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AUTOMATIC HEAT-SENSITIVE FIRE DETECTION SYSTEMS

by

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INTRODUCTION

During recent years, there has been a growing interest in the use of automatic fire detection systems in buildings. In this article, the part such systems can play in reducing fire losses, and the main factors which affect their performance and reliability, are discussed. While it is intended to apply to heat-sensitive systems, some of the information is likely to apply to smoke-sensitive systems also.

About one half of the total direct loss of approximately £25 million per annum is caused by a relatively small number of large fires. For example, in 1954, of a total direct loss of £26 million, some £12,800,000 loss was incurred in 239 large fires, each costing £10,000 or more. Of these large fires, which accounted for about $\frac{1}{2}$ per cent of the total number of fires attended by Fire Brigades that year, 152 occurred in industrial premises, and caused a loss of £8 million. An analysis of fire reports shows that the majority of the fires were well-developed when discovered, particularly those occurring at night. It is therefore likely that earlier warning would have given every chance of a considerable saving in fire loss.

TASK OF AN AUTOMATIC DETECTION SYSTEM

An automatic detection system is required to give sufficiently early warning of fire to allow the occupants of a building the best possible chance of escape, and to enable the Fire Brigade to come into action before the fire has developed to a serious stage. The delay from the start of a fire to the arrival of the Brigade may be divided into three periods.

a) From start of fire to detection.

b) From detection to warning of the Brigade.

c) From warning of the Brigade to their arrival at the fire.

If the sum of the three periods is greater than the time for the fire to gain a substantial hold, the chance of the Brigade being able to limit damage will be greatly reduced. The automatic detection system has its main effect in reducing the delay between the start of the fire and its detection. For example, large fires occurring at night in buildings without automatic detection are often discovered from outside the building, a fact which shows how large they have become before discovery.

The delay between detection and warning may also be substantially reduced by an automatic detection system, if it is linked directly to the Fire Brigade. The warning should, of course, also be given at some central manned point such as the Works Telephone Exchange, or Night Watchman's Post, but this should not be regarded as a substitute for automatic relaying to the Fire Brigade, for if the control point happens to be unmanned at the time of the alarm the warning system would lose its usefulness. The sutomatic detection system has, of course, no influence on the delay between warning and arrival of the Brigade, as this is controlled solely by the fire cover in the district.

IMPORTANCE OF QUICK RESPONSE

While the automatic system is vitally important in setting in motion the train of events which brings the Brigade to a fire, it can only have a direct influence on the time from the start of the fire to its detection. It is appropriate to ask how important is sensitivity (defined broadly as the ability to respond quickly to fire conditions) in an automatic-detection system. A fire detection system should never be so sensitive as to be likely to give false alarms under non-fire conditions, as this can only bring it into disrepute and cause it to be ignored, or action on it to be delayed. It is necessary to study the local temperature conditions of the installation since these set an upper limit to the sensitivity. There is little point in having a fire detection system which is not at least as sensitive as a sprinkler system, since the latter has the advantage of being able to apply water immediately it operates. The sprinkler response might therefore be considered as setting a lower limit to the sensitivity of a detection system.

With these considerations in mind a method of testing the sensitivity (i.e. time of response) of heat-sensitive detectors has been developed and is described in British Standard 3116 : 1959. "Heat sensitive detectors for automatic fire alarm systems in buildings", in which upper and lower limits of sensitivity are defined for use in normal occupancies. The importance of short times of response in automatic detection systems depends on:-

a) The type of risk to be protected.

b) The fire cover in the district.

Thus any response time within the prescribed limits may be considered satisfactory in occupancies of low or medium fire risk, particularly in urban areas. In occupancies where the fire is likely to develop more quickly, particularly if these are in rural areas, it is important to use detectors which are set to give response times nearer the lower limit. These points are explained graphically in the Appendix.

