sleeve, the sleeve and the body and the piston and the body. A slot in the lower part of the body accommodates the wire loop of the parachute and an anvil in the form of a drop nose pin passes through the body to retain the lanyard.

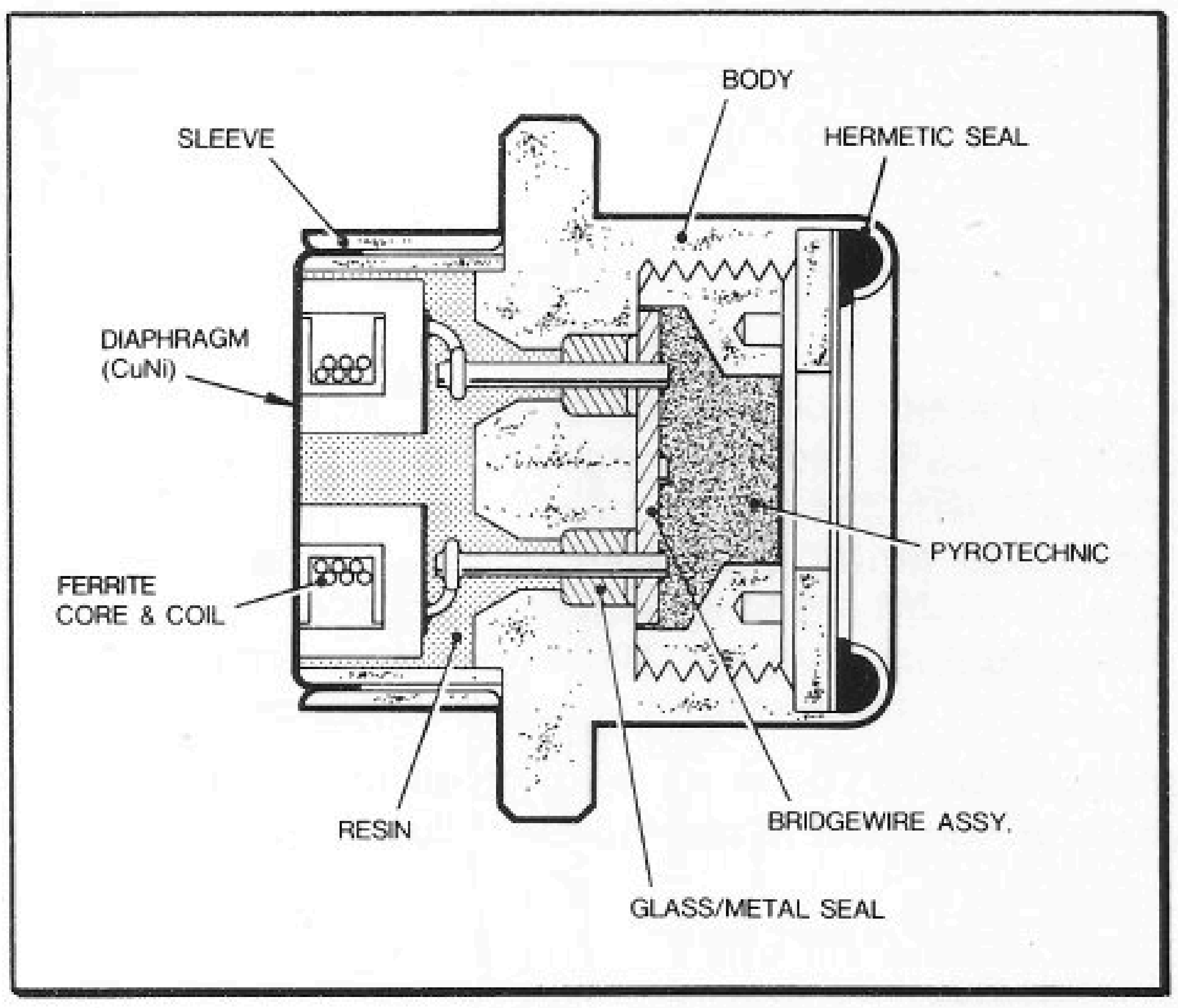
The piston fits into the body and incorporates a locating shear pin to initially restrain the piston during the build up of gas pressure after the explosive has been fired.

PYROTECHNIC RFAC DEVICES



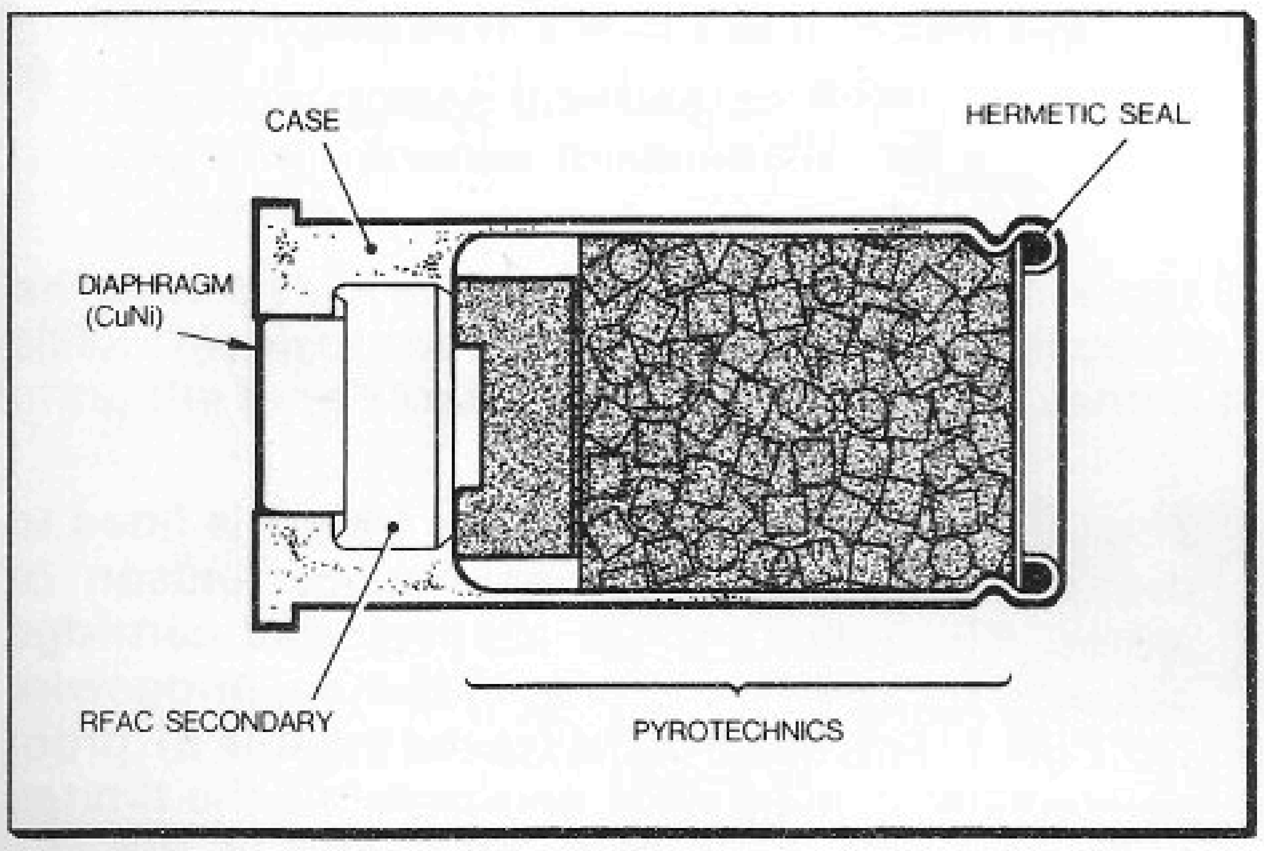
Igniter ML91

The unit comprises the secondary of an RFAC together with a Type E fuzehead used to initiate the operation of explosive latches, actuators and similar mechanisms. The fuzehead has a 'no-fire' threshold sensitivity of 80 mW or 2.3 milli-joules. Tests have shown that even when the diaphragm forming the Faraday shield on the secondary is removed, a safety margin of 40 dB is provided by the device in the NWS 6 UK radiation hazard environment. A variety of 12 mm primaries may be used to trigger this unit dependent on the particular application.



