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NEMP HANDBOOK

FOR

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NEMP HANDBOOK

1.0 INTRODUCTION

The scope of this handbook includes introduction to NEMP effects on lines entering shelter areas and effects on equipments connected to those lines.

Included is a brief description of surge protection devices and systems. Methods of selecting and applying NEMP protection are also included.

This handbook is intended for use in assisting contractor A & E personnel and others responsible for specifying NEMP protection of electrical and electronic systems and subsystems in shelter areas subject to NEMP hazards.

1.1 <u>NEMP Effects on Electrical Systems</u>: The Nuclear Electromagnetic Pulse (NEMP) is one of many transient phenomena caused by a nuclear explosion. These phenomena include heat, ionizing radiation (such as x-rays) particle radiation, and if the explosion is in the atmosphere or underground, a shock (or overpressure) wave.

This handbook will be concerned only with the electromagnetic pulse in the form of voltage and current transients as they appear on any conductor penetrating a shelter. It is assumed that equipment is individually shielded or installed in a shielded shelter so that the user of this handbook need not be concerned with transients induced directly into equipment and systems. It is further assumed that all conductors except grounded leads entering the shelter are equipped with heavy duty lightning arresters. The user is, therefore, not concerned with selection of these first-stage protectors, although he will need to know their characteristics in order to select and apply any necessary additional protection.

1.1.1 <u>Magnetically Induced Surges</u>: A nuclear explosion generates a massive net flow of charged particles, equivalent to a very large current in a long conductor. In many respects, this phenomenon is similar to a severe lightning discharge. As in the lightning discharge, the current appears as a series of extremely sharp pulses. These current pulses generate severe magnetic and electric fields which propagate from the source as pulsed radio waves. The energy in these pulsed fields is contained in a relatively broad band of frequencies.

The changing magnetic field will induce a voltage in any conducting circuit proportional to the rate of change of the field and to the net area of the field enclosed by the circuit. The induced voltage is reduced by such practices as using twisted conductors, metal conduit, guard wires, and earth burial of the circuits. In spite of these practices, however, the induced voltage can be dangerously high in the vicinity of a nuclear explosion where shock and temperature effects could be withstood.

NEMP HANDBOOK (CONTINUED)

1.1.2 Electrostatically-Induced Surges: The electrostatic field pulse is directly related to the magnetic field pulse. It induces a charge on any conductor immersed in it, and the resulting current is proportional to the rate of change of the field for a given conductor capacitance. The effects are reduced by guard wires, shielding, balancing, and earth burial, but remain dangerously high.

1.1.3 NEMP Propagation on Conductors: The NEMP pulse shapes are described in classified literature. These pulse shapes are stretched and otherwise drastically altered as they propagate on various conductors. For example, on a low-loss transmission line with poor impedance matching, a pulse can be intensified or can become a train of several pulses because of reflections. On lines with losses, the high frequency portions will be reduced and the pulse becomes less sharp but lasts for a longer time. Also, on low loss lines, the stretched pulse can be transmitted at dangerous levels for a distance of several tens of miles.

Since the characteristics of NEMP pulses are similar in qualitative respects to lightning-induced surges, it is logical to expect that necessary lightning arresters will incidentally give some degree of NEMP protection. We shall assume that "first stage" or external lightning arresters are present.

1.2 Standard External Protection

1.2.1 Primary Power Distribution Arresters: The most common primary power distribution lines operate in the range of 2.4 to 7.2 KV line-to-neutral or 4.16 to 12.5 KV line-to-line rms nominal voltages. Because of efficiency and other considerations, most primary distribution is wye-connected 4-wire grounded neutral. Lightning arresters are connected from each line to ground. To minimize interruptions by lightning surges, the most common type of arrester on primary distribution lines is the valve-type. This type interrupts the power-follow arc at the first zero-voltage crossing after the surge. Primary distribution arresters are placed as near as possible to transformers and substations to provide maximum protection to expensive equipment. Other arresters may be located at periodic intervals on the line to protect insulators. The typical primary arrester will fire at less than three times normal peak voltage within a few microseconds and will discharge 50,000 amperes or more for a few milliseconds at 200 - 300 volts or so.

1.2.2 Secondary Power Distribution Arresters: Secondary distribution voltages normally range from 120 to 440 volts rms, with numerous variations of single phase and three-phase service. Some services do not use a neutral wire.

In some cases primary distribution may enter the shelter directly, and the transformer or substation and all secondary distribution may be in the shelter. In this event there may be no secondary lightning arresters.

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Although secondary distribution lightning arresters are available, many power distribution systems do not use them for lightning protection. It should not be assumed, therefore, without checking that secondary arresters are installed before selecting additional circuit protection against NEMP surges.

Electrical characteristics of secondary valve-type distribution arresters are very similar to those of primary arresters. However, the spark-over voltage (1200 - 1500 Volts typical) in standard arresters has a much higher ratio to normal peak voltage thanit does in the primary arresters. This poses no problem for the distribution system, which is designed to withstand the surges. However, it does represent a serious hazard to connected utilization equipment. To protect utilization equipment, it may be necessary to use special arresters or hybrid surge suppression networks. These are described in another section of the handbook.

1.2.3 Antenna Spark Gaps: It is essential to protect exposed transmitting and receiving antennas both against lightning and NEMP-induced surges. Since the problem of power-follow is not usually present on antennas, some form of spark gap is usually adequate as the first stage lightning or EMP protection. The first stage spark gap prevents insulator damage and restores normal operation as soon as the surge threat has been reduced to a safe level. Additional stages of NEMP protection will be required to prevent transmitter or receiver burnout or breakdown, RFI, and personnel hazard.

1.3 System Protection Vs. Subsystem or Unit Protection: When it can be avoided, no attempt should be made to provide individual surge protection for each electrical or electronic unit or subsystem. This approach is both costly and unreliable because of the difficulty of proper coordination. A much more successful approach is to provide one or more stages of surge protection at the point of entry of each conductor into the shelter facility. Properly selected surge protectors will limit voltage transients to 1.5 times normal peak voltage or less. This is adequate to protect most circuit components against failure. Some additional protection may then be required for unusually sensitive units, or to reduce RFI transients in particularly sensitive or critical circuits, but this will be a minimum.

2.0 SURGE-PROTECTION DEVICES AND NETWORKS

2.1 Spark Gaps: The sparkover voltage of a spark gap is a function of dielectric material, electrode geometry, density, and wave shape of the driving voltage. The minimum practical and repeatable dc sparkover voltage is between 200 and 300 volts. The sparkover voltage for a transient is much higher as the transient rise time becomes very small. The

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spark gap requires approximately the same total energy to breakover for any wave shape whose crest is well over the dc sparkover voltage and which rises fast enough to break down the gap before appreciable energy can be dissipated. Total energy is proportional to the product of voltage and time. Therefore, the faster the voltage rises, the shorter the response time. If this relationship is plotted as in Figure 1 , the resulting graph is a "volt-time" curve. This constant-energy curve is characteristic of most impulse-actuated devices, including all types of arresters, circuit breakers, and fuses.