With very rapidly-developing fires, particularly in rural areas, a stage is reached where an alarm system, although valuable in warning the occupants and alerting the Brigade, cannot provide sufficiently early warning to ensure that the Brigade has a good chance of reaching the fire in its early stages. While the time for the Brigade to respond to the call may itself be small (5 min or even less), it is large compared with the time for the fire to develop to serious proportions. In such cases, reliance should also be placed upon local fire-fighting methods (extinguishers, first-aid hose reels, automatic sprinklers, Works Fire Brigades etc.) and training of local personnel to man them. In practice, it should be the general aim in the design and installation of an automatic fire-detection system to ensure that it is as sensitive as possible without risk of false alarms.

SITING OF DETECTORS

The operation of a heat-sensitive detector depends on the transfer of heat from the hot gases of the fire to the sensitive element of the detector. The siting of detectors should therefore take account of the distribution, temperature and velocity of the hot gases beneath a ceiling. Of these factors, the first two have the greatest influence. The Joint Fire Research Organization has investigated the distribution of temperature and velocity of the hot gases beneath roofs and ceilings of different heights and types e.g. flat, pitched, clerestory, Northlight, corridors etc.

CEILING HEIGHT

The results so far show that ceiling height has a large effect on the temperature of the gases. Thus a fire which at any moment produces a temperature rise of 100°C beneath a ceiling 10 ft above it, would produce a temperature rise of about 30°C beneath a 20 ft ceiling. If therefore a fire is to be detected when it reaches a certain size, the sensitivity of the detector must be greater the higher the ceiling. While any sensitivity within the limits of B.S. 3116 is adequate for ceilings up to 15 ft, detectors having response times nearer to the lower limit will be desirable for larger heights. It may even be necessary, for very high ceilings, to use detectors with response times less than the lower limit of B.S. 3116, provided that the ambient conditions would not give rise to false alarms. Where this is not possible detection of the fire at a later stage will have to be tolerated.

CEILING TYPE

Ceilings which are "channelled" e.g. corridors, Northlight roofs, open-joisted ceilings etc., tend to direct the flow of gases in the direction of the channels. It is desirable to have a detector in each channel except where the channels are shallow and narrow e.g. open-joisted ceilings, when the hot gases may spread while rising to fill two or three adjacent channels.

SPACING

Provided a detector is adequately sensitive for the height of ceiling, the spacing of detectors beneath a ceiling would be expected to be controlled by the reduction in the gas temperatures as they spread from the fire. In most cases however this reduction has been shown to be small and the spacing is likely to be governed more by obstructions, ventilation ducts etc., which could prevent hot gases reaching a detector head.

MOUNTING OF DETECTORS

The highest temperatures and greatest velocities in the stream of hot air moving below a ceiling with flat surfaces e.g. flat or bay ceilings, occur at a depth of some 1-4 in. below the ceiling. For ceilings of the "channelled" type e.g. open-joisted, Northlight roof etc., the gases tend to collect at the apex and the layer may be thicker. It is considered however that the figure of 1-4 in. is still a good guide. It is therefore best if the sensitive element of the detector is within this range. Thus any attempt to reduce the response time of detectors by hanging them at some distance below the ceiling will be ineffective unless, by chance, the fire occurs immediately below a detector. Warning must be given against the recessing of detectors within ceilings. This has the effect of creating a "dead air" space around the sensitive element and can produce a marked increase in its response time to a fire. It should therefore be avoided.

LOCAL TEMPERATURE CONDITIONS

While the principles above generally apply, local temperature conditions can have an overriding effect on the siting and sensitivity of detectors. Heating ovens in industrial premises, particularly under low ceilings, heating and ventilation systems and similar equipment, can produce abnormal ambient ceiling temperatures and thereby necessitate less sensitive detectors than those permitted by the upper limit of sensitivity specified in B.S. 3116. In addition it may be necessary to site detectors carefully to avoid the areas immediately adjacent to such equipment. Solar heating under roofs with low insulation can also affect sensitive detectors. Records of local temperature variations are invaluable in cases of this sort. It is intended that the British Standard Code of Practice C.P. 327/404/402.501 "Electrical fire alarms" will be amended in due course to give advice on which may be based the spacing and placing of fire detectors in buildings.