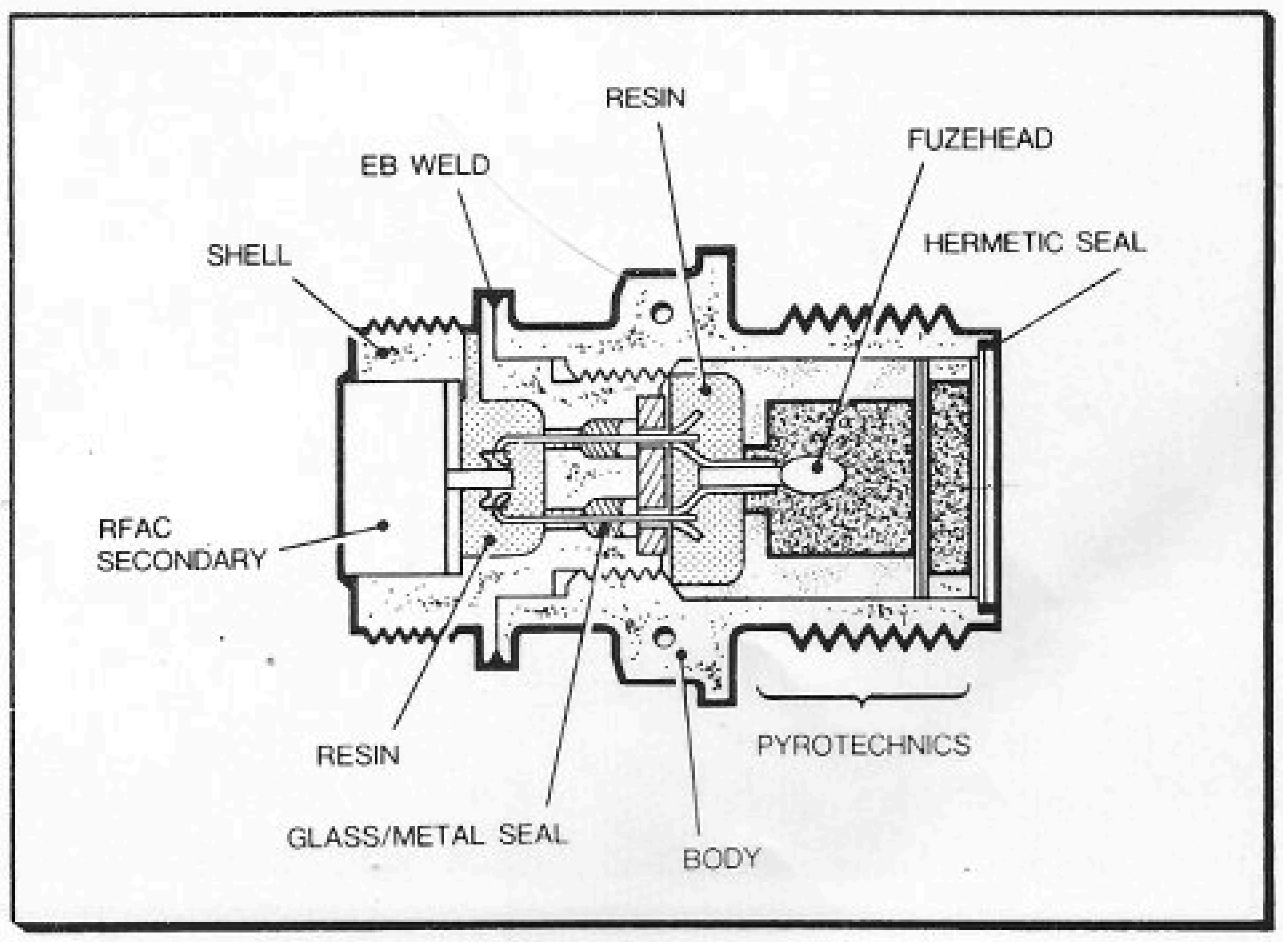
Igniter Induction Bridgewire No 1 Mk 1

The Igniter Induction Bridgewire No 1 Mk 1 contains 325 mg of RD 1652 and duplicated transformer secondary windings which are connected via contact pins to 2 separate bridgewires. It is closed at the transformer end by a copper nickel diaphragm and at the output end by a copper-nickel closure disc supported by a washer and sealed with an 'O' ring.



Ejector Cartridge SG No 4 Type 1

The RFAC Ejector Cartridge SG No 4 Type 1 is fired by a transfer of power from the RFAC primary to the RFAC secondary by the inductive coupling principle previously described.

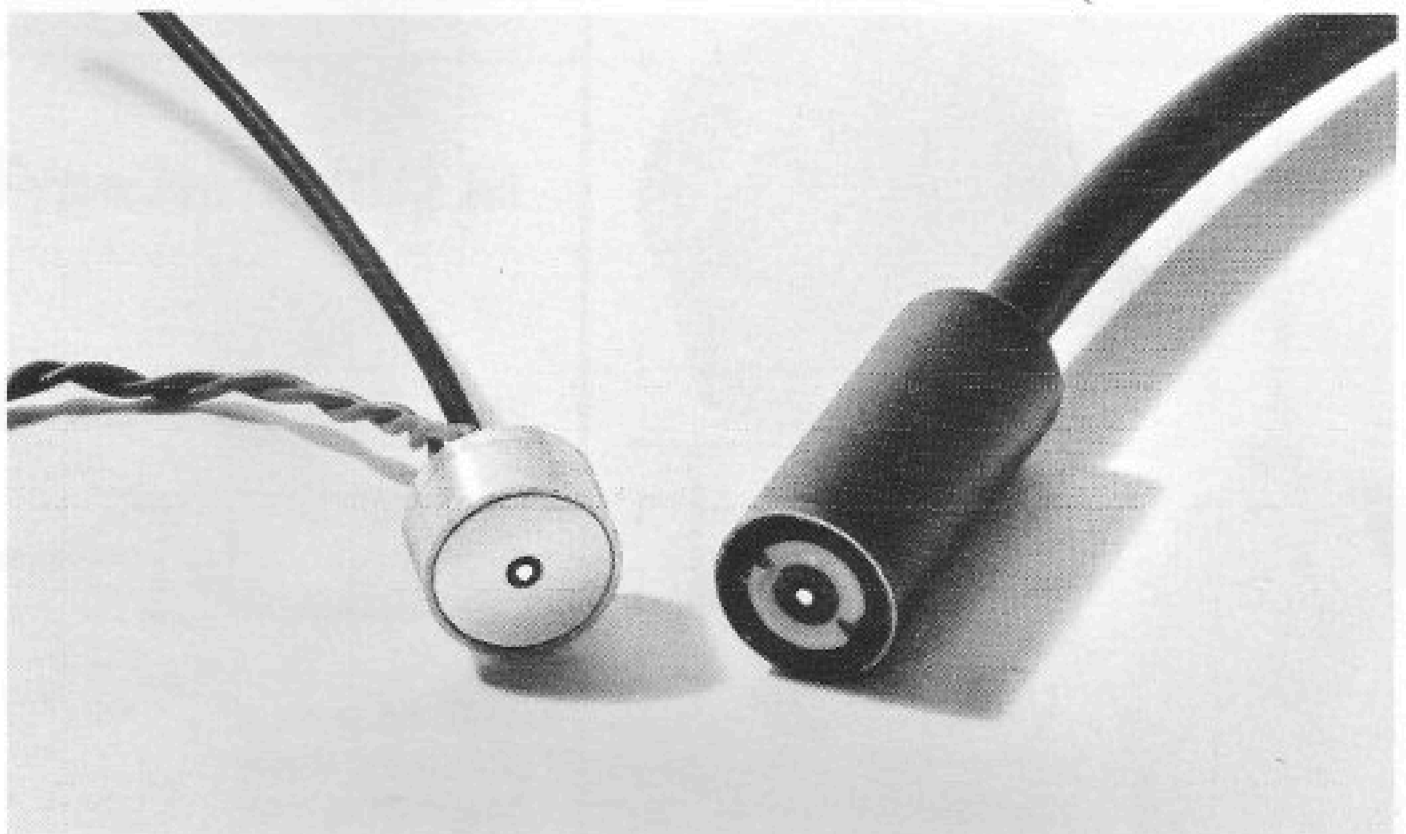


HAS Mk 3 Cartridge

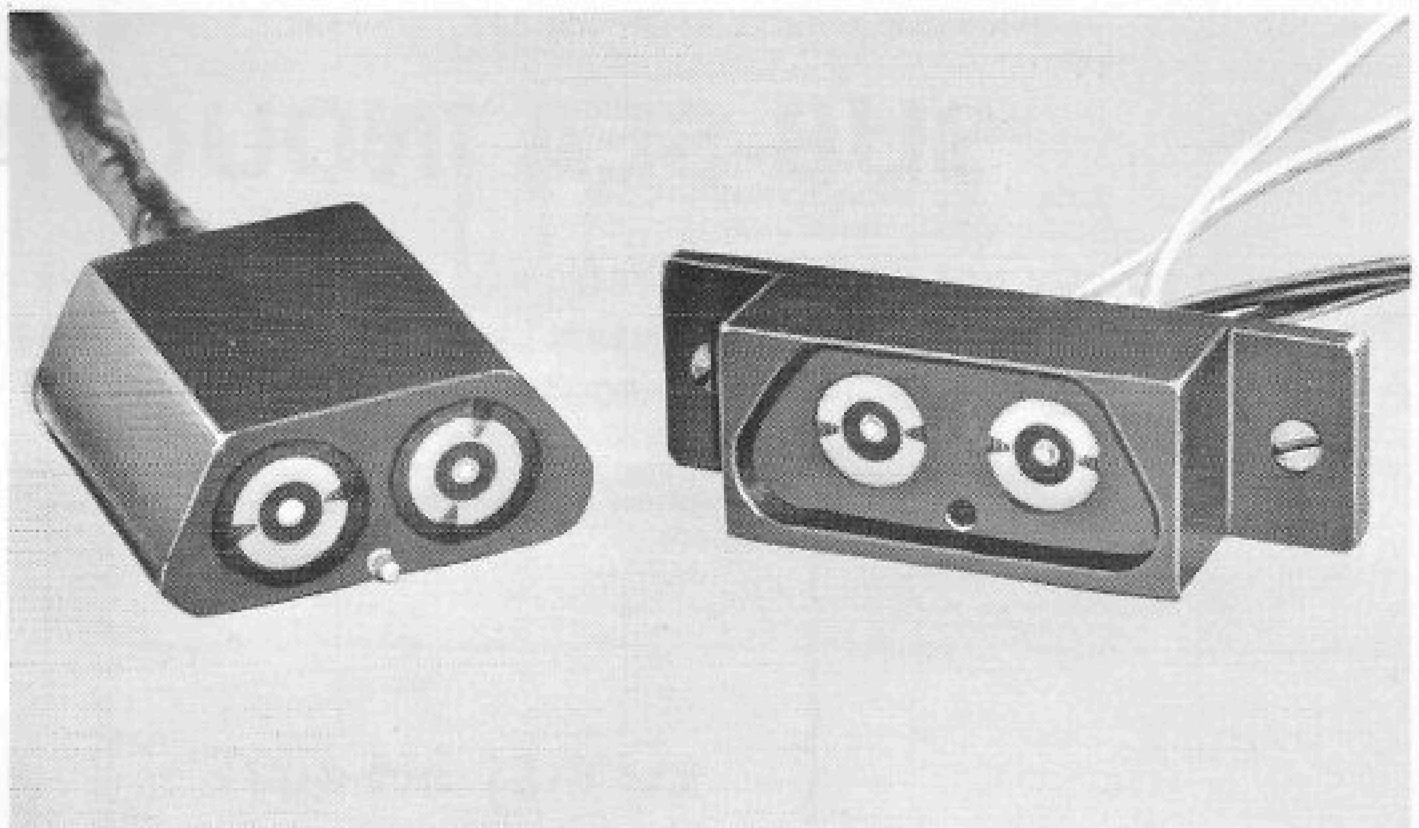
The RFAC HAS Mk 3 cartridge is fired by power received via the RFAC secondary initiating a Type E fuzehead. This initiates the igniter charge which in turn ignites the main charge.

