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British Standard Guide to Prevention of inadvertent ignition of flammable atmospheres by radio-frequency radiation

Guide pour la prévention de l'inflammation intempestive des atmosphères
inflammables par rayonnements à fréquence radioélectrique

Leitfaden zur Verhinderung des unbeabsichtigten Zündens einer entflammbaren
Atmosphäre durch hochfrequente Strahlung

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Foreword

This British Standard has been prepared under the direction of the Electronic Equipment Standards Committee.

This standard, together with BS 6657, supersedes BS 4992 : 1974, which is withdrawn.

Electromagnetic waves produced by radio-frequency (r.f.) transmitters (e.g. radio, television and radar) will induce electric currents in any conducting structure on which they impinge. The magnitude of the induced current depends on the shape and size of the structure relative to the wavelength of the transmitted signal and on the strength of the electromagnetic field. When parts of the structure normally in contact are caused to break or separate momentarily (e.g. during maintenance or as a result of vibration) a spark may occur if the induced voltage and current at the break are sufficiently large. If this happens in a place where a potentially flammable atmosphere may be present a hazardous situation can occur. However, the possibility of ignition will depend on many factors including whether the spark can deliver sufficient energy to ignite the particular atmosphere. This British Standard provides a systematic procedure to assist transmitter operators, plant managers and all others concerned with a logical method for the assessment and elimination of r.f. induced ignition hazards.

BS 4992 : 1974 presented practical considerations relating to the presence of flammable substances or electro-explosive devices (EED) in the radiation field of a transmitter. A later amendment warned that some of the numerical information contained in BS 4992 was incomplete and that certain clauses were being given further consideration. Measurements of the powers that can be extracted from typical structures, including cranes, were subsequently carried out and the minimum powers that are required to ignite various types of flammable atmospheres were also measured. These measurements form the basis of the assessment procedures contained in this standard.

NOTE. The numbers given in square brackets used throughout the text relate to the bibliographic references given in H.3.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

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Guide

1 Scope

This British Standard provides guidance in assessing the potential ignition hazard from the inadvertent extraction of energy from electromagnetic fields, propagated from communication, radar or other transmitting aerials to plant where a potentially flammable atmosphere may be present. The standard is not concerned with similar hazards arising from electromagnetic fields generated by other means, such as electric storms, electricity generating installations or other radiating electrical equipment, nor is it concerned with any hazard arising within telecommunication or other electronic equipment.

This standard does not consider the hazards associated with the use of electro-explosive devices (EED) or the biological hazards of exposure to r.f. fields.

This standard also provides advice on how to mitigate the hazard in cases where the assessment indicates that a hazard may exist.

NOTE. The titles of the publications referred to in this standard are listed on page 49.

2 Definitions

For the purposes of this British Standard the definitions given in BS 4727 and BS 5345 : Part 1 apply, together with the following.

2.1 circuit factor, Q_k . A performance parameter for a structure acting as a receiving aerial (see reference [1]).

NOTE. Assuming the structure to be tuned to the transmission frequency f_t , Q_k is the ratio of f_t to Δf , where Δf is the difference between those frequencies, one above and one below f_t , at which the structure resonates when it is retuned so that the open circuit voltage at f_t has fallen by 3 dB. Q_k is closely related to the Q factor of a tuned circuit.

2.2 extractable power. The power dissipated in a resistive load connected across a discontinuity in a structure acting as a receiving aerial.

NOTE. The extractable power reaches its maximum when the structure is tuned to the frequency of the transmitter and the resistive load equals the resistance of the tuned structure.

2.3 modulus match power. The maximum value of extractable power that can be achieved with a resistive load at a frequency to which the structure is not tuned (see reference [1]).

2.4 structure efficiency. The ratio of the extractable power that the structure can deliver to a matched load and the maximum extractable power delivered by a lossless short dipole in free space immersed in the same field.

2.5 thermal initiation time. The time during which energy deposited by the spark accumulates in a small volume of gas around it without significant thermal dissipation (see reference [2]).

NOTE. For times shorter than the thermal initiation time the total energy deposited by the spark will determine whether or not ignition occurs. For increasingly longer times, the power or rate at which energy is deposited becomes the determining factor for ignition.

2.6 transmitting aerial gain. The directional capability of an aerial (see 4.4).

2.7 vulnerable zone. The region surrounding a transmitter in which a potential hazard could arise within a hazardous area of a plant.

3 General considerations

3.1 Radio-frequency hazard

The hazard assessment requires detailed consideration of the conditions that have to be satisfied simultaneously for a hazard to exist; these are as follows (see reference [3]):

- (a) electromagnetic radiation of sufficient intensity;
- (b) structure capable of behaving as a receiving aerial; only structures in a hazardous area (as defined in BS 5345 : Part 2 : 1983) need be considered (see clause 6);
- (c) establishment of a mechanism whereby the received energy or power can be delivered as a spark;
- (d) presence of a flammable atmosphere.

The simultaneous occurrence of these four conditions is unlikely.

An electromagnetic field of sufficient intensity may be generated by a fixed or mobile transmitter, the magnitude of the field depending on the transmitted power, the aerial gain and the proximity to the site under consideration.

In this context mobile transmitters in vehicles, ships and aircraft need to be considered.

All conducting structures behave as receiving aerials, but the magnitude of induced current and voltage will depend on the method of construction and the configuration. Experience gained in practical measurements on structures has shown that for frequencies below 30 MHz the loop configuration represents the most efficient receiving system. At higher frequencies all structures are large compared with a wavelength and their behaviour is conveniently treated by the use of long dipole theory. The behaviour of these structures is discussed in clause 5.

The generation of a spark is dependent on the appearance of a small discontinuity in a receiving structure, for example when parts of a structure normally in contact are caused to separate either during maintenance or at any time by flexing, mechanical vibration or similar actions.

The spark energy required to ignite a flammable atmosphere depends on the nature and composition of the flammable atmosphere. In making the assessment, it is assumed that the composition is at its optimum for ignition to take place. This in itself provides a margin of safety under most circumstances, since the energy required for ignition of a particular atmosphere generally increases rapidly as its composition moves away from the optimum.

3.2 Philosophy of the systematic method of approach

A potential hazard only exists in relatively few locations (the small number of incidents that have been reported as possibly attributable to this cause supports this view) and a full assessment of the hazard can entail onerous calculations and field experiments. To reduce to a minimum the need to carry out such work, this standard is based on a series of graded assessments, each requiring a progressively more detailed analysis.

The initial assessment procedure is very simple and is designed to eliminate from further consideration the many locations where it is highly unlikely that a hazard exists. It is based on 'realistic worst case' estimates of the radius of the zone around different classes of transmitter within which a hazard might result from the presence of a structure in a hazardous area.

If the initial assessments indicate that a hazard could exist, then the full assessment procedure should be followed. This provides a method of computing the maximum power available in any spark produced, based on more detailed information about the actual transmitter and plant and their relative location. This calculated power can be compared with the minimum power required to ignite the particular flammable atmosphere concerned. Tables and figures are provided in this standard to facilitate the assessment as far as is possible.