TYPES OF HEAT-SENSITIVE DETECTION SYSTEMS

The automatic detection systems available on the market may be divided into those in which the detectors are of the "point" or "spot" type, i.e. those which respond to temperature and velocity changes at a given place, and those with "line" or "continuous" detecting elements which record the cumulative effect of these changes over a ceiling area. In each case the response is normally conveyed to an electrical circuit which gives the warning. Point detectors are the most numerous type and fall broadly into three classes:

a) Those with bi-metallic strip elements which deflect on heating, and close or open electrical contacts.

b) Those in which the electrical resistance of the sensitive element changes on heating. This effect is utilised to give the alarm.

c) Those in which the sensitive element is a "link" of two strips of metal, joined by a low-melting point solder (e.g. m.p. 150°F).

Line detectors operate generally in one of the following ways:

(a) Hot gases from the fire heat a fluid in a metal tube, and the expansion of the fluid exerts a pressure on a diaphragm and causes the alarm to sound.

b) The hot gases produce a change in the resistance of a length of wire, and this change causes the alarm to sound.

Some detectors are arranged to give "compensation" for a rapidly-developing fire i.e. at rates of temperature increase above a chosen minimum, they are designed to give a quicker response than would a similar detector without compensation.

The limits for time of response imposed by B.S. 3116 are applicable to all types of point detector regardless of its method of operation. A testing procedure for line detectors is under consideration.

RELIABILITY OF DETECTION SYSTEMS

CORROSION

It is essential that a detection system shall operate satisfactorily after perhaps several years installation in dirty corrosive atmospheres.

A test for indicating weakness in the design and protection of detectors, which might prevent their operation (in corrosive atmospheres) has been developed and is included in B.S. 3116. A further test simulating marine atmospheres has been included in the standard.

VIBRATION

Ceiling vibrations may cause resonance effects in detectors resulting in false alarms and damage and a test to determine the possibility of this is also included in British Standard 3116.

Although the reliability of detectors may be determined to some extent by the appropriate tests, the only way to ensure the continued good working order of a system is by regular maintenance, so that defects can be observed and remedied in good time before failure occurs.

THE DESIGN OF DETECTORS

While it is anticipated that automatic detection systems which comply with the British Standard will be capable of providing satisfactory and reliable service, there are, naturally, many different approaches to the general and detail design of detectors on the part of manufacturers. It is possible as a result of testing many proprietary systems, to reach certain general conclusions on desirable features in the design of detection systems. Some of these desirable features are given below.

a) It is an advantage if a detection system can be "monitored" in order that any circuit defect which would prevent its operation may be discovered.

b) The use of moving parts, or open contacts, should be accompanied by a careful choice of materials to avoid corrosion which might prevent the functioning of a detector.

c) Since a fire may start in any direction in relation to a detector, it is important that the latter is equally, or almost equally, responsive to hot gases approaching it from any direction. Any protective covers round the sensitive elements should be designed with this in mind.

d) A detector should be as small as possible, commensurate with adequately robust construction and satisfactory operation. Small detectors are less liable to be struck accidentally than larger ones.

APPENDIX

The importance of sensitivity in an automatic detection system was briefly discussed (on page 2) in relation to the effect it could have on the overall time from the start of a fire to the arrival of the Brigade. The value of the reduction of the time period up to the point of detection, in comparison with the overall time period from the start of the fire to the arrival of the Brigade, will depend upon the rate of development of the fire, and the proximity of the Brigade. In Figures 1, 2 and 3, a comparison is made of the percentage of fires estimated to be reached by the Brigade <u>before</u> they are fully developed, where the fires are detected by:

1) an "ideal" detector operating immediately the fire starts, or a

2) sensitive detector with response equivalent to the lower limit and B.S. 3116.

3) an insensitive detector with response equivalent to the upper limit of B.S. 3116.

4) personnel after 4 min.

5) personnel after 10 min.