FIBRE OPTIC RFACs

Fibre optic technology is being applied increasingly to aircraft, missile and ship systems to provide protection against the severe EMC and ECM environments in which modern weapon systems must operate. This technology may be combined with the ML RFAC to provide a considerable number of significant advantages.



Simplex Fibre Optic RFAC Coupler



Duplex Fibre Optic RFAC Coupler

For example, the conventional 'hard wire' trigger circuit used in many RFAC applications may be replaced by an optical fibre input connection. The RFAC will operate only when the appropriate electrical supply is applied and the correct infra-red code is transmitted along the fibre optic input connection into the device. Low cost light-emitting diodes (LEDs) and infra-red detectors are the only components required for normal weapon system applications. The code required to operate the RFAC will be unique to that particular connector, consequently it is possible to feed several RFACs from a common fibre optic data bus. The discrete code may be preset into the device during manufacture.

Weapon control and sub-systems employing modern microprocessor techniques will normally be capable of generating the appropriate code through software programmes. With the co-operation of leading manufacturers the RFAC may be incorporated in a range of standard military connectors (for example to MIL-C-81511D, MIL-C-26482 Pattern 602) that combine the convenience of conventional connectors with the outstanding RADHAZ protection afforded by the RFAC and fibre optic techniques.

'Snatch' versions are under development for fuzing applications.

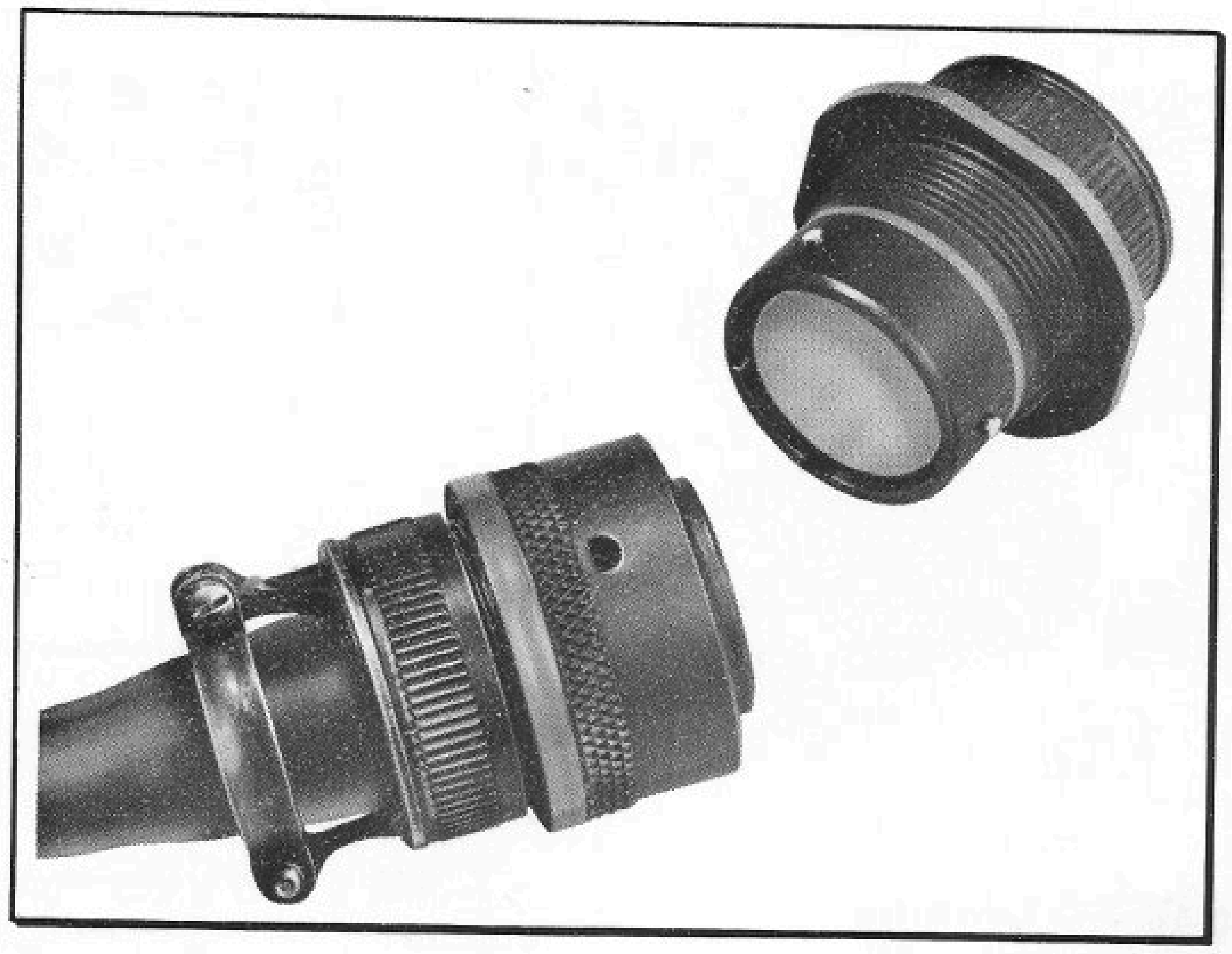
In addition to the fibre optic trigger, RFACs are under development incorporating a centrally mounted fibre optic data highway. The data transmitted into an ordnance device can be utilized only if the electronic circuitry within the device is supplied with power. The RFAC secondary may be provided with isolated windings to provide and protect the multiple supply rails required by the weapon system, from RADHAZ and electrostatic effects.

Examples of devices under development to the requirements of MIL Spec 1553B and similar specifications are shown.

MILITARY PLUG/RECEPTACLE CONFIGURATION

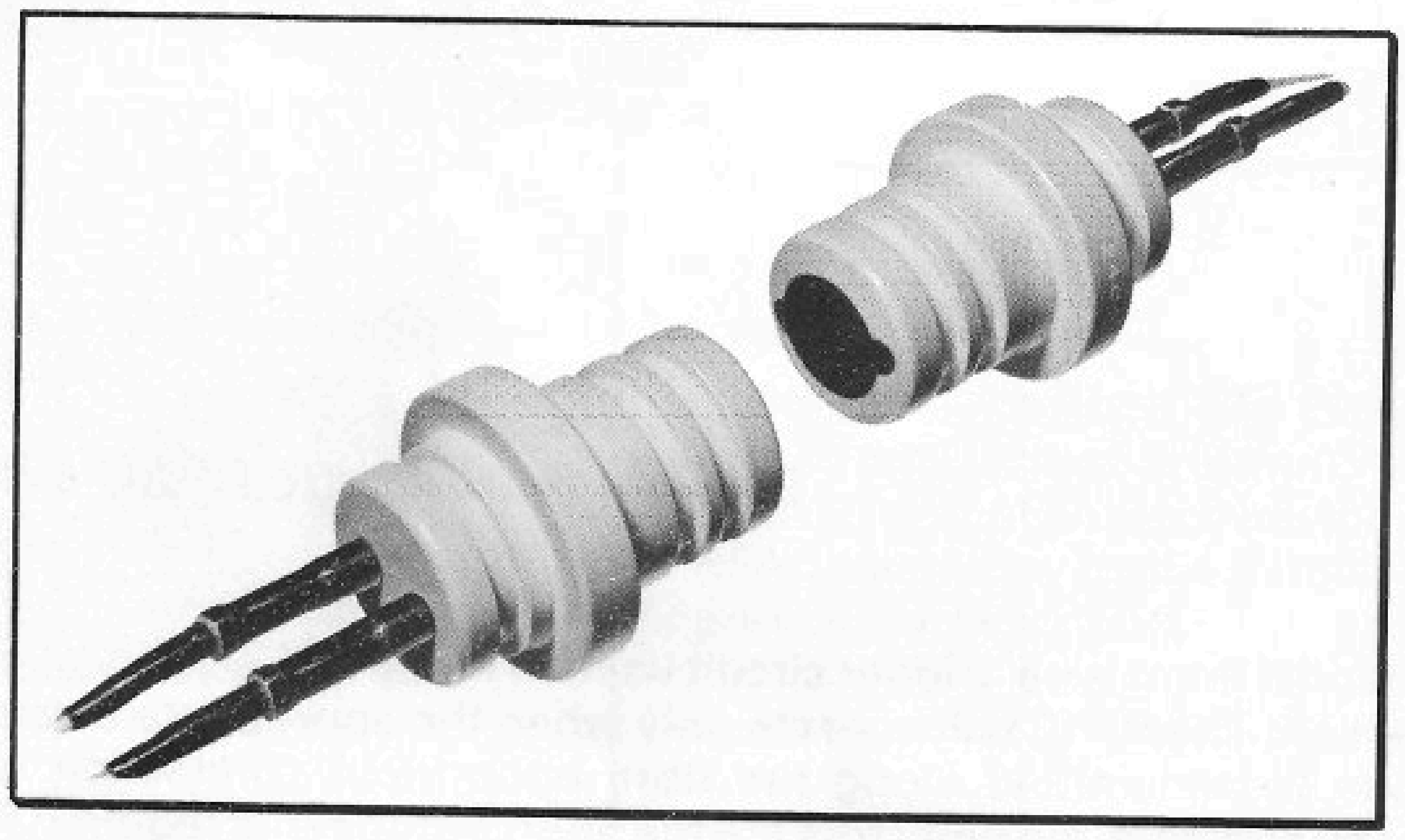
ML Aviation, in co-operation with leading connector specialists, is proposing to make RFACs available in military style connector shells.