In following this procedure, it will quickly become apparent whether the available information is adequate for an assessment to be made with a high degree of confidence or whether additional information is required from practical measurements on site. If, in the final analysis, doubt exists, then it is advisable to seek expert opinion (see appendix H). The assessment procedures given in clause 8 apply generally to all circumstances. Special considerations on the use of cranes, mobile transmitters and oil rigs are dealt with in clause 10.

3.3 Responsibility for making the hazard assessment

Current UK legislation* requires that employers safeguard their employees and others who may be placed at risk by their activities. Hence, transmitter operators and operators of plant in which a flammable atmosphere may be present have a responsibility to ensure that existing operations and proposed changes or developments are safe, so far as is reasonably practicable. Further regulations† will impose restrictions in areas controlled by port authorities where flammable gases or liquids are handled or loaded.

Additional legislation‡ places a responsibility on the occupier of any factory to prevent the presence of any means likely to ignite a flammable vapour where such a vapour may exist. In the case of r.f. ignition hazards there

should be some element of cooperation and flow of information between transmitter and plant operators, since both are subject to the requirements of current legislation*.

In mining, quarrying and related activities the owner and manager have statutory responsibilities to provide a safe working place§. In the case of land based exploratory drilling sites the main contractor and, where necessary, the subcontractor will be expected to assess the dangers and risks of flammable gas ignition by r.f. radiation.

It is recommended that operators of a proposed plant in which a flammable atmosphere may be present should send details to the transmitter operators listed in appendix H and request information about relevant transmitters in the locality of the site. The plant operator will then be able to use the assessment procedures given in this standard, if necessary, in consultation with the transmitter operators concerned.

Similarly, the operator of a proposed new (or altered) transmitter should contact all operators of plant with potentially flammable atmospheres within the vulnerable zone for his transmitter, and use the procedure given in this standard to assess the potential hazard at each location.

Where both plant and transmitter already exist but an assessment is required, it is recommended that the plant operator be responsible for ensuring that an assessment is made.

If for some reason relevant information cannot be made available to the body responsible for the assessment, it is recommended that the responsibility to have an assessment carried out should be assumed by the body unable to release the necessary information.

As an aid to those who need to make a hazard assessment but do not have the necessary technical resources, a list of sources of information and of specialist organizations capable of providing consultation or test facilities is given in appendix H.

4 Transmitters and transmitter output parameters

4.1 General

This clause provides information on various types of transmitter and transmitting systems. This information is necessarily rather brief for certain types of radar and other military equipment but basic details are given and further information may be sought from the specialist organizations listed in appendix H.

*The Health and Safety at Work, etc. Act 1974.

†There are proposals for regulations to control the conveyance and storage of dangerous goods in port areas.

‡Regulation 9 of the Highly Flammable Liquids and Liquefied Petroleum Gases Regulations 1972 made under the Factories Act 1961.

§Mines and Quarries Act 1954.

4.2 Frequency range

The main frequency range covered is from 15 kHz to 35 GHz; it is considered that transmissions below 15 kHz are unlikely to cause r.f. ignition hazards. The types of transmitter considered include the following:

- (a) radio and television broadcast transmitters in specific bands in the range 0.15 MHz to 1000 MHz;
- (b) fixed and mobile transmitters for communication purposes, private, commercial and amateur, in specific bands above 0.4 MHz;
- (c) radar, in specific bands at 220 MHz, 600 MHz and above 1 GHz;
- (d) navigational equipment, non-directional beacons, etc. from 15 kHz upwards.

4.3 Transmitter output power

Transmitter output power from a few watts up to megawatts may be encountered depending on the frequency range and the application. The method of specifying the power varies and this is significant for hazard assessment when highly directional aerials are in use and when considering different modulation systems. In general, values are specified for either the carrier or the peak power output from the transmitter together with the aerial gain although the product of the two is often quoted to give the effective radiated power.

4.4 Aerial gain

Any aerial that concentrates the radiation in a particular direction is said to have gain in that direction. The gain of an aerial is always related to a specified reference aerial. The gain G of an aerial in a particular direction is given by the equation:

$$G = \frac{R}{A} \quad (1)$$

where

R is the power that needs to be radiated from the reference aerial (in W);

A is the power that needs to be radiated from the given aerial (in W);

to give the same field strength at a fixed distance in that direction. The gain is often expressed in logarithmic form, when it is stated in decibels.

An isotropic aerial that radiates uniformly in all directions is a purely hypothetical concept which is nevertheless very useful for reference purposes. When the gain of an aerial relative to an isotropic reference aerial is stated in decibels it is denoted by dBi. In practice the gain of an aerial is often expressed relative to a half-wave dipole which itself has a gain of 1.64 (or 2 dB) relative to an isotropic aerial. In special circumstances other reference aerials may be used, for example a short monopole, and thus it is important that the reference aerial be specified. The maximum gain for typical aerials is given in appendix A.

4.5 Modulation

4.5.1 General. Radio-frequency transmissions may be unmodulated in which case the radiated power is constant and the quoted power can be used for assessment purposes.

Such transmissions are sometimes referred to as continuous wave (CW). However, most transmissions are modulated in order to convey information or to enable them to achieve specific tasks (e.g. radar). The characteristics of the principal modulating systems are described in 4.5.2 to 4.5.5. A factor m is used to take account of modulation when calculating the effective field strength E in clause 8.

4.5.2 Frequency modulation (FM). The frequency of the transmission is varied to carry the information but the output power remains constant as with CW transmissions. Frequency shift keying (FSK) is a form of frequency modulation. Phase shift keying (PSK) and phase modulation (PM) are treated similarly in that no allowance for modulation is needed since the output power is not affected by the modulation.

4.5.3 Amplitude modulation (AM)

4.5.3.1 General. The amplitude of the transmission is varied to carry the information. The latter may consist of speech or music or a coded transmission or it may be a television picture waveform.

4.5.3.2 Speech and music. When speech and music are transmitted, the power quoted is that of the unmodulated or carrier transmission but the instantaneous field strength at the modulation peaks may be up to two times greater when the speech or music is at its loudest volume. Since the duration of the modulation peaks may exceed the thermal initiation time of the gas, some allowance for the power increase needs to be made when making an assessment. As a result of experience gained with amplitude modulated broadcast transmitters, a modulation factor m of 1.4 has been found to be appropriate in calculations of effective field strengths for r.f. ignition effects (see references [4 and 5]).

4.5.3.3 Coded transmissions. A version of amplitude modulation used for morse and other coded transmissions is known as modulated continuous wave (MCW). The carrier is fully modulated by a continuous tone and a modulation factor m of 2 should be used.

4.5.3.4 Television transmissions. For television transmissions the peak power is usually quoted but in this case no allowance for modulation is needed, because the mean power is approximately equal to the peak power.

4.5.4 Single sideband (SSB) operation. For single sideband (SSB) operation the peak envelope power is usually quoted and a value of 0.7 for m can be taken.

4.5.5 Pulsed radar. This consists of pulses transmitted at frequent intervals. The transmissions are characterized by a peak power P_o , a mean power P_m , a pulse duration t (in s) and a pulse repetition rate of n pulses per second. These are related by the equation:

$$P_o = \frac{P_m}{nt} \quad (2)$$

where

nt is the duty cycle.