Low voltage spark gaps must be sealed in a gas atmosphere such as neon. Spark gaps operating in atmospheric air will not operate reliably below about 1.5 KV. Other techniques used to lower sparkover voltage or to speed response include use of sharp edges or points on electrodes, reduction of gas or air pressure, use of radioactive materials to ionize the dielectric, and use of an intermediate trigger electrode.

Once the spark gap flashes over, the gap voltage is clamped to the voltage drop of the arc, typically 10 to 20 volts. If this is less than the normal voltage, the gap will continue to arc and will be destroyed by heat or will cause service to be interrupted by a circuit breaker or fuse.

The spark gap is somewhat more tolerant on ac circuits. Since the applied voltage periodically passes through zero, the arc will be extinguished and will not re-strike if the ionized material between electrodes can clear the gap before the voltage rises to a sparkover level again. On dc circuits, some auxiliary means must always be used to interrupt the arc.

Simple ac spark gaps can be made self-extinguishing up to perhaps 250 volts. Higher voltages require special techniques. These include confinement of the arc in a tube with internal baffles, or use of a magnetic coil. When the arc is confined, the heated gases are rapidly expelled from the tube. This both cools and lengthens the arc, which increases the voltage drop and interrupts the power follow current when the applied ac voltage passes near or through zero. In the magnetic coil (or "blowout") arrester, the magnetic field reacts with the arc and forces it away from the electrodes.

2.2 Valve Arresters: The valve arrester, which is in common use on primary power distribution lines, is a simple modification of the spark gap. In this type of arrester, a resistor is connected in series with the spark gap. The resistor may be a non-linear element such as silicon carbide or a heavy non-inductive shunt type.

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The non-linear resistor has the characteristic current relationship $I = KV^n$ in which I and V are the current and voltage drop, respectively, and the exponent n ranges typically between 2 and 4. K is a characteristic constant of the particular resistor.

This relationship shows that a voltage surge will, in effect, reduce the resistance and allow heavy current to flow to ground. When the surge has passed, the resistance rapidly rises, and the resulting voltage drop quenches the power follow arc. Some manufacturers claim that a properly designed non-inductive resistor is a more stable and repeatable quenching element, and use this in their lightning arresters.

2.3 Gas Filled Gaps

2.3.1 Gas filled spark gaps have the advantage that the sparkover voltage may be made quite low in a controlled manner. Sparkover voltages as low as 100 volts are possible on a repetitive basis. In addition, this type of gap combines very fast response (less than .1 μ sec) with bilateral response characteristics. (Only one required to give bipolar protection.)

2.3.2 Gas filled gaps have the disadvantage of a poor volt time turn up characteristic. The time response to the dc flashover voltage may be several microseconds. Also, some type of quench circuit is required when these devices are used in conjunction with power line systems. The power follow arc is not self quenching.

2.3.3 This type of gap is recommended primarily for signal line applications ahead of a filter or other higher order protective device.

2.4 Semiconductor Clamps and Crowbars

2.4.1 Semiconductor devices such as SCRs and various types of diodes may be used in conjunction with conventional gaps and non-linear impedance devices to form effective low voltage clamping circuits. An example of an SCR crowbar is shown in Figure 2 . This circuit operates in conjunction with a conventional spark gap made by the Dale Manufacturing Company.

2.4.2 SCR's (Silicon Controlled Rectifiers) exhibit the property of exhibiting a very high impedance in both polarities until a gate voltage is applied in a positive direction with respect to the cathode. The device will then conduct as a conventional diode until forward bias is removed at which time the SCR returns to its bi-directional blocking state.

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2.4.3 Conventional diodes exhibit a low impedance path when forward biased. The volt drop in the forward direction is typically ½ volt. Conventional diodes are useful in protecting against reverse polarity transients on signal and dc lines. They may also be used in a back to back configuration across receiving antenna feeds for bi-polarity protection.

2.4.4 The Zener or Avalanche type diode is similar to the conventional diode in the forward biased direction. In the reverse direction, avalanche diodes will begin conduction at a predictable low dc voltage. Voltage ranges are available from 3 to over 100 volts in this type of device.

2.4.5 The gas thyratron is a vacuum tube equivalent to the SCR. The thyratron is capable of withstanding very high voltages (several kilovolts) and probably would not have advantages as a transient suppressor over conventional spark gaps.

2.4.6 The semiconductor devices mentioned in the preceeding paragraphs offer the advantage of having very low resistance during conduction. Repeatibility and reliability will be excellent as long as device ratings are not exceeded. This type of device should be used as a component in a hybrid type arrestor system and never as a primary arrestor.

2.4.7 Semiconductor devices will have the following disadvantages which should be considered before employing them as transient suppressors.

2.4.7.1 Limited Power Dissipation for This Application: Typically 100 ampere devices will be near the maximum practical size with a reasonable response time.

2.4.7.2 High Cost: 100 ampere epitaxial SCRs typically cost $50 to $100 each depending on voltage rating.

2.4.7.3 Unipolarity Protection Only: Two devices must be employed to protect against bipolar transients. (Exception: "Triac" shown in Figure 2)

2.4.7.4 Non Fail-Safe Operation: Semiconductors SCRs and similar devices are likely to fail shorted if their ratings are exceeded.

2.5 Filters: Filters may be useful for NEMP protection of specific equipments such as those with narrowband susceptibility characteristics, and those which are unusually sensitive to very low energy pulses. (Computers, radio receivers, instrumentation, etc.). Where a filter is to be used solely or primarily for such NEMP suppression, it should have one or more additional stages of protection. The purpose of the additional stages is to protect the filter elements and to reduce the transient to a level which the filter is then capable of fully suppressing without spurious responses.

2.6 Relays and Circuit Breakers: Electromechanical devices should never be relied upon for NEMP protection. Because of the mass of moving parts, response is far too slow for NEMP transient. Circuit breakers are not suitable because there is not enough assurance that the series gap will not arc and reclose the circuit on the transient, also, service is interrupted unnecessarily and the breaker will not respond fast enough if it is electromechanical.

2.7 Special Problems of DC Protection: DC circuits are very likely to employ semiconductor regulators or other protective circuits which are very susceptible to line transients. The presence of polarized capacitors such as tantalums, invites disaster if any significant reverse transients occur.

This type of susceptibility suggests the use of hybrid circuits discussed earlier. Special power interrupt or quenching circuits will be necessary to release SCR's from power follow currents.

3.0 PRINCIPLE OF INSULATION COORDINATION

3.1 Fault Isolation and Clearing: Basic requirements of insulation coordination for lightning, NEMP, or other types of surge protection are:

3.1.1 Quickly isolate any fault to affect the minimum fraction of the power or communications system.

3.1.2 Clear the fault as quickly as possible and restore the system to normal operation.

Surge suppressors as required for NEMP can be thought of as intentional weak insulation points in the system. When a surge stresses the system insulation, a fault (short circuit or over current) develops at one or more of these weak points. Obviously, the fault will be less harmful if it discharges at a spark gap which is left undamaged than it is if it breaks a line insulator and causes the line to burn down.