Preliminary developments have incorporated RFACs into shells of outline MIL-C-81511, MIL-C-26482 and MIL-C-83723.



SUB-SEA INDUCTIVE COUPLERS

Although strictly not an RFAC, a range of sub-sea inductive couplers has been developed and manufactured to the requirements of Marconi Avionics Limited and are in sea bed use in North Sea oil exploration and production. A typical example is the epoxy moulded and encapsulated type illustrated in a mateable pair format.



They are suitable for remote coupling of signal or low power functions at virtually unlimited depth. The 18 mm coupler has a 1 watt continuous power rating.

There are no orientation problems because of the symmetry of design.

Tolerance to lateral displacement is relatively high – 1 mm for the 18 mm coupler illustrated.

Gaps of 0.1 mm can be accepted in mating without significant performance degradation.

Electrical isolation in sea water at a continuous pressure of 500 psi is greater than 100 Megohm at 500V.

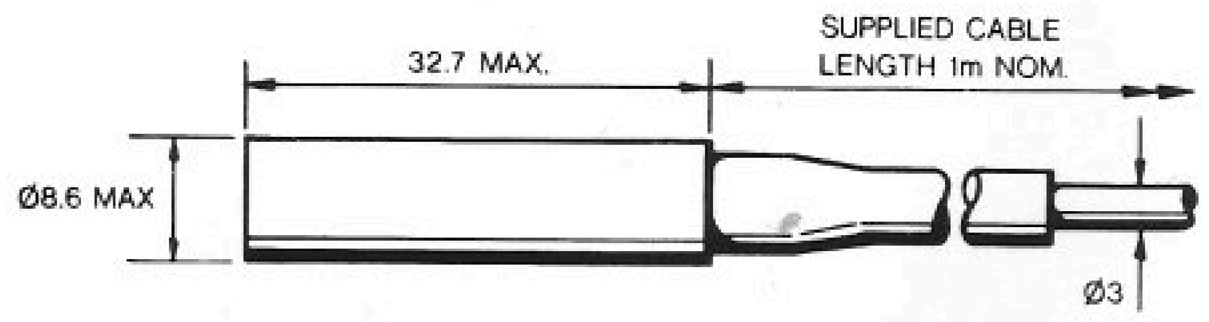
Because each coupler is a half transformer, the electrical characterization of mated parts is highly flexible. Frequencies of up to 1 MHz may be used. Typically, into 200 ohm, the 3 dB bandwidth of a mated pair of 18 mm couplers with a primary-to-secondary ratio of 50 : 100 turns is 400 Hz to 130 KHz. For 200 : 200 turns, 200 Hz to 10 KHz.

Use is not restricted to under-sea work and the coupler may be used wherever remote coupling is needed in adverse pressure or chemical environments. The coupler may be mounted in any suitable connector shell or may be moulded/machined to specific customer required form.

SPECIFICATIONS FOR STANDARD RFAC PRIMARY AND SECONDARY UNITS

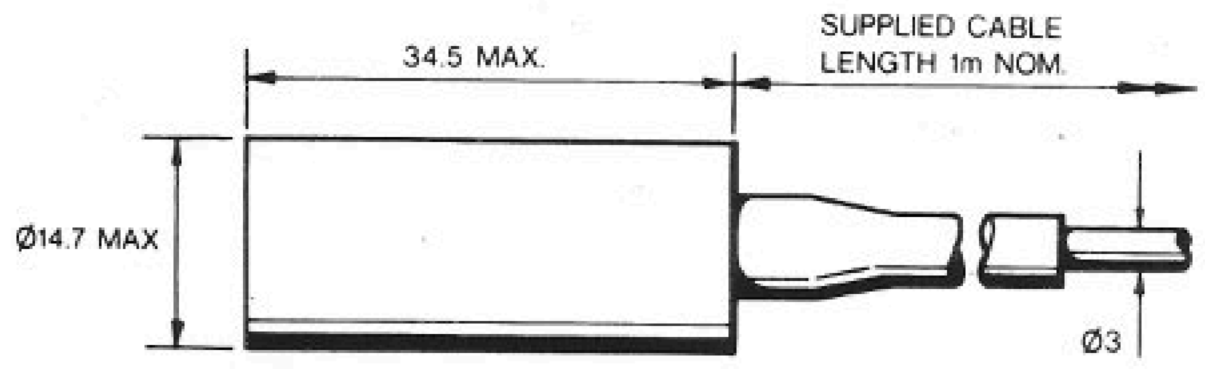
Primary Units

Type No 7/10/2 M



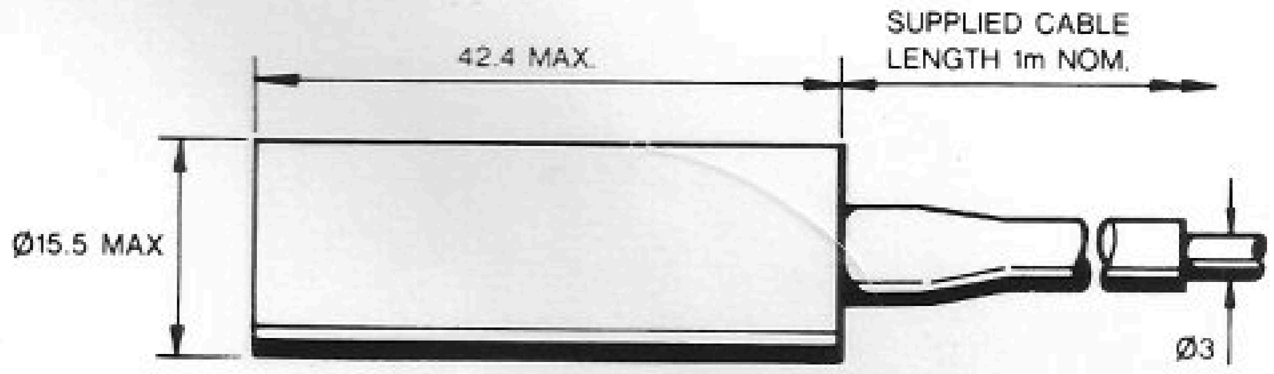
WEIGHT 6.0 GRAMS (excluding cable)
MINIMUM POWER TRANSFER (At 28V DC) = 10 WATTS
MAXIMUM PULSE RATING = 50 MILLISECONDS ON
1 MINUTE OFF
MAXIMUM CURRENT DEMAND (At 28V DC) = 1.25 AMPS

Type No 12/25/2 TF



WEIGHT 8.0 GRAMS (excluding cable)
MINIMUM POWER TRANSFER (At 28V DC INPUT)
= 25 WATTS
MAXIMUM PULSE RATING = 50 MILLISECONDS
MAXIMUM CURRENT DEMAND (At 28V DC) = 2 AMPS

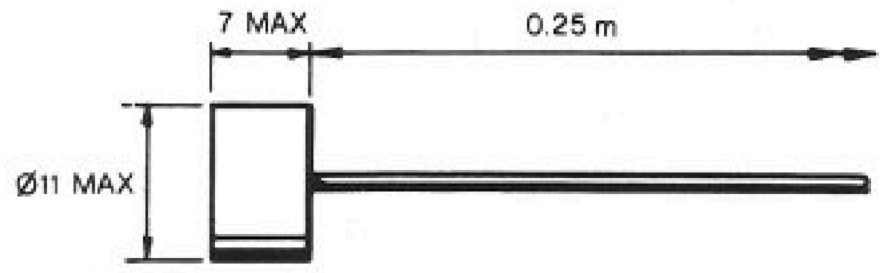
Type No 14/50/2



WEIGHT 20.0 GRAMS (excluding cable)
MINIMUM POWER TRANSFER (At 28V DC) = 50 WATTS
MAXIMUM PULSE RATING = 5 SECONDS
CURRENT DEMAND AT 28V = 4.5 AMPS