The peak power should be used for assessment purposes and no additional allowance for modulation need be considered (see references [2 and 6]).

5 Structures and spark-making mechanisms

5.1 Structures

Voltage and current can be induced in a metal object in an electromagnetic field; when two such conducting objects are in intermittent contact an r.f. discharge may result. The source of r.f. power for ignition by discharge is, in effect, an aerial situated in the incident electromagnetic field. The aerial configuration may be formed by any metallic object or assembly of objects such as pipelines, storage tanks bridged by walkways, tanker loading facilities and vent stacks. However, not all the metallic objects on a site are capable of delivering significant energy into a discharge and some classification of structures can be achieved in order to identify possible hazard situations.

For analogy with simple aerial types, structures may be divided into loop types or vertical (monopole) types for consideration at frequencies below 30 MHz and can be easily identified in a survey of the plant. At higher frequencies sections or small parts of the structure may behave as an efficient aerial, but there is no requirement to identify them since due allowance for their characteristics has been made in the assessment procedure (see clause 8) where it has been assumed that their behaviour is not significantly different from that of a long dipole (see reference [7]).

5.2 Loop-type structures

At frequencies below 30 MHz it has been found that structures which form loops (see figure 1) are more efficient as receiving aeriels than other types of structure (see references [1, 8, 22 and 23]). When the internal loop perimeter is about one half-wavelength, the structure is self-resonant and its efficiency is a maximum. Loop structures having a smaller loop perimeter than the optimum can, however, be brought into resonance by the presence of stray capacitance across the discontinuity. The efficiency decreases rapidly when the ratio of the loop perimeter to the wavelength is below 0.5 and remains approximately constant for values of this ratio greater than 0.5.

At any potential discontinuity in the structure, it is possible to calculate the maximum extractable power, provided that information is available regarding the following:

- (a) the structure perimeter;
- (b) the frequency of the transmission;
- (c) the incident field strength at the structure location.

Cranes form particularly efficient loop-type structures and are thus treated as a special case (see 10.1).

5.3 Vertical structures

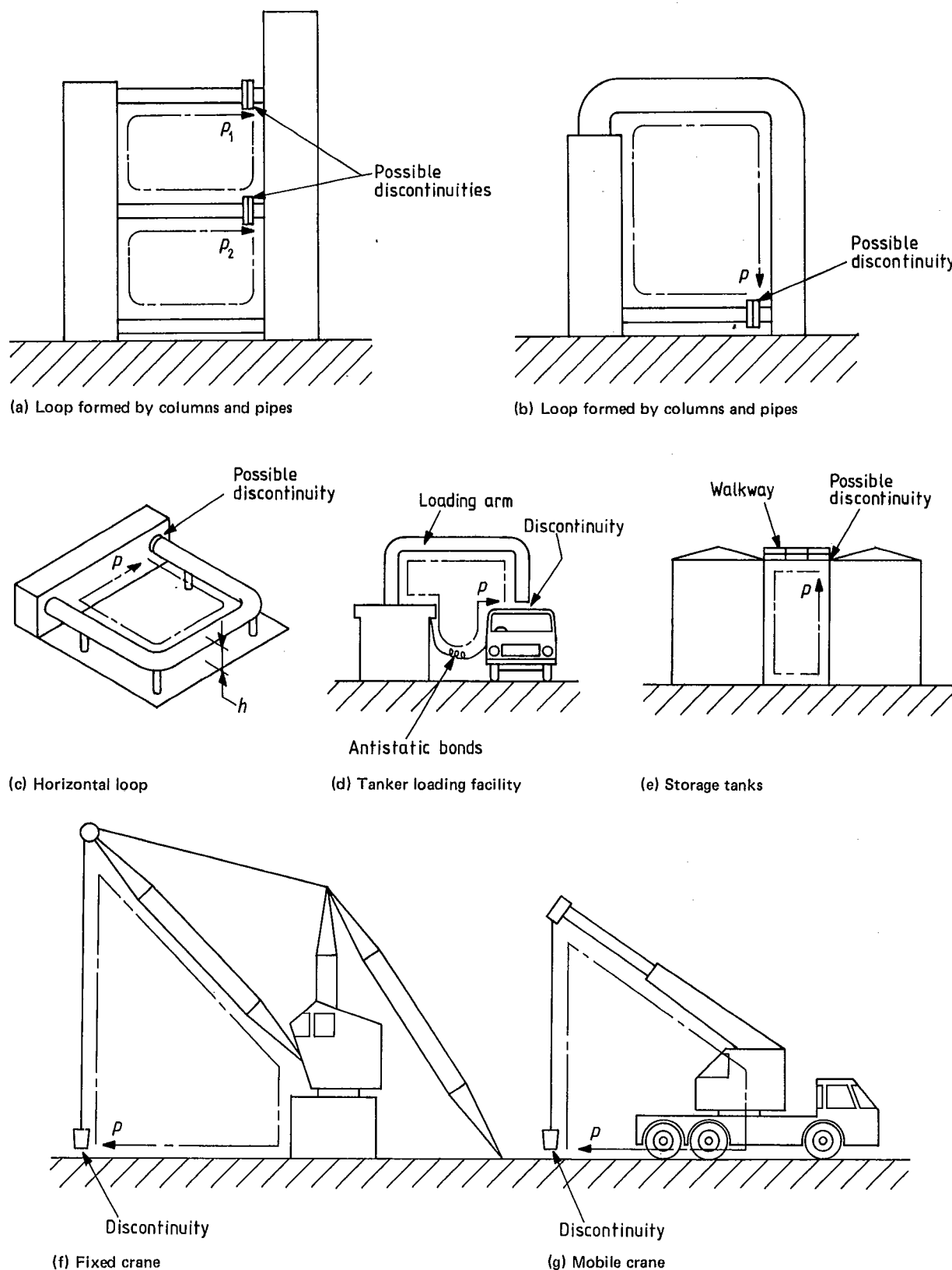
Many vertical structures can be observed in a plant or area where flammable material is used. Probably the most easily identifiable vertical structure is the vent or flare stack, although any free-standing structure such as a fractionating column would come into the same category.

However, it has been found that even for structures that are situated on a concrete base, the base affords a low impedance path to earth at high frequencies and at lower frequencies, and the power that can be extracted at this point is extremely low (see reference [8]). Free-standing vertical structures are therefore not classified among the more efficient types of structures acting as receiving aeriels and generally can be omitted from consideration except where part of a vertical structure forms one side of a loop. The structure should then be assessed on the basis of the internal perimeter of the loop.

5.4 Spark-making mechanisms

Although a high r.f. potential may exist between two parts of a structure, the nature of the gap and the spark-making mechanism is highly relevant to the r.f. ignition of gases or vapours present around the discontinuity. Radio-frequency discharges occur most easily if two parts initially in contact are drawn apart, i.e. if a break-spark occurs. The breakdown of gaps that are not in intermittent contact requires considerably higher voltages than those necessary to produce ignitions from break-sparks, and therefore discharges across a fixed gap are not considered to be a significant problem (see reference [9]).