NEMP HANDBOOK (CONTINUED)

Perhaps less obvious, but vitally important, is the necessity of selecting the "weak points" (arresters) so that even the momentary discharge fault is confined to the smallest possible part of the system. This requires that successive surge arresters and circuit interrupters affecting larger portions of a system respond more slowly than those affecting smaller portions. This requirement has to balance (or "trade off") against the possibility that a severe surge near a major distribution point may be too attenuated to operate the remote arresters or interrupters and could cause a major system interruption because the local protection is set too near the insulation failure voltage.

4.0 APPLICATIONS OF SURGE PROTECTION

4.1 Classification of Circuit Protection Limits: Before any plan of protection can be instigated, it is first necessary to ascertain the characteristics of the most susceptible piece of equipment in a given area. For the pruposes of this handbook, the assumption is made that the areas to be protected consist of complex shielded enclosures each containing a group of electronic equipment of some type. The level of protection will be on the individual enclosure basis. The most sensitive piece of equipment in a given area will determine the class of protection for the entire shielded room.

Example: If a single room contains a motor generator set, a calrod heating system and an electronic computer, the protection schemes will obviously be designed to accomodate the computer. For this reason, it is wise to group equipments with similar protection requirements in the same enclosure when possible to reduce the number of advanced protection systems required.

For the purposes of the handbook, the leads penetrating a given enclosure shall be divided into three classes: AC power, DC power, Signal leads. For each one of these classifications, three possible levels of protection are possible below first stage which is already assumed to exist. These will be known simply as second, third and fourth.

In each case, the amount of protection is indicated by the level, with fourth being the most elaborate possible for a given situation. Figures 6 through 11 are used to illustrate typical examples of each level of protection for each of the three classes of lines mentioned earlier.

4.2 Classification of Circuit Protection Limits: The table shown in Figure 3 is an attempt to classify various types of equipments based on the type of protection required for each equipment. The information presented here is of a general nature and, therefore, it is emphasized that all available information for a specific piece of equipment should be obtained before determining the type of protection to be used.

4.3 Special Equipment Protection Requirements:

4.3.1 The most important consideration for a given piece of equipment attached to the power line is the characteristics of its power supply. With regard to NEMP transient susceptibility, a few observations concerning power supplies may be made.

4.3.1.1 Power supplies of the 50 - 1000 Hz line frequency should be avoided. These wide range power supplies contain transformers with much lower leakage inductance than those of the 50 - 60 Hz variety. The leakage inductance in this power transformer will be instrumental in suppression of transients as this inductance appears in series with the primary in the equivalent circuit.

4.3.1.2 Power supply susceptibility may be improved by adding a 1 μf capacitor (non-polarized across each of the secondary windings of the power transformer.) This capacitor forms an "L" type low pass filter with the leakage inductance and further reduces susceptibility to incoming transients.

4.3.1.3 Power supplies employing bridge or full wave rectifier assemblies should use controlled avalanche type diodes or vacuum tube diodes. This type of rectification system is much less likely to suffer damage as a result of an over voltage condition than is a conventional diode assembly.

4.3.1.4 The term "solid state" when applied to a power supply usually means that an electronic regulation scheme is employed utilizing transistors and/ or integrated circuits. Because of the inherent sensitivity of solid state devices to over-voltage damage, it is imperative from a NEMP transient standpoint that the conditions as stated in 4.3.1.1 - 4.3.1.3 be observed whenever solid state regulation is employed. Investigation of the type of protection employed by manufacturers of solid state equipment will reveal some very adequate systems.

For example: Fairchild - Electro-Metrics Division powers their EMC receivers on batteries continuously, and the AC power supply serves only to charge the batteries when power is available. Such a scheme affords excellent NEMP protection, as the entire AC power supply could be damaged by a transient and the equipment would continue to operate on battery power.

4.3.1.5 DC to DC converter protection

4.3.1.5.1 DC to DC converters are susceptible to damage of the "off" state transistor resulting from incoming line transients. Such transients appear in addition to the "off" state V CE which is nominally twice the power supply line voltage. See Figure 5 .

4.3.1.5.2 The transient bucking transformer described in Figure 4 and Paragraph 4.4.3.2 in combination with the capacitor across the input leads of the converter should be a very effective transient suppression scheme. It is important, however, that the low side of the inverter input not be grounded to the shield or arrestor ground or the bucking winding of the transformer will be shorted.

4.4 Use of Passive Filters for NEMP Protection:

4.4.1 Passive filters may be used effectively against NEMP transients on power line when preceeded by some type of conventional arrestor. The passive filter will essentially band limit the spectrum of the transient and from this standpoint the requirements for the filter as stated in the following paragraphs should be considered.

4.4.2 Filters for protection of equipments connected to 60 Hz, 115 VAC commercial lines.

4.4.2.1 When measured at full rated load per MIL-STD-220A, filters should have a ±3 DB response to not greater than 1 KHz. Filters must exceed 100 DB from 14 KHz to 1 GHz for extreme rating, 60 DB for severe, 40 DB for moderate. Filters should employ gasketing on mounting surface to facilitate low impedance ground paths.

4.4.2.2 Filters must employ inductive inputs and capacitive outputs.

4.4.2.3 The input inductor in these filters should:

4.4.2.3.1 be single sweep wound and employ adequate spacing between start and finish leads to withstand a 5000 V transient breakdown test.

4.4.2.3.2 have its core taped with suitable insulating material (preferably teflon tape) to withstand 5000 VDC from the winding to the core. Cores should be powdered iron or molybdenum permalloy material.

4.4.2.3.3 employ heavy Formvar or heavy Soldereze wire only. Litz wire should not be used.

4.4.2.4 The capacitors in these filters should be of the self healing mylar or metalized mylar construction and should have a breakdown voltage of not less than 600 VDC.

4.4.2.5 Potting material should be high temperature (125°C) wax or heat conductive epoxy. Oils, except flame retardant silicon oils, or foam type materials should not be used.

4.4.3 Use of filters for protection of equipments attached to 28 VDC power lines.

4.4.3.1 Filter Characteristics: Filters should have characteristics as stated in 4.4.2 except that capacitors need only be rated at 200 VDC. DC filters should be preceded by spark or gas discharge arrestors.

4.4.3.2 DC lines may also be protected by transient bucking transformers connected as in Figure 4 . This scheme is especially effective in the protection of DC to DC converters from burn out due to V CE over-voltage resulting from line transients. Adequate line to ground protection should be provided ahead of the transient bucking transformer.

5.0 RECOMMENDED INSTALLATION PRACTICES

5.1 Optimum Placement of Surge Protectors:

5.1.1 Surge protectors should be installed on the high voltage or primary side of power distribution transformers whenever possible. When this is done the surge protector output amplitude will be reduced by the turns ratio of the transformer.

5.1.2 Use of constant voltage transformers after second stage type protection is recommended for reasons given in 4.3.1.1.

5.2 Surge Protector Grounding:

5.2.1 As most second and third stage type protectors are of a line to ground nature. Adequate grounding of the protector is a must.