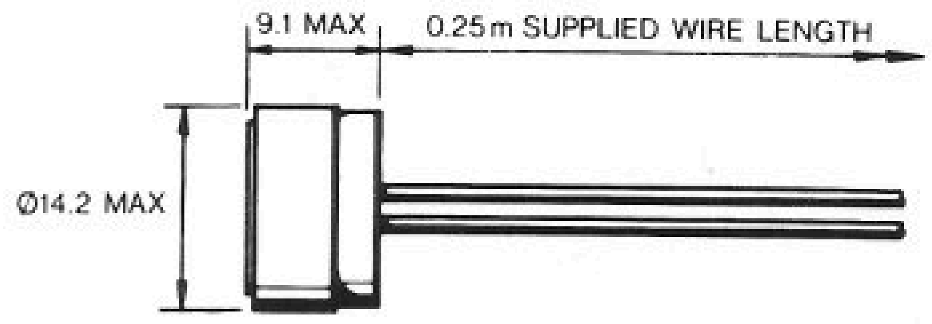
Secondary Units

Type No 7/S1



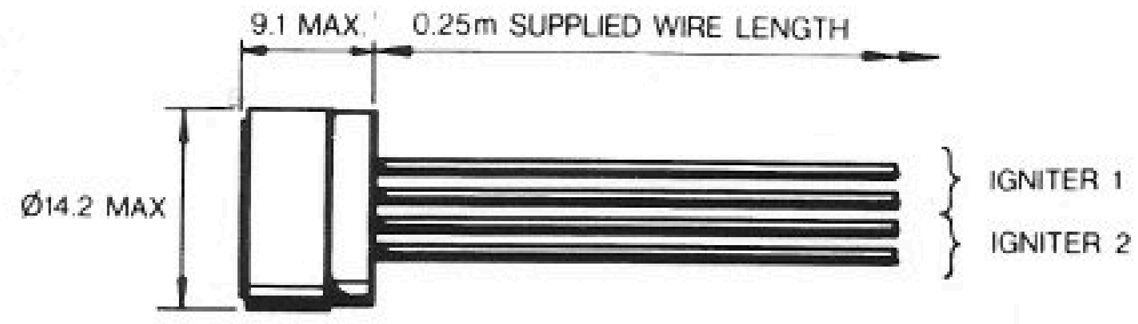
CAPABLE OF TRANSFERRING
10 WATTS INTO AN IGNITER OF
0.15 TO 1.6 Ω RESISTANCE

Type No 12/S1



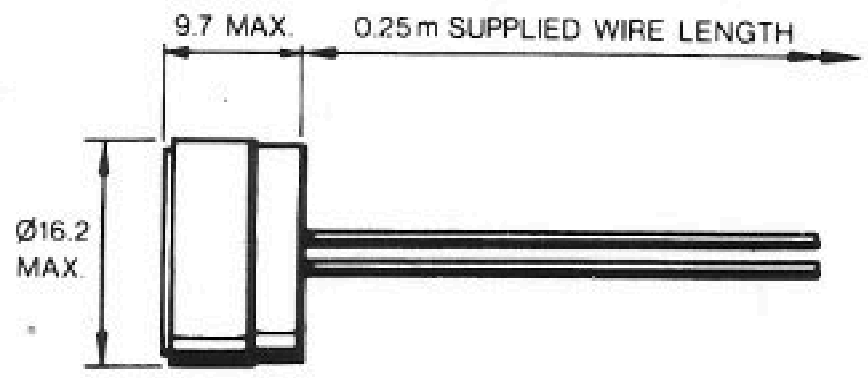
CAPABLE OF TRANSFERRING THE
FULL POWER OUTPUT OF ANY
TYPE 12 PRIMARY INTO AN IGNITER
OF 0.15 TO 1.6 Ω RESISTANCE

Type No 12/S1/2



CAPABLE OF TRANSFERRING HALF
THE POWER OUTPUT OF ANY TYPE 12
PRIMARY INTO EACH OF TWO
IGNITERS OF 0.9 TO 1.6 Ω RESISTANCE

Type No 14S/1.5

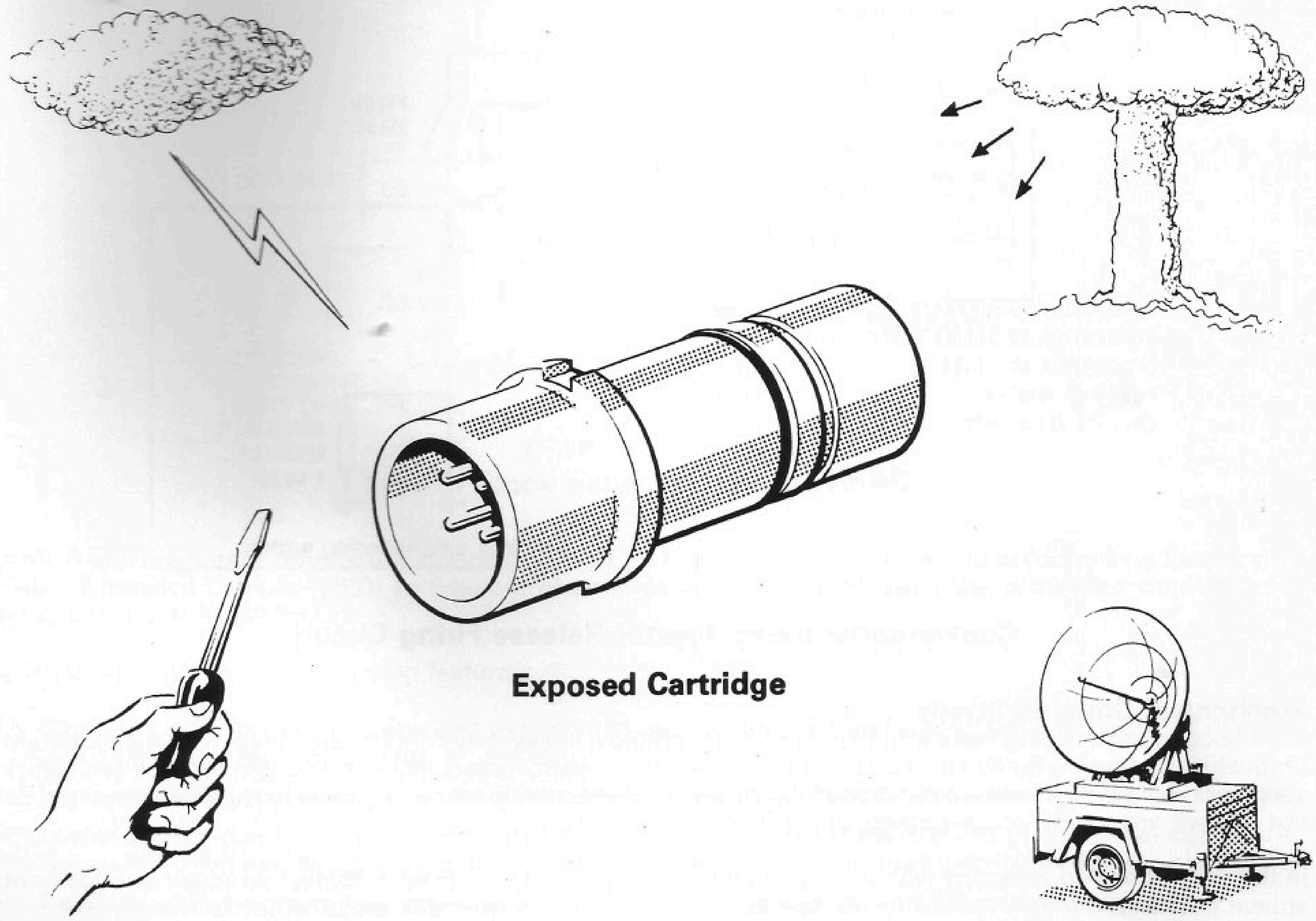


POWER TRANSFER INTO 1.5 Ω
IGNITER 50 WATTS

CONTENTS

SAFE IGNITION OF EXPLOSIVE DEVICES

THE PROBLEM



Exposed Cartridge

In the increasingly harsh radio frequency environment associated with modern aerospace and missile systems, it is essential that safety standards are maintained or improved where electrically initiated explosive devices (EIEDs) are involved.