The types of construction or operation that are likely to result in an intermittent contact across a discontinuity are to be encountered in, for example, road tanker loading facilities, where rubbing contact can occur between the loading arm and the tanker; very often the loop circuit is completed by anti-static bonds from the tanker to the base of the loading system. Similarly, when flanges are parted or valves are removed during maintenance procedures, an intermittent contact may be obtained thereby providing a discontinuity in the loop; this condition would be one worthy of consideration, particularly if the loop formed by the pipework is of the optimum dimension for resonance. Discharges are also more easily obtained if one of the conducting members forms a sharp point as for example at the ends of the strands of a wire hawser.



NOTE. p is the internal perimeter of the loop
 h is the height of the loop

Figure 1. Typical loop-type structures

6 Ignition of flammable atmospheres

6.1 Flammable atmospheres

A flammable atmosphere is an ignitable mixture of flammable gas, vapour or mist with air which can occur in a hazardous area as described in BS 5345 : Part 2 : 1983. For spark ignition to occur the power or energy in the spark has to exceed a certain threshold value, which depends both on the nature and the concentration of the flammable gas or vapour. Flammable gases and vapours are grouped according to their ease of ignition in accordance with the tables from BS 5501 : Part 1 : 1977 reproduced in appendix B. The threshold power or energy of a r.f. spark for the different groups has been established using a representative gas for each group as given in table 1.

Table 1. Representative gases for gas groups	
Gas group	Representative gas
I* and IIA	Methane
IIB	Ethylene
IIC	Hydrogen
*Group I refers to fire damp in mines (mainly methane).	

Furthermore, in each case the most easily ignitable concentration of the flammable gas or vapour has been used, for example 8.3 % by volume of methane in air, and 21 % by volume of hydrogen in air. This provides a margin of safety since for concentrations different from these the threshold power or energy is higher.

In making the hazard assessment, no distinction is made between the different zones (0, 1 and 2) of a hazardous area as defined in BS 5345 : Part 2 : 1983. To assess the potential hazard, therefore, significant structures as described in clause 5 should be identified in hazardous areas, together with the group of the associated flammable gas or vapour.

6.2 Ignition by radio-frequency discharges

The nature of a r.f. discharge and the way the energy in the spark is transferred to the gas around it are complex phenomena. However, laboratory experiments and site tests have shown that the ability of a spark to ignite a flammable atmosphere can be characterized by the power or energy that can be extracted by a spark across a discontinuity in a structure (see references [2, 9 and 10]). The threshold values of power or energy are worst-case values, and generally speaking higher values than those quoted will be needed to cause ignition in a practical case.

For any particular flammable atmosphere, there is a thermal initiation time, during which thermal dissipation of the energy deposited by the spark is negligible (see reference [2]). For times shorter than the thermal initiation time, the significant quantity determining ignition is the energy of the spark. For longer times, ignition is determined by the power of the discharge. These two cases can be reconciled by considering the power averaged over the thermal initiation time. Thus, if the discharge is caused by a

pulsed transmission, whose pulse duration is shorter than the thermal initiation time and for which the interval between pulses is longer than the thermal initiation time, the peak power required is greater than the average power by the ratio of the thermal initiation time to the pulse duration. For methane and ethylene the thermal initiation time is approximately 100 μ s, for hydrogen it is approximately 20 μ s.

6.3 Criteria for ignition

6.3.1 General. The criteria for ignition of flammable atmospheres used in this guide are based on the results of considerable research (see references [3 and 11]).

6.3.2 Effectively continuous transmissions. For practical purposes the threshold values of r.f. power P_{th} needed to cause ignition have been established as those given in table 2, for continuous transmissions and for pulsed transmissions whose pulse duration exceeds the thermal initiation time.

Table 2. Radio-frequency power thresholds for structures excluding cranes	
Gas group	Threshold power, P_{th}
I and IIA	W
IIB	8 averaged over any 100 μ s* period
IIC	4 averaged over any 100 μ s* period
	2 averaged over any 20 μ s* period
*Thermal initiation time.	
NOTE 1. Source impedance assumed = 3000 Ω (see reference [11]).	
NOTE 2. The threshold powers for cranes, at frequencies below 30 MHz, are given in table 7 (see 10.1).	

6.3.3 Radar transmissions. For pulsed radar and other transmissions where the pulses are short compared with the thermal initiation time (and are separated by a period longer than the thermal initiation time) it has been found that the energy in a single pulse is a better criterion and the threshold energy values Z_{th} are as given in table 3 (see reference [6]).

Table 3. Radio-frequency energy thresholds for all structures	
Gas group	Threshold energy, Z_{th}
I and IIA	μ J
IIB	7000
IIC	1000
	200
NOTE. Most pulsed radar transmissions have pulse durations that are short compared to thermal initiation times. However, longer pulse transmissions may be encountered and if the pulse duration exceeds half the thermal initiation time, expert guidance should be sought unless use of the thresholds in table 2 indicates no hazard.	

7 Practical measurements and tests

7.1 Measurement of electromagnetic fields

Full information on the test equipment requirements and the method of measurement of electromagnetic field strengths is given in appendix C. The measurement of field strengths in the context of the spark ignition hazard does require, however, that consideration be given to a number of factors that could have a significant bearing on the assessment of the potential hazard; these are as follows.

- (a) Measurements of field strengths should be made at a point where the measured value is representative of the field which is incident upon the structure. The presence of the structure can however affect the field in its immediate vicinity due to re-radiation; measurements should ideally be made either at the site of the structure before it is erected or at some point on open ground at approximately the same distance from the transmitter and in a similar direction in order to avoid errors due to the directional properties of the transmitter.
- (b) Although higher field strengths may be expected when the ground is wet, the effect of variations in ground conditions has been shown to be unimportant and no correction to measured field strengths is required even where the ground appears dry or is concreted.
- (c) For horizontally-polarized transmissions at frequencies below 30 MHz, it is important that the measurements are made at a height that is similar to that of the mean height of the structures concerned.
- (d) The possibility of infrequent transmissions, e.g. from mobile transmitters and ships, has to be considered and arrangements made to ensure, where possible, that all relevant transmitters are operating.
- (e) Where a test transmitter has been set up to simulate a proposed transmitter, the measured field strength can be corrected by one factor which allows for the difference in power and another for the difference in distance, if necessary (see D.3).

Warning note. Precautions should be taken to prevent the exposure of persons to intense r.f. radiation.

7.2 Measurement of extractable power

The power that can be extracted at a discontinuity in a structure irradiated by r.f. electromagnetic waves can be determined by direct measurement. There are two basic methods in current use; these are as follows.

- (a) *Frequency selective measurements of current and voltage.* The extractable power at a particular transmission frequency can be calculated from values of voltage and current measured at the discontinuity in the structure. Details of the test equipment and the test method are given in appendix D.

(b) *Broadband power measurement.* Measurements are made of the total power (from all transmitters) that can be delivered to a fixed resistive load using an instrument developed specifically for r.f. ignition hazard assessments (see reference [12] and appendix D). This method affords a simple means of assessment at frequencies up to 10 MHz and enables the measured aggregate extractable power at a discontinuity in a structure to be obtained very quickly.