5.2.1.1 Protectors with terminal connection grounds should be grounded with a minimum length copper braid such as automobile battery ground cable. Grounding should be to the shield of the shielded enclosure. The protector should be located such that the ground lead length does not exceed 2 feet.

5.2.2 Ground leads must be of minimum resistance and impedance. Copper or brass strap or braid should be used.

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5.2.3 Grounding of protecters should not be to neutrals or ground returns. Grounded shield walls or external ground rod systems should only be used for protecter grounds.

5.3 Protection of Neutrals and/ or Ground Returns:

5.4 Protector Location: Protectors should be located as close to the penetration of the leads in question through the shield as possible.

5.4.1 Protectors should be located on the inside of the shielded enclosure.

5.4.2 Protectors should be easily accessible to personnel to enable replacement if necessary.

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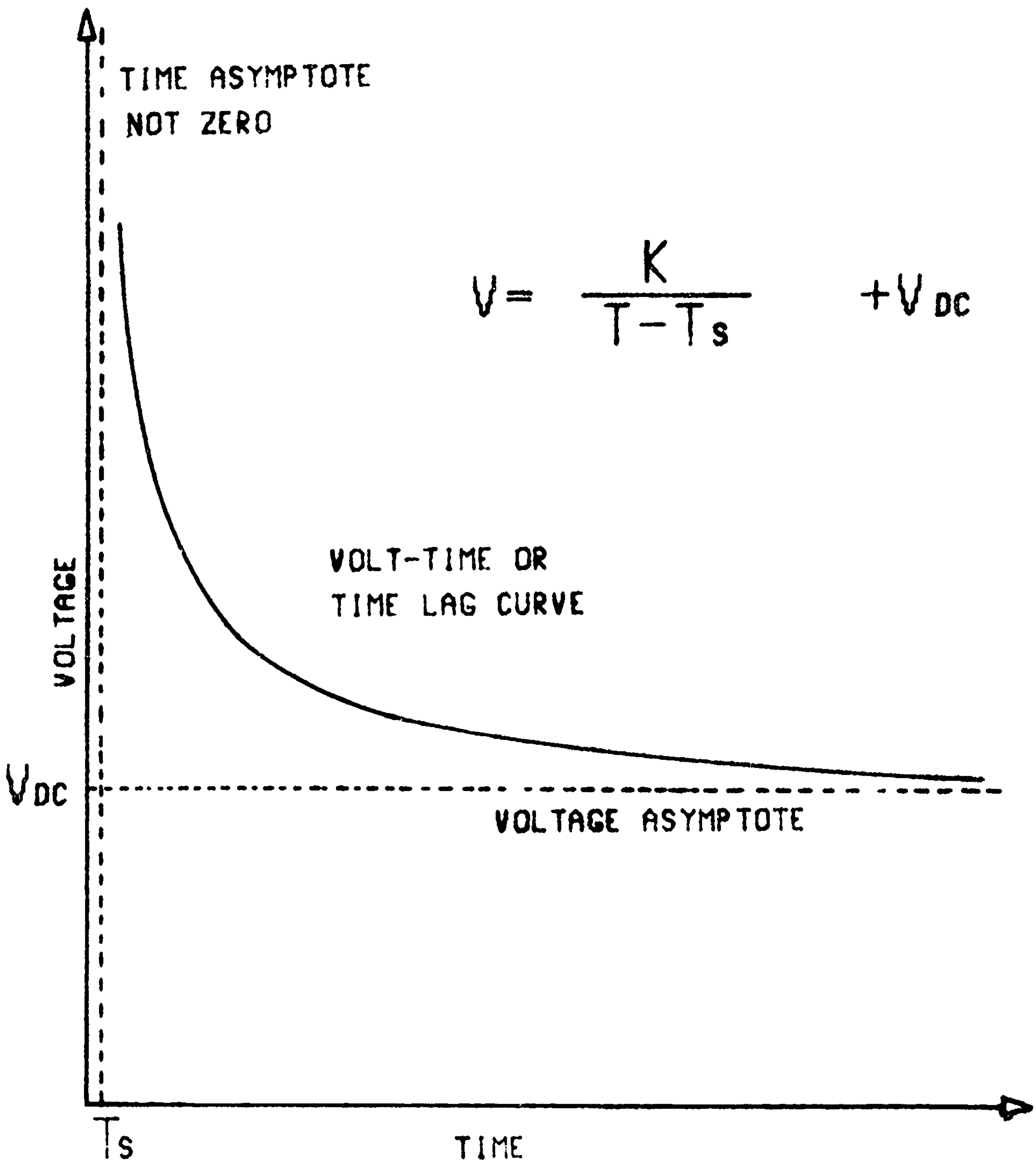
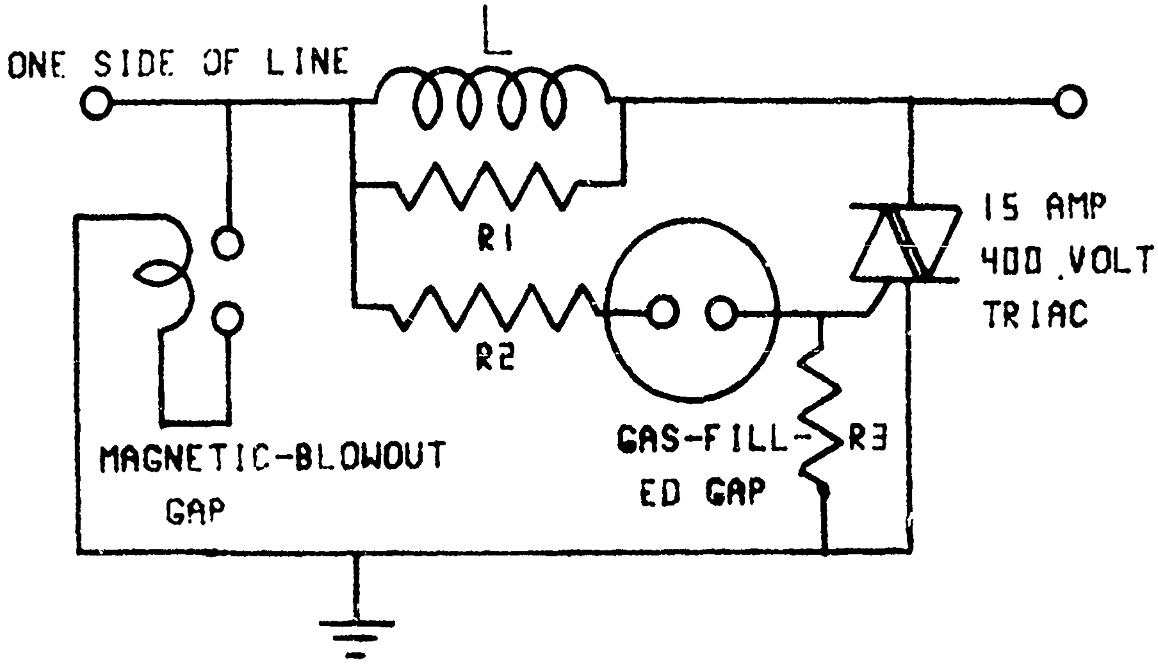
APPENDIX