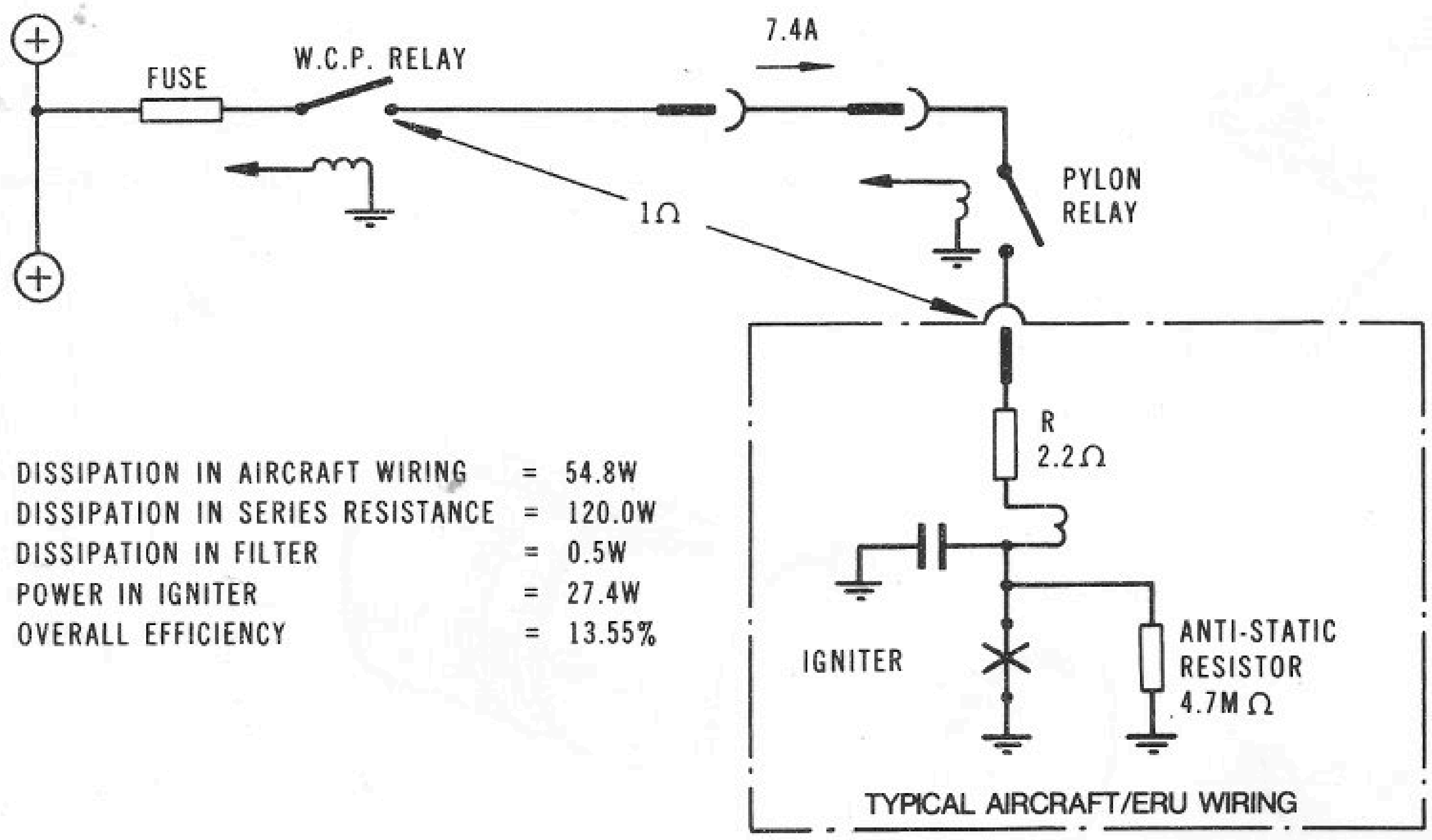
The ideal EIED would be safe from such hazards as:- radio frequency (RF), electrostatic discharge, electromagnetic compatibility (EMC), electromagnetic pulse (EMP), and electronic countermeasures (ECM) under all conditions during handling and when installed in a unit.
In an expendable cartridge or rocket motor it is impracticable to sacrifice an RF filter or filters. The existing policy, therefore, has been to fit the RF filters in the firing circuits of the installation and to ensure that the bridgewire or fuzehead used in the device has a high 'no fire' threshold level to cope with the hand-held mode.

THE CONVENTIONAL APPROACH

Electrical Considerations

The increase in the EIED 'no fire' threshold level and hence the power required to operate the device, conflicts with optimization of circuit design which attempts to minimize the current required to operate the system, and to increase reliability. The resistance due to faults which may be tolerated in the system is directly determined by the current necesary to operate the EIED, and problems associated with semi-conductor or relay contact switching are approximately proportional to the square of the current involved. The rating of cables and associated connector pins must be adequate to carry the current demanded. The diagram shown is typical of a wired release system and similar arguments apply to the semi-conductor switch elements in digital multiplex systems. Typical EIED bridgewires may present a resistance of 0.5 ohm or 1.0 ohm to a 28 volt system. In addition to high current requirements of conventional igniter circuits, the EIED will often present a short circuit to the aircraft system during or after ignition.

To prevent damage to contacts or semi-conductor switches or undue loading of emergency bus-bars, it is necessary to introduce a resistor in the firing line, typically of 2.2 ohm. In the case of weapon circuits, the igniters may be supplied by thermal or chemical injection batteries of limited power capability. A series resistor results in large power loss.

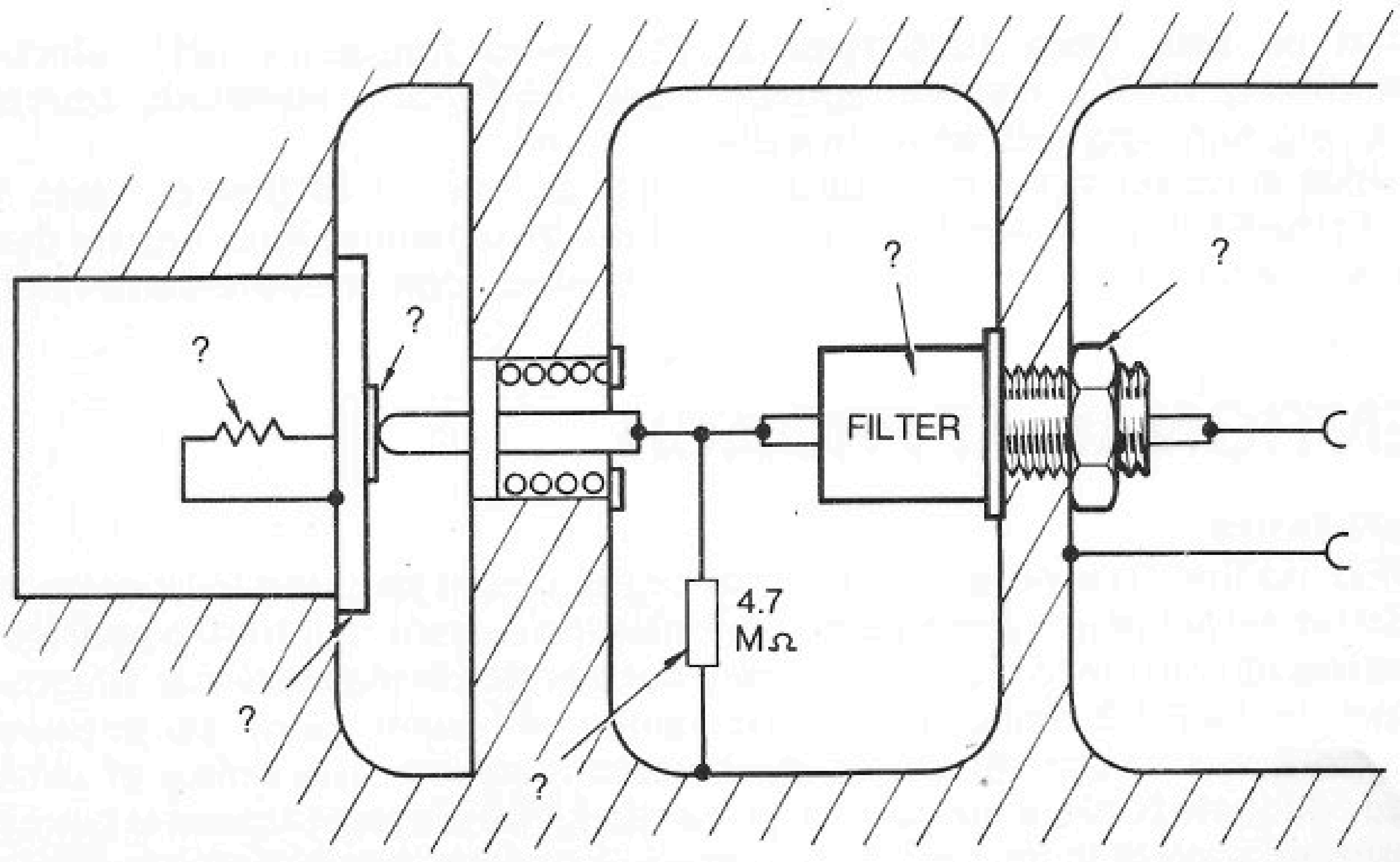


Conventional Bomb Ejector Release Firing Circuit

Mechanical Considerations

In addition to the use of igniters with high 'no fire' thresholds, heavy duty contacts and filters with their inherent unreliability; cleaning fluids and abrasions may affect the breech contact and extreme temperature and shock variations, may influence the filter capacitors. However, these additional components to the overall system do not achieve any safety improvements in the 'hand-held' mode.