7.3 Test transmissions

Where test transmissions are to be used, a temporary low-power transmitter should ideally be located at an alternative site lying in the same direction as the proposed site of the transmitting aerial. The output power of the test transmitter may need to be about 50 W to 100 W to provide sufficient signal at the plant. No provision for modulating the test transmission is necessary.

Appendix D provides information on the use of test transmissions and on the scaling factors that are required to modify the measured values of field strength or extractable power.

NOTE. In the UK, Department of Trade and Industry approval would be required for such test transmissions.

7.4 Incendivity tests

Tests can be carried out to determine whether the power extractable from the structure is sufficient to cause ignition of a flammable gas or vapour surrounding the discontinuity. At frequencies below 10 MHz these tests are carried out with a spark test apparatus (as described in BS 5501 : Part 7 : 1977) except that a rotating rusty steel disc is used (see reference [2] and appendix D). For operations in hazardous areas, the apparatus may be surrounded by an enclosure continuously purged with inert gas or other equally effective means taken to prevent the external ignition of a flammable concentration of gas or vapour.

At higher frequencies further modifications of the spark test apparatus are required (see references [2 and 6]).

Warning note. It is essential that all practical on-site tests be carried out with the full cooperation and under the guidance of safety and operations personnel. The test programme should be devised and discussed with all personnel intimately concerned with the safe operation of the areas where tests are to be made. For example, some tests may involve the parting of flanges, removal of valves, etc. and adequate provision has to be made for the support of incomplete structures and safety of the personnel carrying out the tests. Also where measurements are to be made in a hazardous area care should be taken that the instruments proposed to be used for measurement purposes are cleared for use in the test area, and that the appropriate permits to work are obtained.

8 Methods of assessment

8.1 General

This clause describes the methods of assessment that can be used to ascertain whether or not a potential r.f. ignition hazard exists on a plant containing hazardous areas.

Subclauses 8.2 to 8.5 describe the theoretical assessments that should be performed in order to determine whether it is necessary to carry out the practical on-site tests that are described in 8.6.

Two flow charts are given in figures 2 and 3 in order to clarify the assessment methods. The 'assessment flow chart' (see figure 2) lists the steps in the theoretical assessment methods and the second 'on-site test flow chart' (see figure 3) outlines the procedures that are recommended for practical tests. The flow charts have been designed so that safe situations become apparent as soon as possible and the initial assessments involve the minimum effort.

An explanation of the flow charts and assessment procedures is given in (a) and (b).

(a) *Explanation of flow charts and assessment procedures.*

The flow charts are designed to provide a step by step guide to the assessment procedure of this clause, the actions required at each stage being clearly indicated in the blocks. The number(s) in the blocks refer to the subclause(s) in this clause which are relevant to the action or decision required. The assessment flow chart shows the procedures for assessment of the risk to a particular plant or for the assessment of the risk from a particular transmitter. These paths are followed until either no hazard is indicated or the full assessment is reached, at which point they merge into a single procedure. If a hazard is indicated by the full assessment, the on-site test flow chart indicates the sequential procedure to be followed for the following cases:

- (1) for existing plant and transmitters;
- (2) for existing plant and a proposed transmitter;
- (3) for an existing transmitter and a proposed plant.

The appropriate path should be selected and followed through until no hazard is indicated.

(b) *Future plant or transmitter modifications.* Even when an assessment of the type described in 8.6 indicates that there is no r.f. ignition hazard at the time the assessment is undertaken, it is important that the assessment be revised whenever a modification to the plants or transmitters is considered.

8.2 Basis of the theoretical assessments

There are three types of theoretical assessments; these are as follows:

- (a) an initial assessment that should be followed when potential risks from a particular transmitter are being ascertained;
- (b) an initial assessment that should be followed when the risks to a particular existing or planned plant are being ascertained;
- (c) a full assessment method that should be carried out if one of the initial assessments indicates a potential hazard.

The initial assessment methods are based on simply comparing the basic parameters of the situation (i.e. the transmitter details, the distance between the transmitter and the plant, and the flammable vapours and gases that might be found on the plant) with tables of distances that define the potentially vulnerable zone. The full assessment method involves evaluating the hazard for the particular existing or planned structures on the plant that is under consideration.

Available knowledge on the behaviour of structures as receiving aerials and the incendivity of r.f. discharges as outlined in clauses 5 and 6 respectively has been used to construct figure 4 which illustrates the relationship between the safe threshold field strength and frequency of transmission for single unmodulated transmissions. The sets of curves at frequencies below 10 MHz are for loop-type structures with various perimeters.

Tables 4 and 5 or table 6 are used in the initial assessment methods and define the size of the potentially vulnerable zone around a transmitter under worst case conditions for three gas categories.

The distances given in tables 4, 5 and 6 have been calculated on the basis of safe threshold field strength data of the type given in figure 4, together with a multiple transmission factor that takes into account the presence of a number of different transmitters on a given site and makes some allowance for the existence of a second transmitting site just outside the vulnerable zone.

At m.f. the multiple transmission factor takes account of the frequency differences between transmissions (see 8.5.5.2). The effective total radiated power is assumed to be twice that of the most powerful m.f. transmitter; this factor is derived from experimental data. At h.f. the effective power is assumed to be four times that of the most powerful transmitter. This factor is considered adequate for up to six separate co-sited transmitters, each having the same power, because h.f. transmissions are normally radiated from directional aerials which point in different directions.

In calculating the radii of vulnerable zones, the powers for single transmitters listed in column 4 of table 4 were multiplied by the multiple transmission factors given in column 6.

Table 4 gives radii of vulnerable zones for the most common transmissions found in the UK, assuming a loop perimeter of 85 mm, which is the largest value found in surveys of large petrochemical and gas handling plant; for horizontal loops a height of 15 m has been taken. The list is not exhaustive but it is considered that the majority of transmissions which are likely to be encountered have been included. For every category, the most powerful transmission has been listed, and in the case of m.f. broadcast transmissions, a range of commonly-used transmitter powers and aerial gains has been stated. Table 5 has been formulated on the basis of the presence of a loop-type structure with a maximum perimeter of 40 m and for a horizontal loop height of 5 m; table 6 gives the maximum sizes of vulnerable zones with both small and large structures.