VOLT-TIME CURVE FOR SPARK GAPS

FIGURE 1



TYPICAL 2 PLACES EACH SIDE OF LINE

EXAMPLE OF HYBRID AC PROTECTOR
SCHEMATIC

FIGURE 2

APPENDIX

EQUIPMENT PROTECTION REQUIREMENTS

CLASS 2 EQUIPMENTS

EQUIPMENT DESCRIPTION	TYPE LINE
1. Motors - AC induction	AC
2. Lamps - filament and fluorescent	AC
3. Heaters, i.e. coffee pots, air-conditioning equipment	AC
4. Motors - series and shuntwound	DC
5. Meters, Line voltage, Line frequency	AC - DC
6. Isolating Motor Generator Sets	AC or DC
7. 60 - 400 Hz converters	AC

CLASS 3 EQUIPMENTS

EQUIPMENT DESCRIPTION

1. Vacuum Tube AC power supplies in general
2. Teletype equipment power supplies
3. Transmitter - High power RF (over 50 watts) power supplies
4. Vacuum tube receivers - all types (power input)
5. Vacuum tube differential input circuits (signal)
6. Solid state receivers with isolation schemes such as 4.3.1.4
7. Alarm system power
8. Intercom power - vacuum tube
9. Telephone signal lines

CLASS 4 EQUIPMENTS

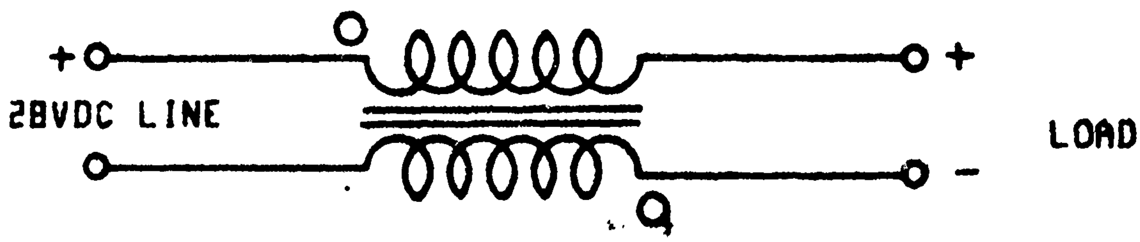
1. Computer power - all types
2. Solid state power supplies in general
3. Single ended or unbalanced coaxial system inputs
4. Computer-line inputs all types
5. Alarm system control leads
6. Intersite intercom signal leads
7. Antenna tracking system power
8. Antenna tracking control leads
9. Radar system power (and control if applicable)
10. Intercom power - solid state

FIGURE 3

APPENDIX (CONTINUED)

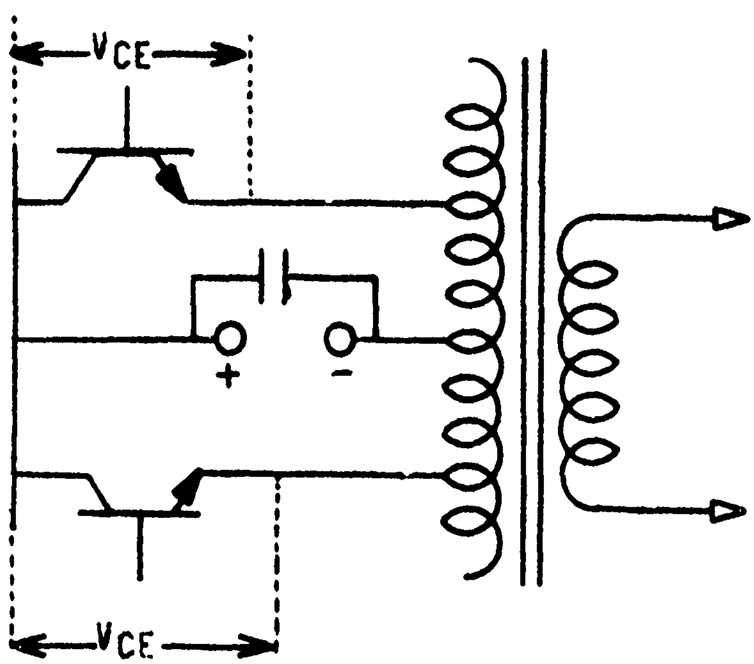
NOTE: The foregoing classifications are based upon the "Severe" threat level. "Moderate" threat classification will allow one stage less protection, i.e. equipments in Class 3 may be protected with Class 2 protection systems.

Evaluation of specific equipments for classification should be done whenever possible.