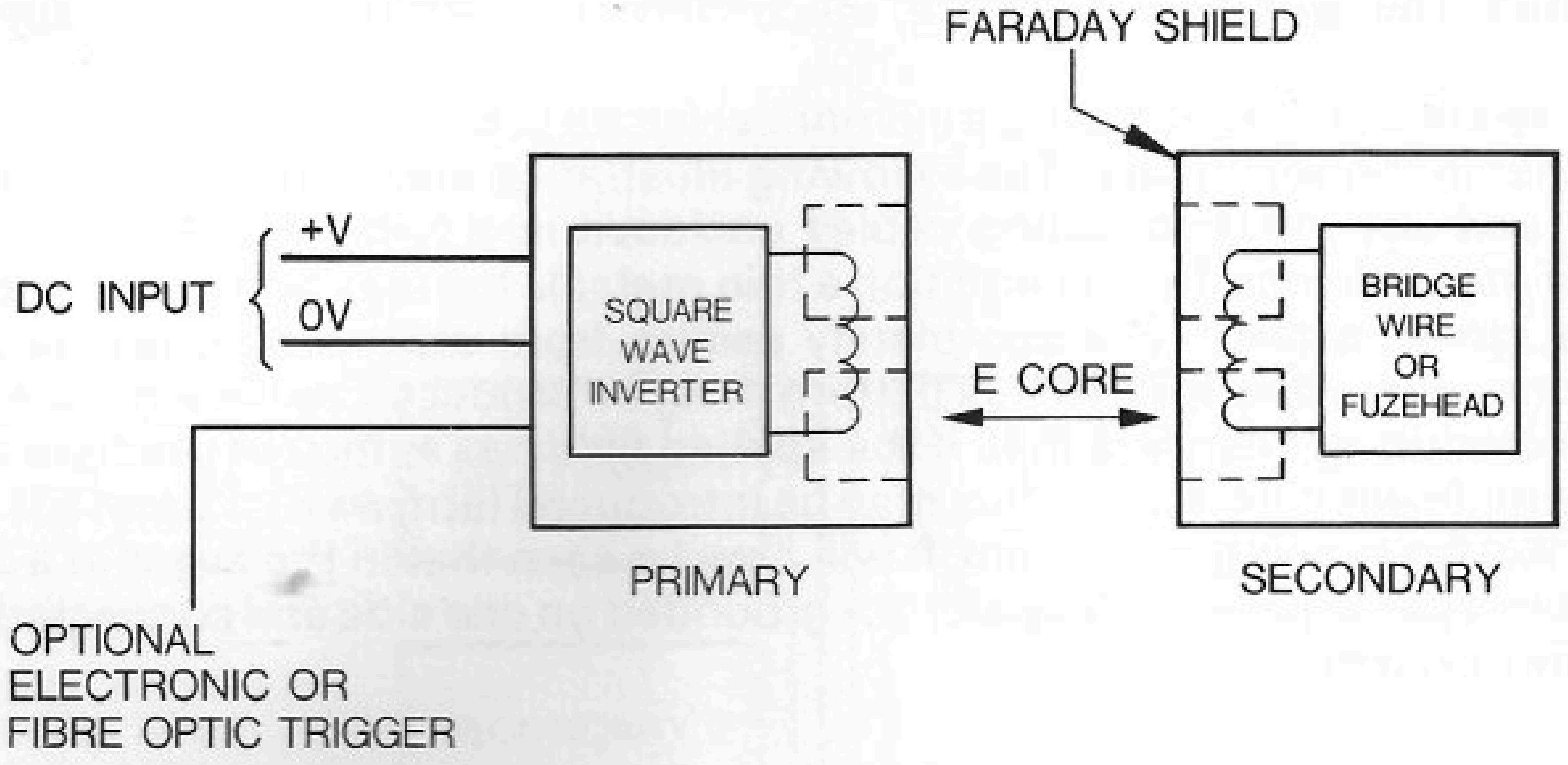
In the case of sealed weapons with a long 'shelf life' the conventional breech contact arrangement does not appear practicable from a reliability standpoint unless testing arrangements are accepted as the penalty.
In addition, on modern variable geometry aircraft which have prominent stores, lightning strike represents a significant risk, particularly during low level sorties below the cloud base. A conventional cartridge has one connection to the EIED grounded at the Ejector Release Unit (ERU) and the other connection to a cable feeding to the aircraft fuselage equipment. The RF filter and any relay contacts will not provide significant protection against voltage differences in the aircraft if a lightning strike occurs.



Typical ERU Breech Arrangement

THE RFAC SOLUTION

In order to provide a satisfactory solution to all the problems outlined, particularly the hand-held situation, a patented inductive coupling method has been developed and is now becoming standard practice on many new aerospace and weapon applications in the UK.
It is now also being applied in commercial systems requiring a similar degree of safety and reliability.



Typical Block Schematic of the RFAC

The ML Radio Frequency Attenuating Connector (RFAC) is the most advanced method of connecting Electrically Initiated Explosive Devices (EIED) to fire-control systems while providing complete protection from RF and electrostatic hazards (RADHAZ).

The RFAC incorporates the following features:

(1) Complete isolation of explosive and pyrotechnic devices from RF and electrostatic hazards in both the 'hand-held' and installed modes.

(2) Improved ignition performance due to elimination of series resistors and the effects of igniter short circuits.

(3) Lower system current requirements due to improved matching of the EIED to the electrical supply. (A typical RFAC can feed two igniters with 2.9 amp each while consuming only 2 amp from a 28V d.c. supply.)

(4) Computer-compatible trigger versions are available suitable for use with TTL and MOS systems.

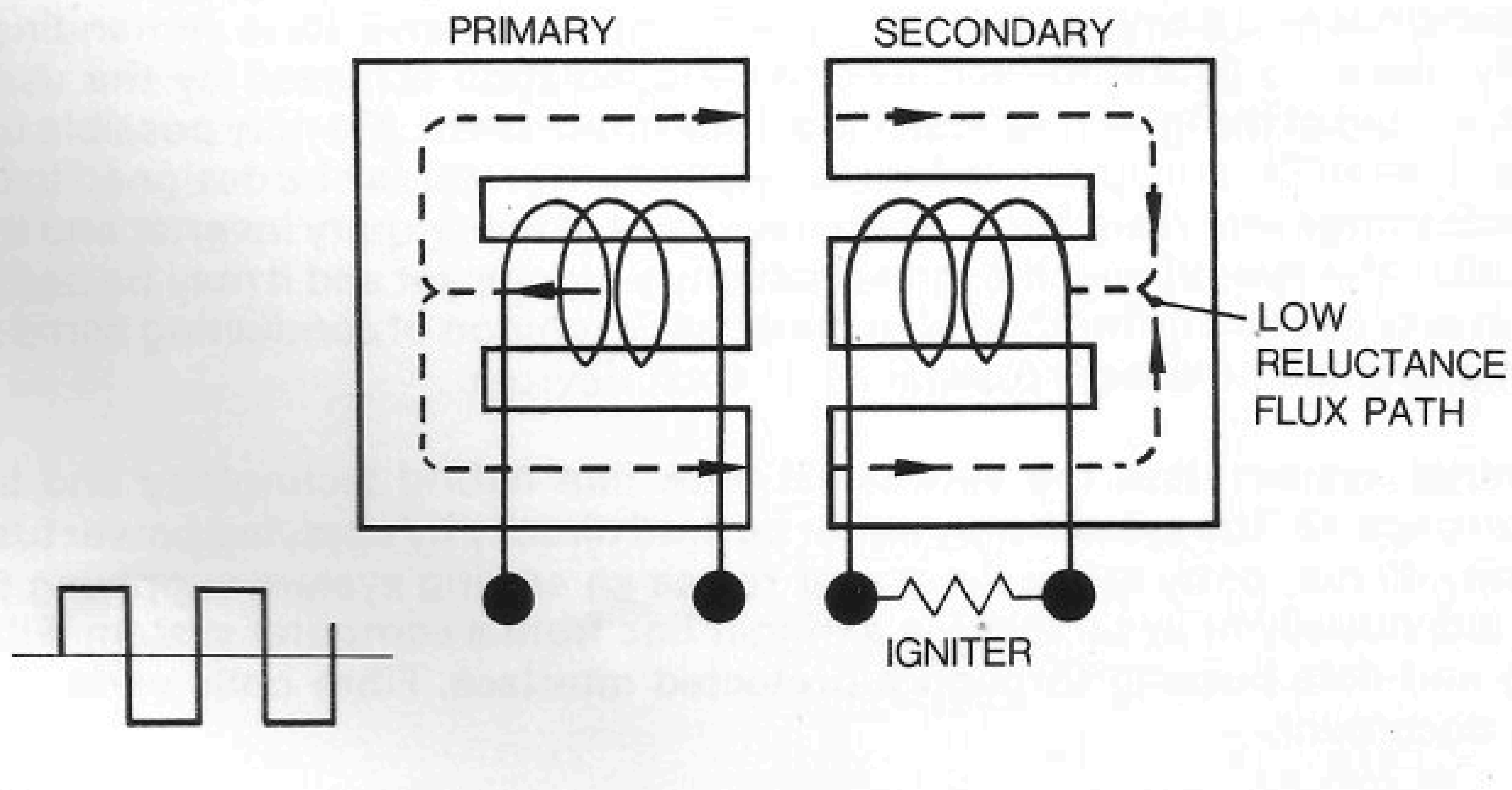
(5) Secondaries comprising single and multiple isolated windings may be used to provide device supply rails together with EIED operation.

(6) Voltage step-up secondaries for operation of high voltage firing systems.

(7) Nuclear hardening can be incorporated.

(8) Simplicity and high reliability of connection, leading to lower system cost.

The principle employed is that of a split transformer directly coupled to a thick film inverter and the general concept is known as the Radio Frequency Attenuating Connector. The system is both a very reliable connection interface and a good attenuator.