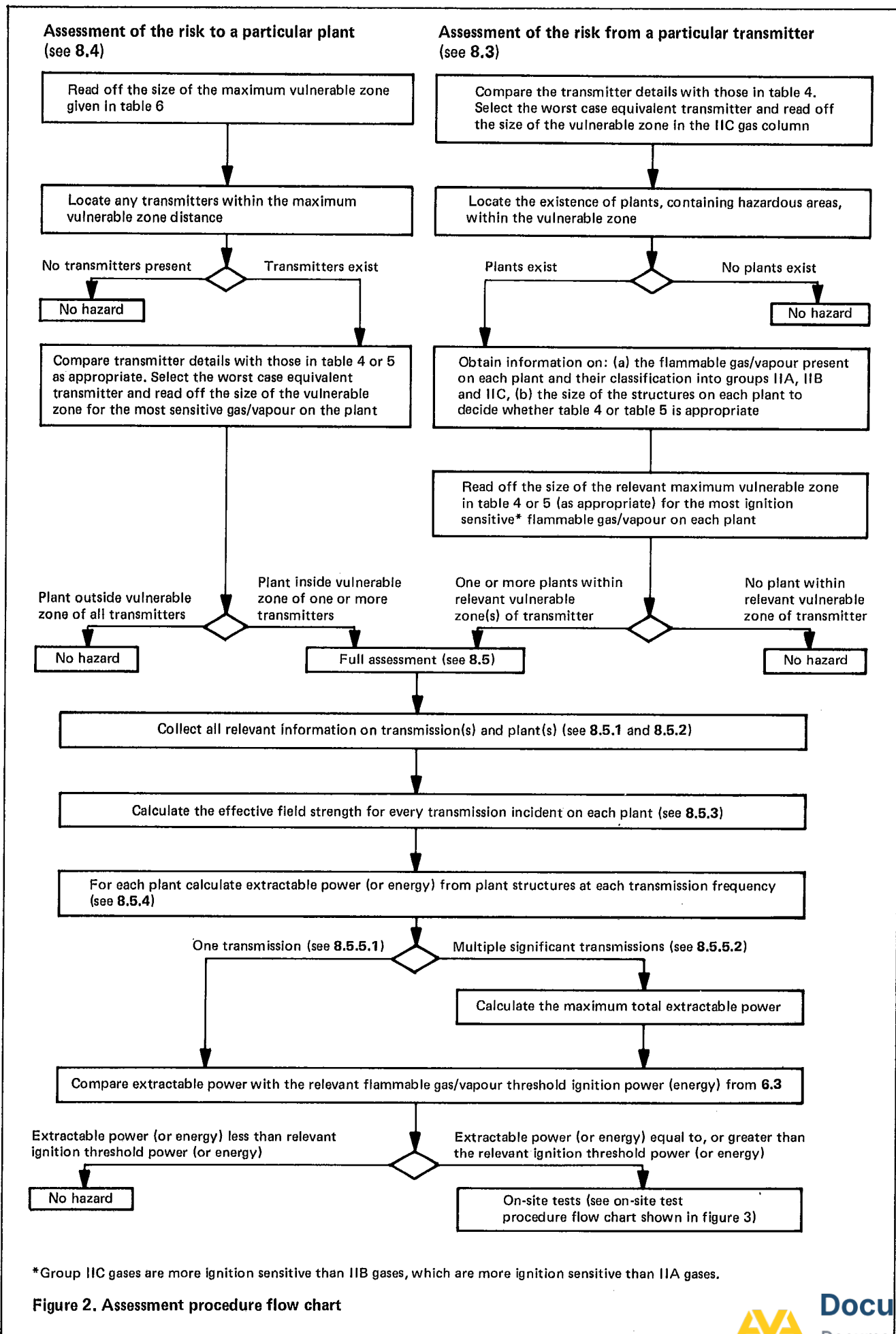


Figure 2. Assessment procedure flow chart

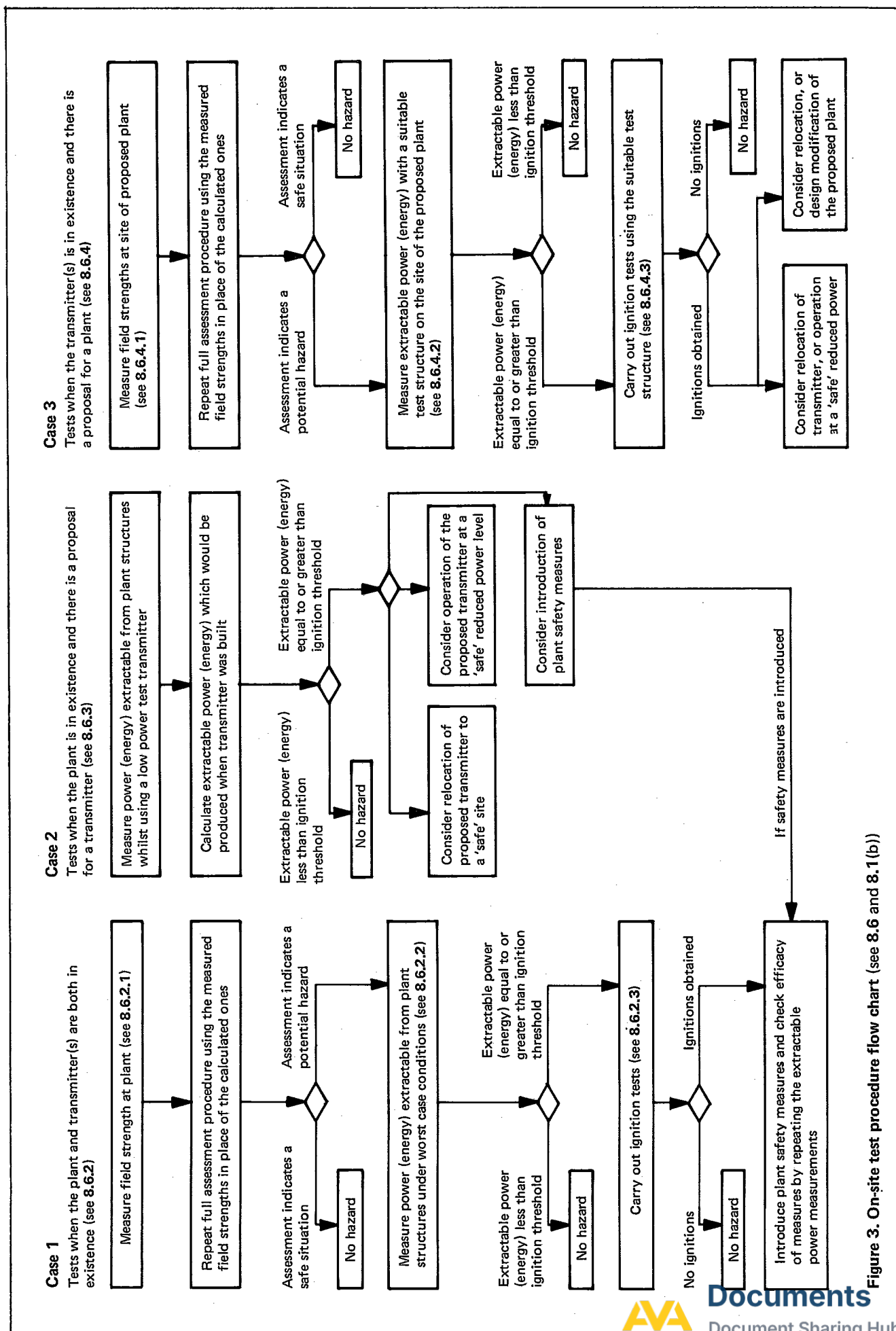


Figure 3. On-site test procedure flow chart (see 8.6 and 8.1(b))