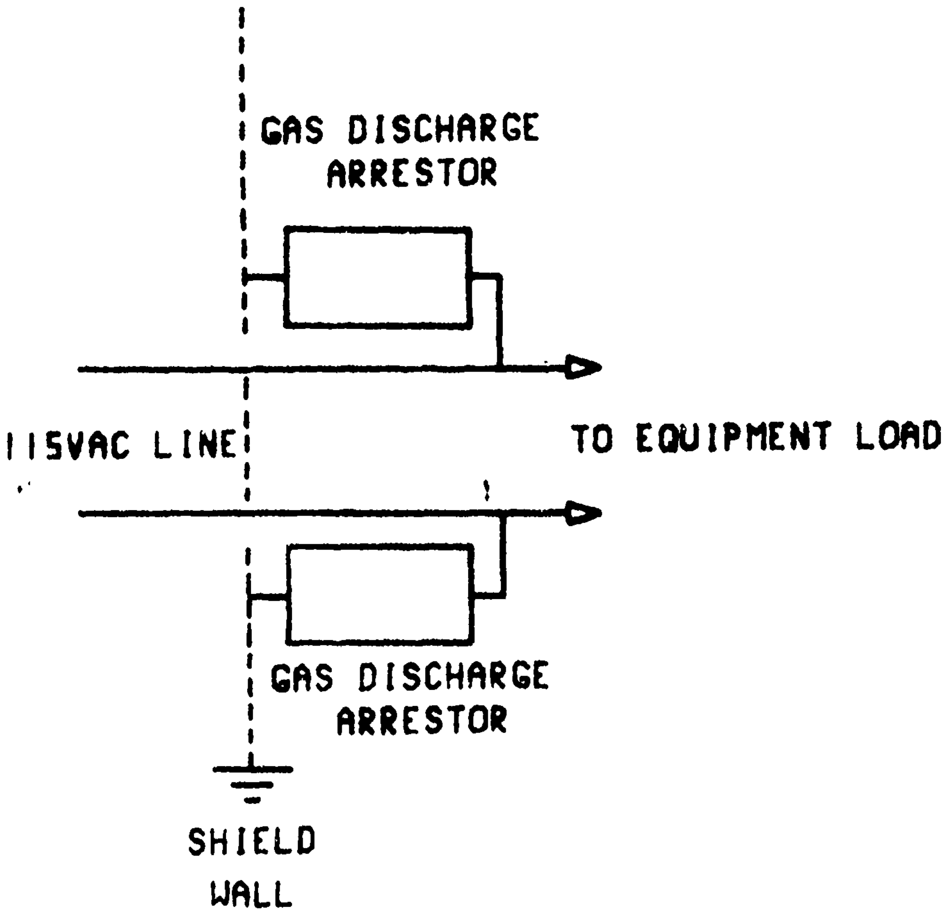
TRANSIENT BUCKING TRANSFORMER

FIGURE 4



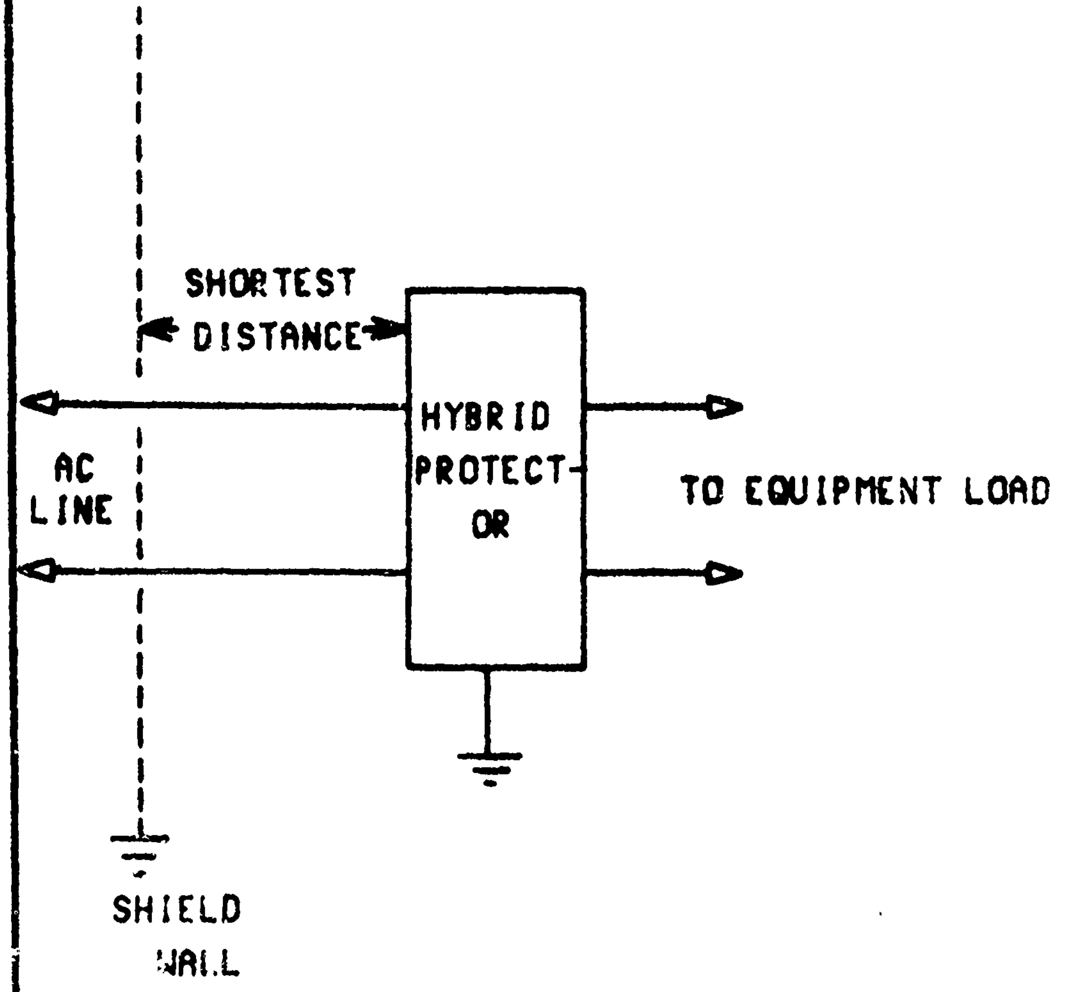
TYPICAL INVERTER SCHEMATIC
BASE FEEDBACK OMITTED FOR CLARITY

FIGURE 5



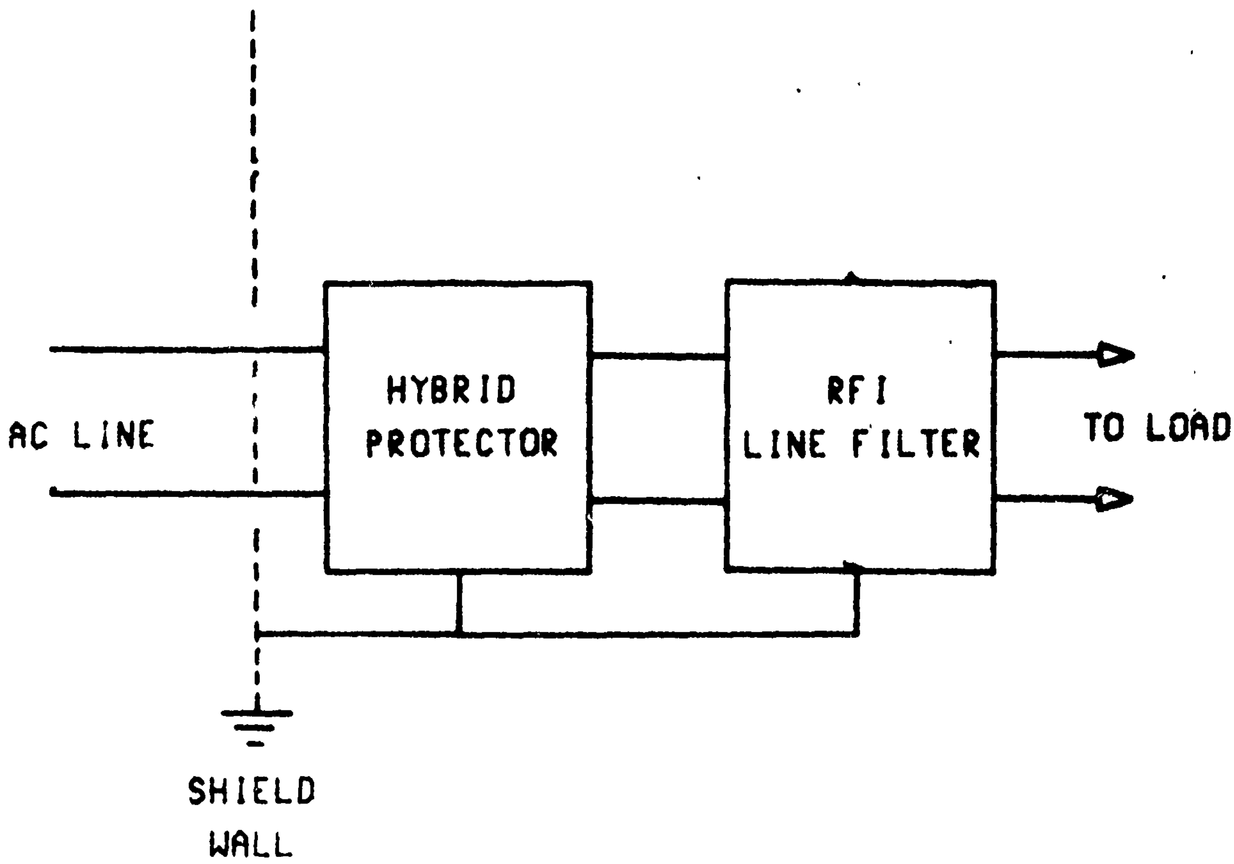
EXAMPLE OF 2ND STAGE PROTECTION
115VAC LINE