The delay from discovery to call included in (4) and (5) has been taken from Table 1, and the delay from call to arrival of Brigade from Table 2. It has been assumed that the automatic detectors (1) (2) and (3) are connected direct to the Fire Station, Figures 1, 2 and 3 refer to rural counties, non-rural counties and county boroughs respectively, and the rates of development of the fire range from 5 min, corresponding to the 'flash over' time for a room with a combustible wall-lining, to 20 min corresponding to the flash-over time for a room with incombustible lining. The personnel discovery times of 4 and 10 min are arbitrary, but in view of the foregoing remarks (page 1) on the condition of fires before discovery in the "night" period, may certainly be regarded as optimistic for a large proportion of incidents.

It may be seen from the graphs that, except for the worst case of a rapidly-developing fire in a rural district, the use of an automatic detection system gives a substantially greater chance of the arrival of the Brigade in the early stages, than does discovery and call by personnel. The graphs do not show the increased chances of personal escape, but there is no doubt that automatic warning can be invaluable, particularly at night where a sleeping risk is involved. The difference between (2) and (3), while considerable for a rapidly-spreading fire, is not so great as the general difference between automatic and personal detection; indeed, it is negligible for normal rates of development of fire in all but the rural counties where the longer response time of the Brigade makes any other time saving proportionately more valuable.

TABLE 1

DELAY FROM DISCOVERY TO CALL

	Percentage in the following time intervals (min)							
	1-2	3-4	5-6	7-8	9-10	11-20	21-30	30
Counties - Non-rural	41	28	9	3	3	15	1	1
Counties - Rural	11	14	27	3	11	27	5	3
County Boroughs	40	40	8	2	4	4	-	-

TABLE 2

DELAY FROM CALL TO ARRIVAL OF BRIGADE

	Percentage in the following time intervals (min)							
	1-2	3-4	5-6	7-8	9-10	11-20	21-30	30
Counties - Non-rural	22	48	20	4	2	4	-	-
Counties - Rural	-	3	27	5	24	35	3	3
County Boroughs	24	54	19	2	-	-	-	1