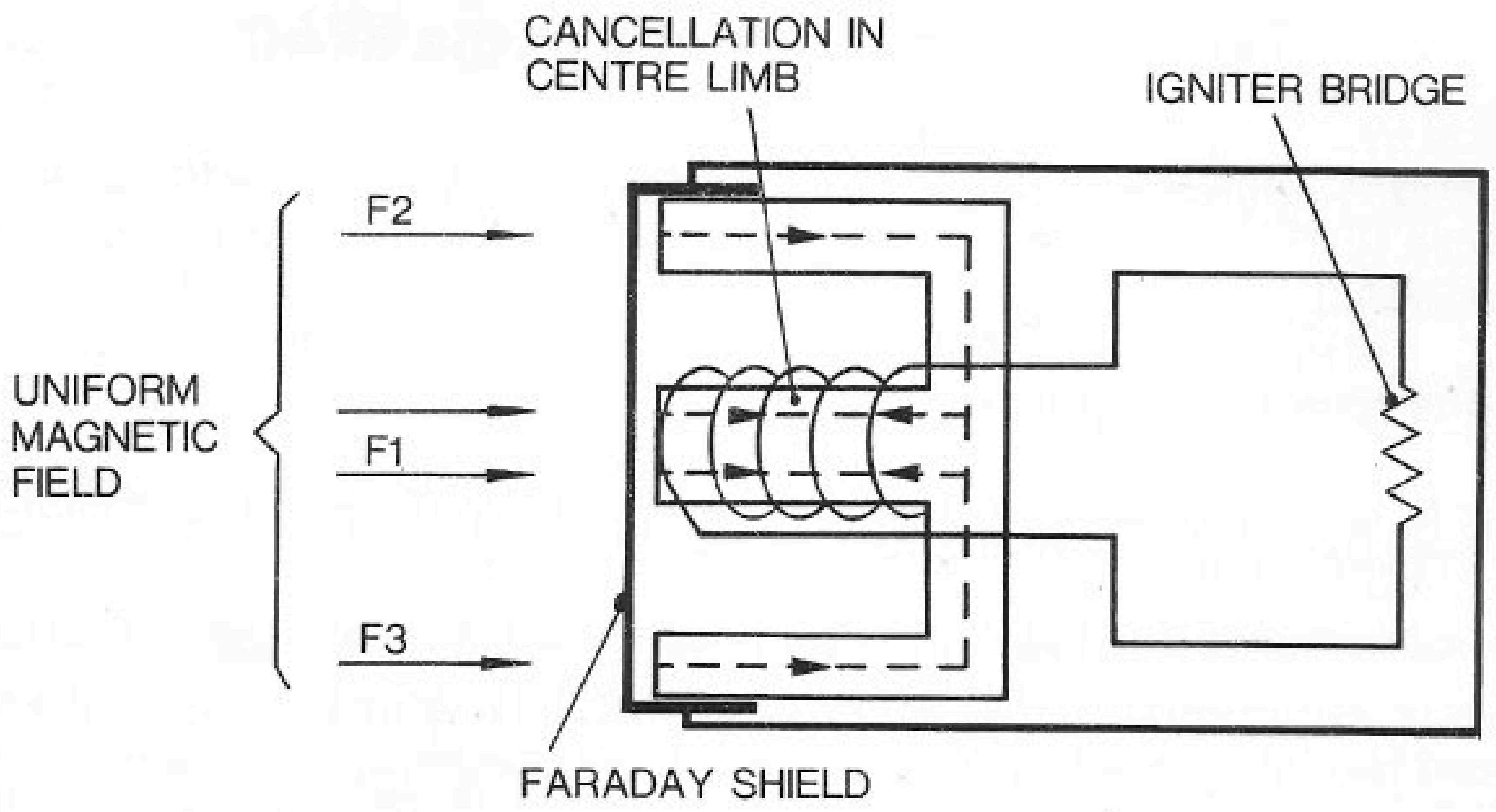


E + E Core Transformer

Attenuations of 50 to 100 dBs have been measured over a range of 50 KHz to 540 MHz. The transformer additionally provides a more practical means of matching the low resistance of the bridgewire igniters in present use with the nominal 28V system found in most aircraft and aerospace systems.

The primary half of the transformer is fed by a solid state thick film square wave inverter at a nominal frequency of 80 KHz. The magnetic flux due to the primary winding may be envisaged as flowing down the centre limb of the E core section, around the outer limbs of the secondary and returning via the centre limb of the secondary on which the igniter coils are fitted. The igniter is, therefore, electrically isolated from dc or ac supply voltages.

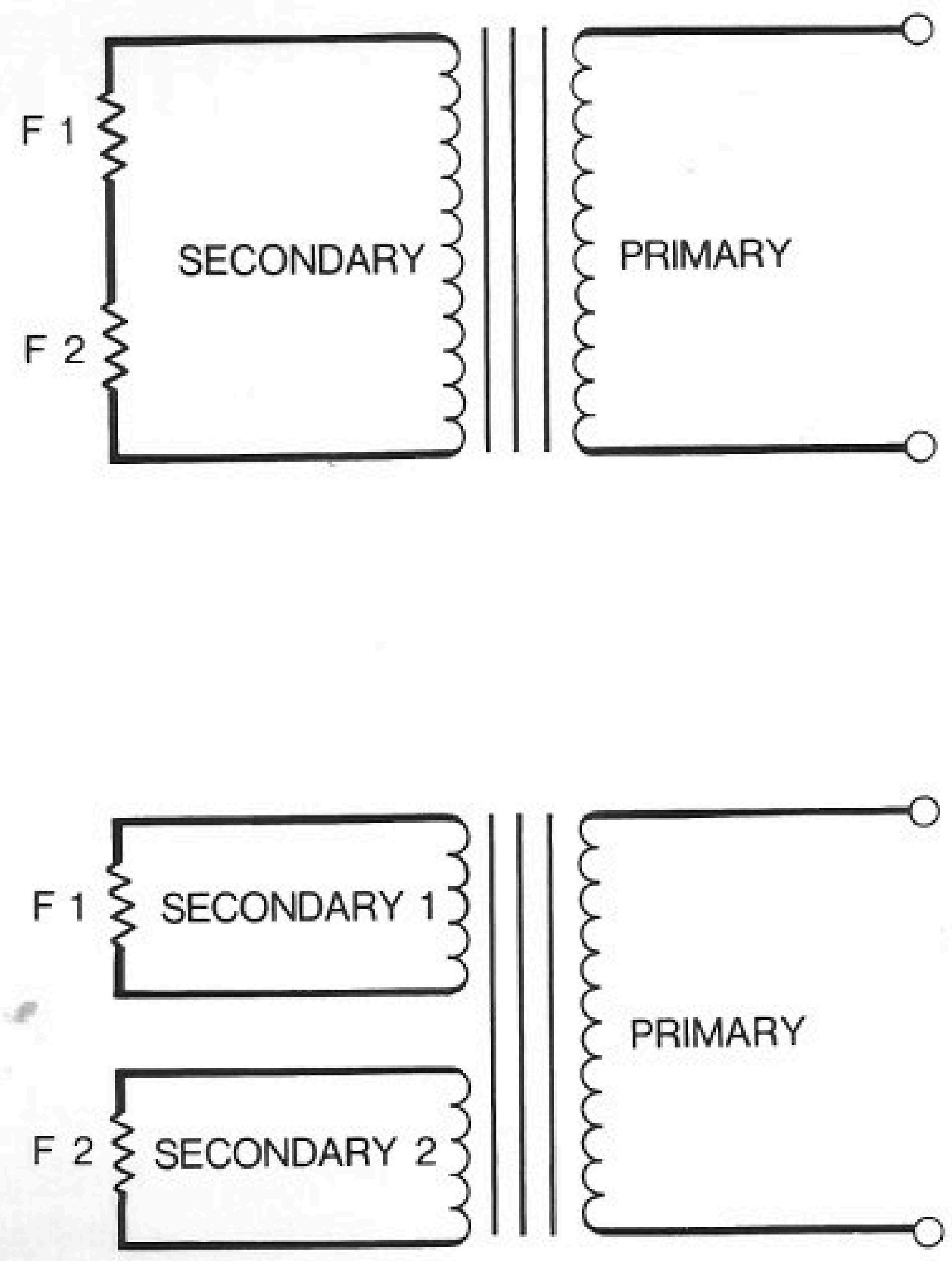
In practice the transformer is constructed using a cylindrical ferrite pot core of E section, one half incorporated in the primary and the other in the secondary. The following illustration shows the secondary assembly including the igniter bridgewire and any interconnecting cables enclosed in a Faraday shield normally formed by the metallic construction of the ordnance item. In addition a thin metallic foil may be incorporated on the contact face of the secondary. The igniter assembly is completely secure from electrostatic discharges and, in order to impress energy in the bridgewire, the applied flux pattern must be produced by the equivalent core structure. The only other method of introducing energy is that, if the applied field has sufficient gradient across the very small distance of the core, a significant difference in flux may be introduced (arrows F1, F2 and F3). In practice, the small physical size prevents this from being a problem. It will now be seen that in the event of a lightning strike to the store or pylon, the igniter is electrically floating and not grounded on one side and connected to an airframe cable, as is the case in existing systems.



Pick-up Mechanism in RF Attenuating Connector Secondary Exposed to Electromagnetic Fields

In addition to the merits of reliable connection and safety, by taking advantage of the matching provided by the transformer action, the inductive coupling method overcomes the problem of the short circuit igniter. The effect of a short circuit on the secondary is to produce an increased current in the primary inverter circuit typically of the order of 25%. The transformer also permits twin igniter bridgewires to be driven with a high degree of isolation between the two circuits and good matching is obtained. For example, it is possible to drive a current of 3A through two independent igniters in a single cartridge, whilst the primary inverter is demanding a peak current of 2.0A from a 28V supply. Because of the RF and electrostatic isolation achieved by the use of the inductive coupling, the 'no fire' threshold of the igniter selected is of little importance. It is now possible to select the igniter technology on the basis of reliability and low cost. Moreover, the turns ratio can be designed to match the primary inverter to the appropriate bridgewire resistance. As the reliability of the primary inverter and transformer is very high, (approximately 0.997), the reliability of the igniter becomes significant and it may be desirable to introduce twin igniters as a normal procedure. The method also permits the ignition of conducting composition igniters by providing a step-up ratio to match the high resistance of such devices.

The RFAC primary inverter system uses the very latest thick film hybrid technology and is available in the configurations shown on page 18. The system may either be fired directly by applying power (usually 28V d.c.) for a period of approximately 40 ms; or by using the power rail as an arming system supplying power to multiple RFACs and firing them individually or in salvoes via a trigger line from a computer system. Fibre optics are also available for triggering and data bussing through a protected interface. Fibre optic variants are discussed in another section of this document.



Schematic of Typical Multiple Fuzing