FIGURE 6



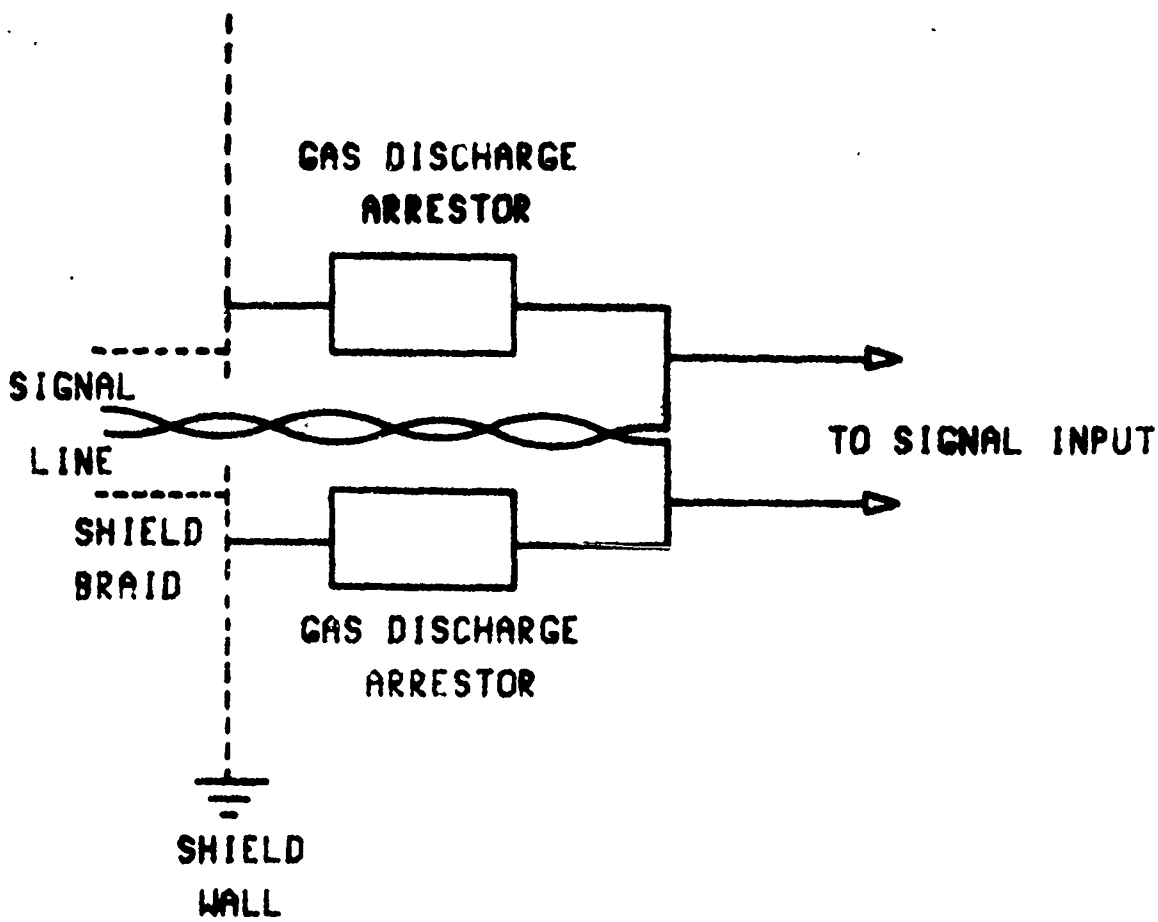
EXAMPLE OF 3RD STAGE PROTECTION
115VAC LINE

FIGURE 7



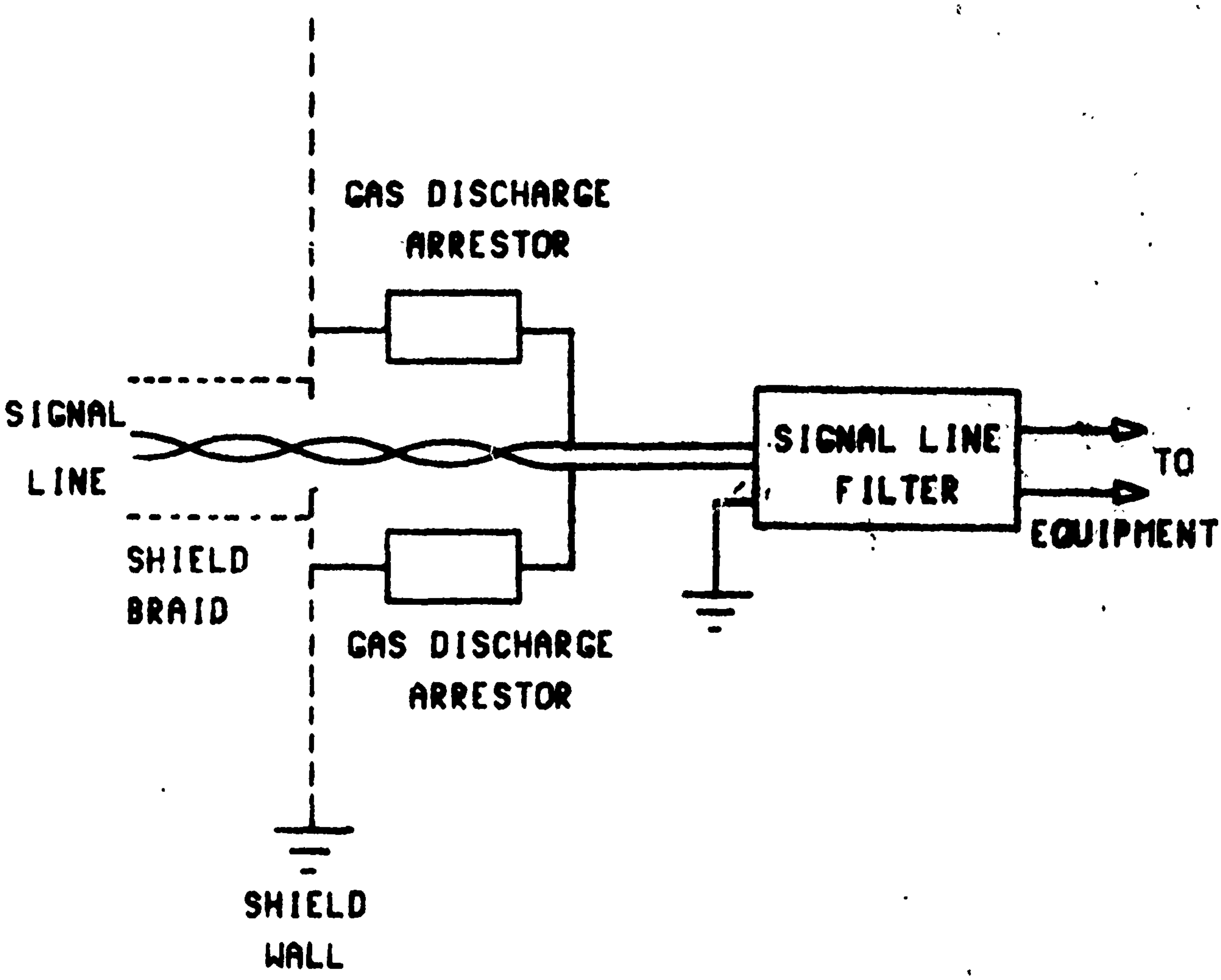
EXAMPLE OF 4TH STAGE PROTECTION
115VAC LINE