Table 4. Radii of vulnerable zones

1	2	3	4	5	6	7	8	9	10	11
Serial no.	Type of transmission	Frequency (see note 1)	Transmitter power (see note 2)	Modulation code*	Multiple transmission factor	Aerial gain (see note 3)	Polarization codet	Radii of vulnerable zones (see note 4)		
								Group I/IIA	Group IIB	Group IIC
1	v.l.f. and l.f.	< 150 kHz	200 kW	FSK	2.0	0	V	m	m	m
2	l.f. broadcast (see note 5)	200 kHz	400 kW	AM	2.0	4	V	1000	1300	1700
3	Radio beacons	285 kHz to 525 kHz	1 kW	MCW	2.0	4	V	3900	5000	6600
4	m.f. ship communication (land)	415 kHz to 525 kHz	5 kW	MCW	2.0	4	V	450	600	800
5	m.f. ship communication (sea)	415 kHz to 525 kHz	800 W	MCW	2.0	0	V	1300	1700	2200
6	m.f. broadcast (see note 6)	0.53 MHz to 1.6 MHz	500 kW	AM	2.0	(see note 6)	V	320	420	560
7	m.f. broadcast	0.53 MHz to 1.6 MHz	150 kW	AM	2.0	8	V	(see note 6)		
8	m.f. broadcast	0.53 MHz to 1.6 MHz	50 kW	AM	2.0	8	V	11500	14200	17500
9	m.f. broadcast	0.53 MHz to 1.6 MHz	10 kW	AM	2.0	5	V	7300	9200	11500
10	m.f. broadcast	0.53 MHz to 1.6 MHz	1 kW	AM	2.0	5	V	2600	3300	4300
11	h.f. broadcast	0.53 MHz to 1.6 MHz	1 kW	AM	2.0	5	V	860	1200	1500
12	h.f. communications: Vertically-polarized transmitter on land	6 MHz to 26 MHz	500 kW	SSB/FSK	4.0	21 (see note 7)	H	2600	3000	3400
13	h.f. communications: Horizontally-polarized transmitter on land	{ 1.6 MHz to 26 MHz 25 MHz	30 kW	SSB/FSK	4.0	12	V	8700	10900	13700
14	h.f. communications: ship transmitter	{ 4 MHz to 25 MHz	30 kW	SSB	4.0	12	V	190	230	260
15	h.f. communications: ship transmitter	{ 1.6 MHz to 4.4 MHz	30 kW	SSB	4.0	18 (see note 8)	H	630	720	830
16	h.f. communications: civil aircraft	{ 25 MHz 6.2 MHz to 26 MHz 2.8 MHz to 23 MHz	400 W 1.5 kW 400 W	SSB	2.0	18 (see note 8)	V	260	290	330
17	Amateur radio (fixed and portable)	1.8 MHz to 2 MHz	26 W	SSB	2.0	5	V	130	170	230
18	Amateur radio (fixed and portable)	{ 3.5 MHz to 29.7 MHz 145 MHz	400 W 400 W 150 W	SSB	2.0	2	V/H	100	140	180
19	Amateur radio (fixed and portable)	430 MHz and above	400 W	SSB	2.0	18	V/H			
20	Amateur radio (fixed and portable)	1.8 MHz to 2 MHz	26 W	SSB	2.0	0	V	35	45	60
21	Amateur radio (mobile)	{ 3.5 MHz to 29.7 MHz 145 MHz	400 W 400 W 150 W	SSB	2.0	5 (see note 10)	H	45	55	65
22	Amateur radio (mobile)	430 MHz and above	400 W	SSB	2.0	12 (see note 10)	H	55	75	95
23	Amateur radio (mobile)	1.8 MHz to 2 MHz	26 W	SSB	2.0	12	V/H	20	25	35
24	Amateur radio (mobile)	430 MHz and above	400 W	SSB	2.0	18	V/H	15	20	25
25	CB radio	27 MHz	150 W	FM	2.0	-10	V	20	20	25
26	FM Radio (band II)	87 MHz to 108 MHz	4 W	FM	2.0	0	V	70	90	110
27	TV broadcast (bands IV and V)	470 MHz to 854 MHz	30 kW	TV	—	5	V	10	10	15
28	v.h.f. and u.h.f. land, fixed and mobile and maritime mobile	68 MHz to 470 MHz	25 W	FM/AM	4.0	6	V	10	15	15
29	v.h.f. and u.h.f. base station	98 MHz to 400 MHz	125 W	FM/AM	4.0	8	V	5	10	10
30	v.h.f. radio link	146 MHz to 174 MHz	25 W	FM/AM	2.0	5	V/H	20	25	30
31	u.h.f. fixed and mobile	862 MHz to 960 MHz	25 W	FM	4.0	8	V	10	15	15
32	u.h.f. radio link	{ 450 MHz and 2.7 GHz	50 W 5 W	FM	2.0	20 35	V/H V/H	10 NH	15 NH	15 NH

Table 4 (concluded)

1	2	3	4	5	6	7	8	9	10	11
Serial no.	Type of transmission	Frequency (see note 2)	Transmitter power	Modulation code*	Multiple transmission factor	Aerial gain (see note 3)	Polarization code†	Radii of vulnerable zones (see note 4)		
								Group I/IIA	Group IIB	Group IIC
33	s.h.f. radio link	3.4 GHz	20 W	FM	1.0	dBi	V/H	m	m	m
34	Tropospheric scatter	900 MHz	10 kW	FM	1.0	46	V/H	NH	NH	NH
35	Tropospheric scatter	2 GHz	5 kW	FM	1.0	46	V/H	900	1200	1500
36	Radar P-band (military)	220 MHz	450 kW	R(10)	1.0	52	V/H	NH	NH	NH
37	Radar ATC (civilian)	600 MHz	500 kW	R(4)	1.0	20	V/H	100	270	610
38	Radar IFF/SSR	1 GHz	(see note 12)	R	1.0	31	V/H	95	260	570
39	Radar (civilian) (see note 13)	1 GHz to 3 GHz	2500 kW	R(4)	1.0	(see note 12)	V/H	5	5	5
40	Radar (military)	1 GHz to 3 GHz	150 kW	R(66)}	1.0	39	V/H	330	860	2000
41	Radar (marine)	1 GHz to 3 GHz	6000 kW	R	1.0	45	V/H	500	1400	3000
42	Radar (civilian) (see note 13)	3 GHz	60 kW	R(1)	1.0	28	V/H	5	10	15
43	Radar (military)	3 GHz to 5 GHz	1000 kW	R(1)	1.0	36	V/H	25	65	150
44	Radar (civilian) (see note 13)	3 GHz to 5 GHz	6000 kW	R	1.0	45	V/H	170	450	1000
45	Radar (civilian) (see note 13)	9 GHz to 10 GHz	60 kW	R(0.5)	1.0	45	V/H	NH	NH	NH
46	Radar (marine)	9 GHz to 10 GHz	2000 kW	R	1.0	45	V/H	NH	85	200
47	Satellite earth station	10 GHz	50 kW	R(1)	1.0	32	V/H	5	5	10
48	Radar (airport)	6 GHz and 14 GHz	1 kW	FM	1.0	50	V/H	NH	NH	NH
		35 GHz	12 kW	R(0.03)	1.0	44	V/H	NH	NH	NH

*Key to modulation code

AM Amplitude-modulated speech or music transmission.