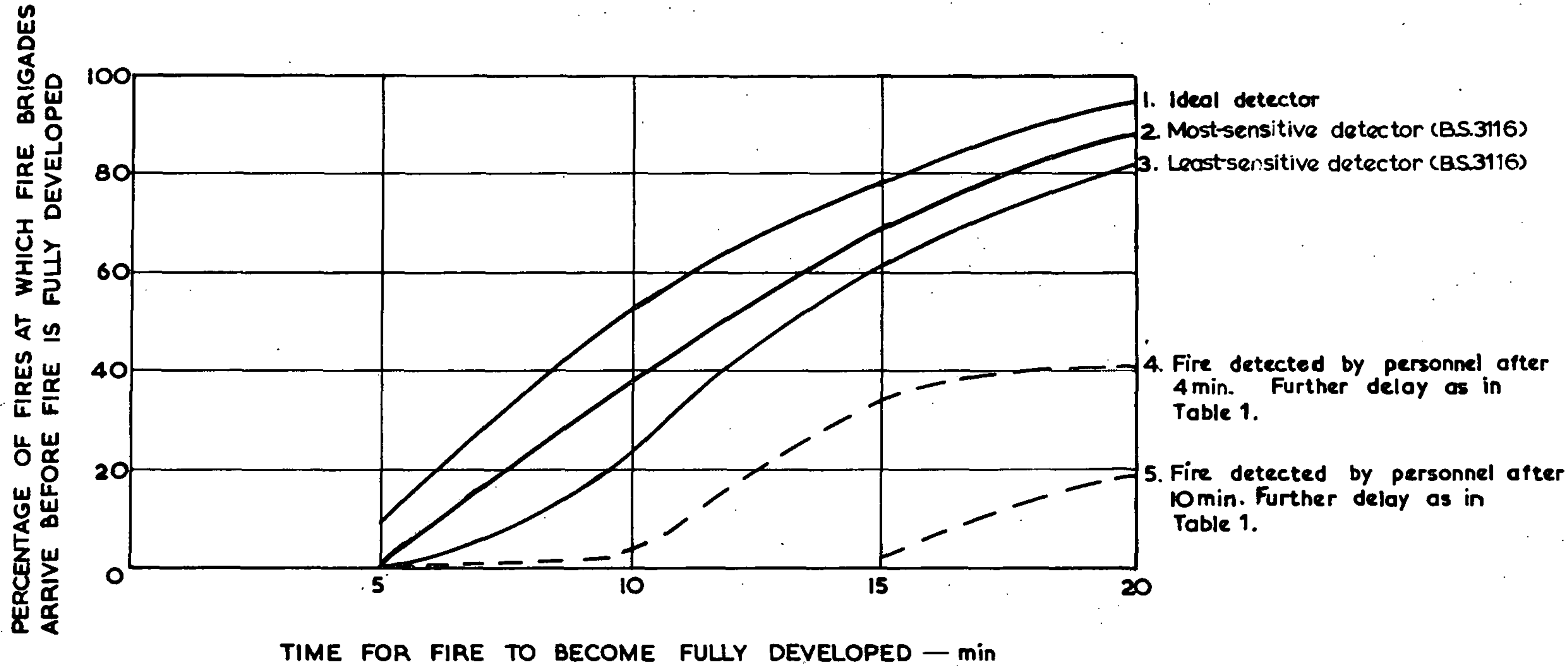

FIG. 1. EFFICIENCY OF AUTOMATIC FIRE DETECTORS — RURAL COUNTIES

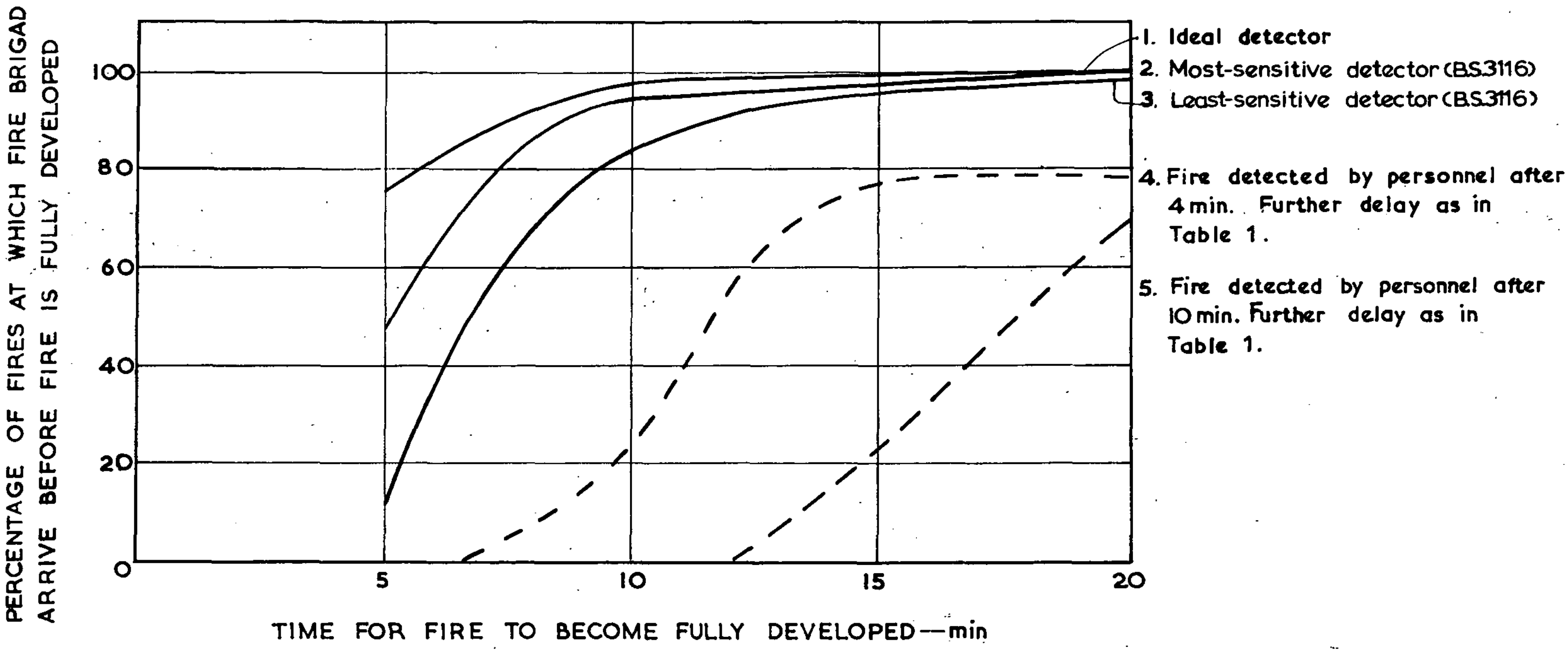