FIGURE 8



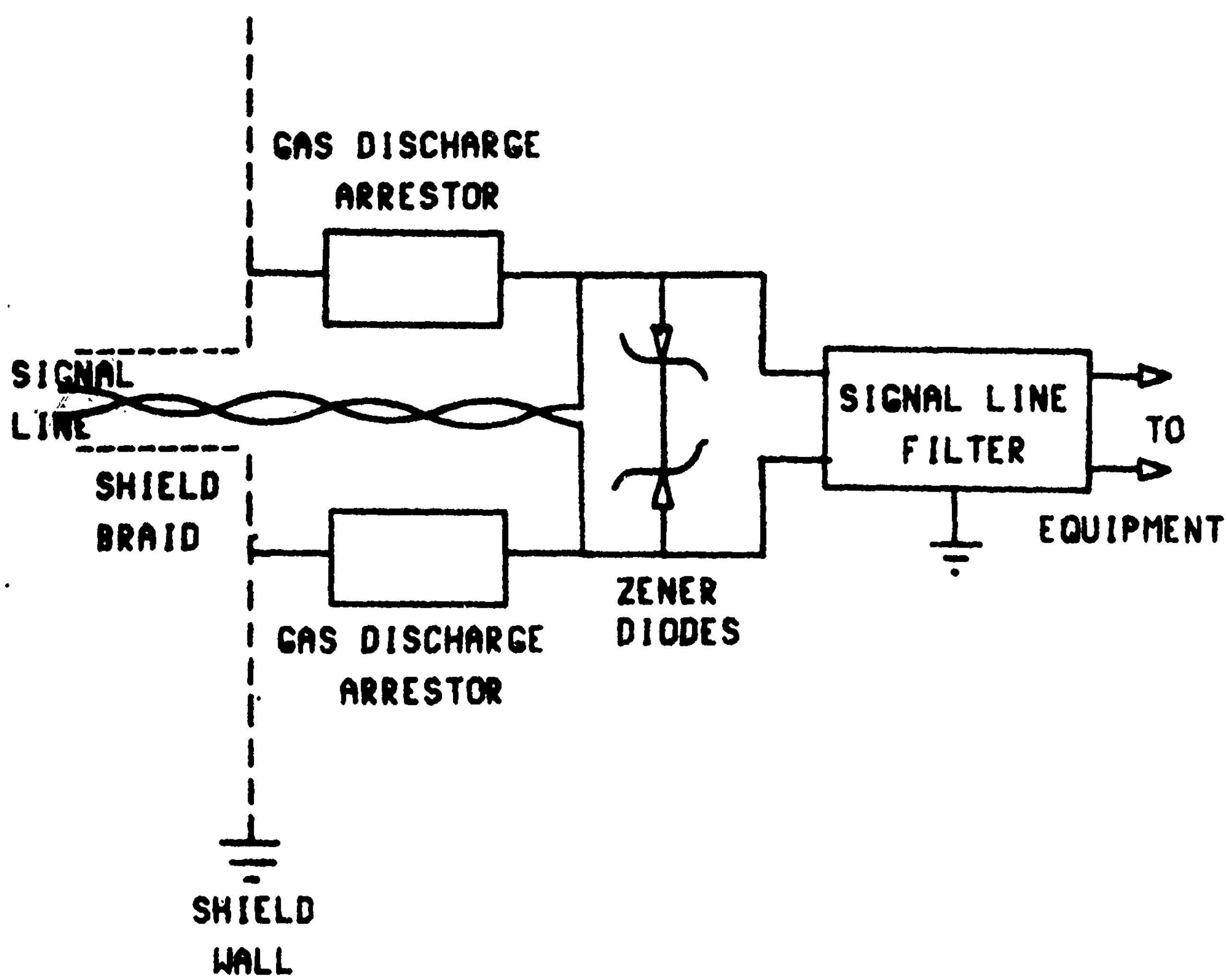
EXAMPLE OF 2ND STAGE PROTECTION
BALANCED SIGNAL LINE

FIGURE 4



EXAMPLE OF 3RD STAGE PROTECTION
BALANCED SIGNAL LINE

FIGURE 10



EXAMPLE OF 4TH STAGE PROTECTION
BALANCED SIGNAL LINE

FIGURE 11

SUGGESTED SOURCES FOR NEMP PROTECTION DEVICES

PROTECTORS

MANUFACTURER	TYPE OF DEVICE AVAILABLE
1. Joslyn Electronic Systems Goelta, California	Hybrids - AC and DC power Hybrids - Signal line - balanced and coaxial
2. Electrons Company 127 Sussex Avenue Newark, New Jersey 07103	Gas filled gaps for 110 - 220 VAC
3. Dale Electronics, Inc. Yankton, South Dakota	Spark gaps; magnetic blowout Types - AC and DC power signal and antenna lines
4. Motorola Semiconductors Phoenix, Arisona	Solid state devices; SCRs Zener Diodes, Zener Protector Assemblies for AC and DC power lines
5. Genisco Technology Corporation 18435 Susana Road Compton, California 90221	Filters: AC and DC power line signal line: coaxial and balanced
6. Spraugue Electric Company North Adams, Massachusetts	Filters: AC and DC power lines signal line: coaxial and balanced
7. Burnell and Co., Incorporated Pelham Manor, New York	Filters: AC and DC power signal line - all types
8. Cornell-Dubilier Newark, New Jersey	Filters: All types
9. Sangamo Electric - Electronic Products Springfield, Illinois	Filters: AC and DC power

ADDITIONAL REFERENCES

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13 ABSTRACT

The scope of this handbook includes introduction to NEMP effects on lines entering shelter areas and effects on equipments connected to those lines.

Included is a brief description of surge protection devices and systems. Methods of selecting and applying NEMP protection are also included.

This handbook is intended for use in assisting contractor A & E personnel and others responsible for specifying NEMP protection of electrical and electronic systems and subsystems in shelter areas subject to NEMP hazards.

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