Carrier power quoted.

MCW Amplitude-modulated tone transmission.

Carrier power quoted.

TV Amplitude-modulated video transmission.

Peak power quoted.

R(1) Pulse-modulated radar transmission. Peak power quoted.

The number in brackets indicates the pulse duration in μ s where known.

FM Frequency modulation.

SSB Single sideband transmission. Peak envelope power quoted.

JOK Frequency shift keying.

Key to polarization code

Vertical polarization.

Horizontal polarization.

H Either vertical or horizontal polarization, or both simultaneously.

NOTE 1. The braces in column 3 indicate a frequency range

that is so large that safe distances have been calculated at the

upper and lower limits. For other frequency ranges, safe

distances have been calculated only for the worst case.

NOTE 2. The inclusion of two power levels indicates the

maximum permitted powers for the two types of modulation

which may be used for serial numbers 19, 20, 23, 24 and 39.

NOTE 3. All aerial gains have been stated in dB relative to an

isotropic source in free space (dBi). At frequencies below

30 MHz, however, the gains of vertical aerials are often stated

relative to that of a short vertical aerial on perfectly conducting

ground; to convert this figure to dBi, 5 dB should be added.

For horizontal aerials at frequencies below 30 MHz, the gain

applies to the main lobe of the radiation pattern and includes a

contribution due to ground reflection. For all polarizations

above 30 MHz, the gain figure applies to the main lobe of the

radiation pattern as if the aerial were in free space, the effect

of the ground being disregarded.

NOTE 4. NH denotes no hazard, but the use of lower gain

aerials (i.e. smaller) than those assumed in the table will

produce higher local field strengths and may therefore

result in a hazard.

NOTE 5. The only 400 kW i.f. transmitter in the UK is at

Droitwich, Worcestershire.

NOTE 6. The only 500 kW m.f. transmitters in the UK are at

Orford Ness, Suffolk. Directional aerials radiating out to sea

are used. For information on vulnerable zones see appendix E.

NOTE 7. Value is based on a HR 4/4/0.5 curtain array (see

table 12).

NOTE 8. Value is based on a 3 λ rhombic aerial (see table 12).

NOTE 9. When the aircraft is on the ground the information

given in note 3 applies and vertical polarization is taken as the

most onerous condition. When the aircraft is flying the

radiation may be of either, or both, polarizations and the gain

figure is assumed to be the free-space gain.

NOTE 10. Values are based on a horizontal aerial 10 m above

ground.

NOTE 11. There is no hazard at ground level because the main

radiation lobe of the transmitting aerial is so designed that it

produces field strengths near the ground that are unlikely to

exceed 1 V/m at any distance (see figure 4).

NOTE 12. Various combinations of transmitter power and

aerial gain may be used provided the effective radiated power

(e.r.p.) does not exceed 52.5 dBW (178 kW).

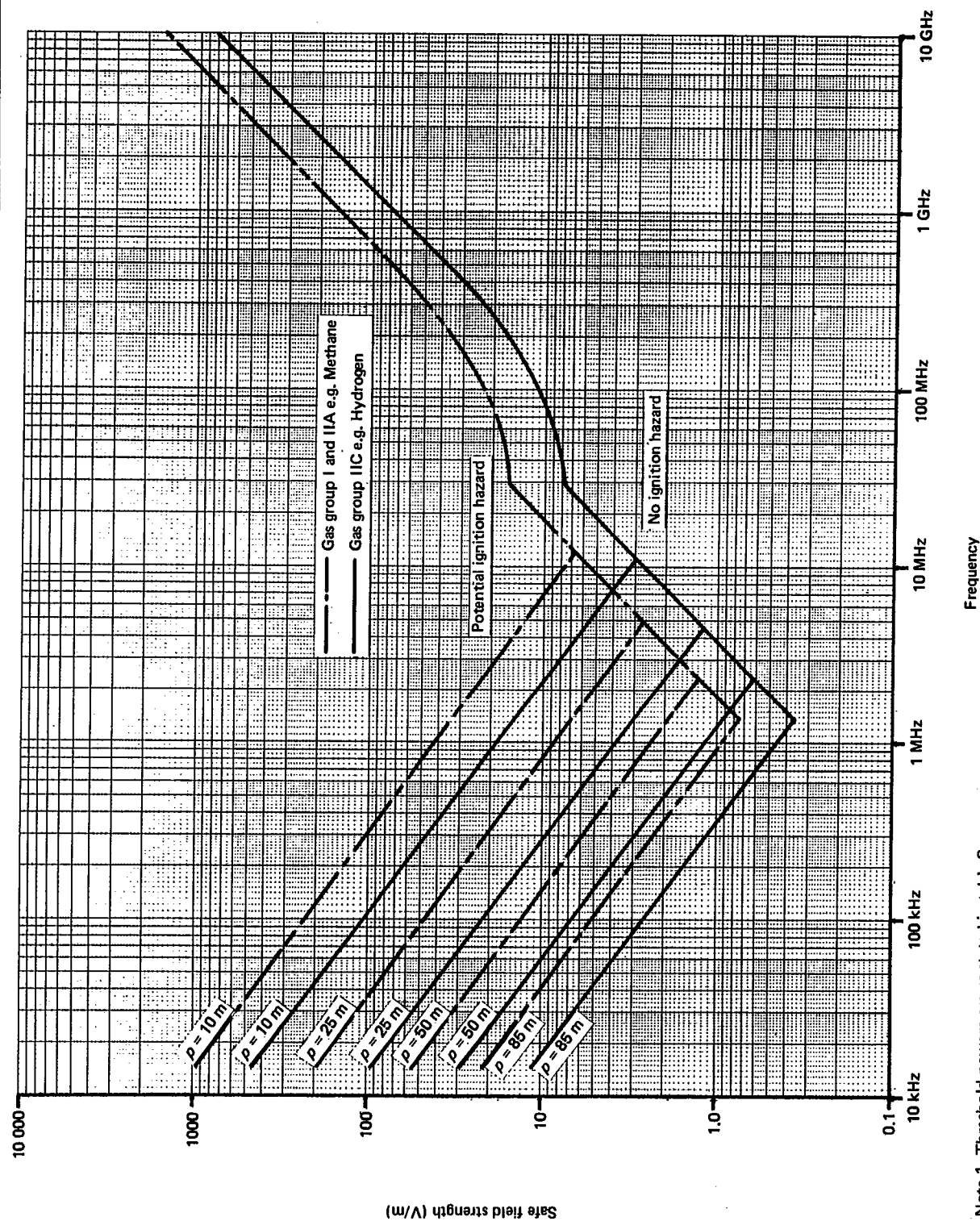
NOTE 13. Radars in these categories are generally operated with

the main lobe elevated relative to the horizontal. It therefore

follows that the full extent of the vulnerable zone is not often

realized at low level. The transmitter operator should be

consulted at the initial assessment stage.



Note 1. Threshold powers are as stated in table 2.

Note 2. Cranes are excluded.

Note 3. p is the loop perimeter.

Figure 4. Safe threshold field strength versus frequency for single unmodulated transmissions