FIG. 2. EFFICIENCY OF AUTOMATIC FIRE DETECTORS — NON-RURAL COUNTIES

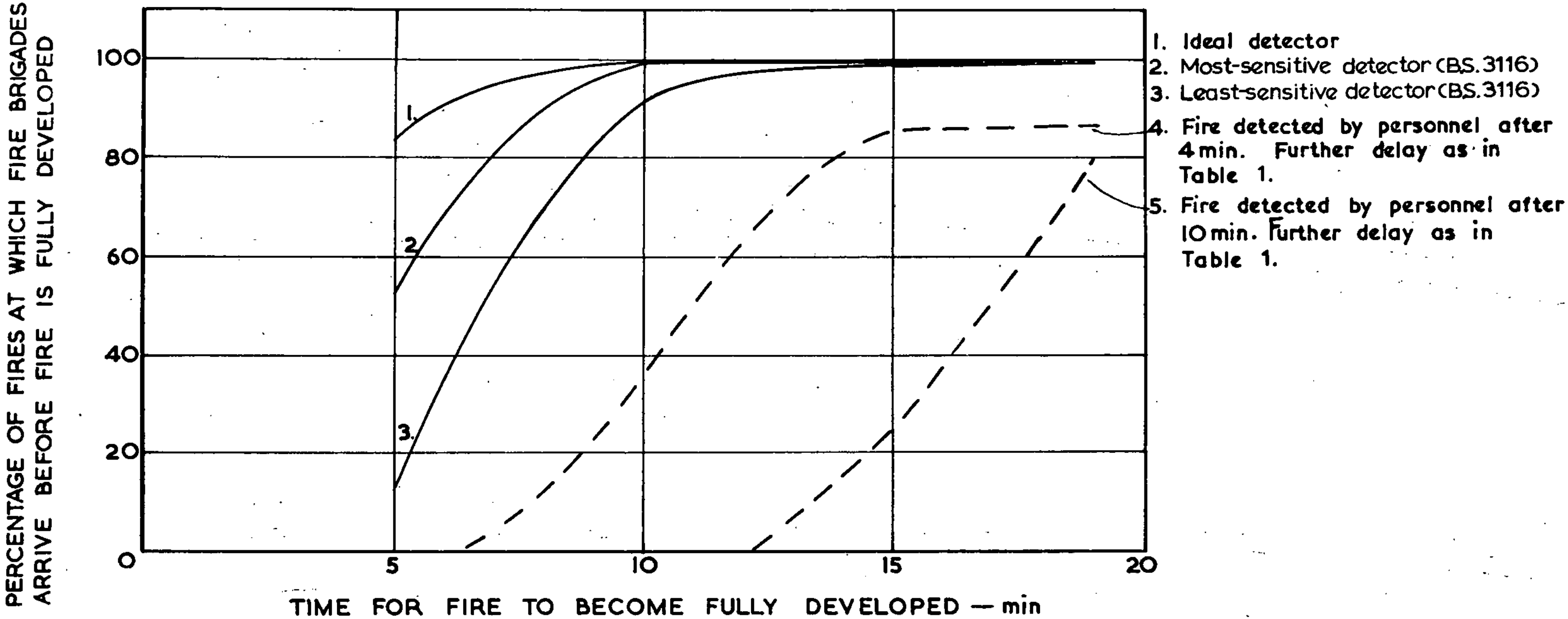

FIG. 3. EFFICIENCY OF AUTOMATIC FIRE DETECTORS — COUNTY BOROUGHS