F.R. Note No.269/1956.
Research Programme
Objective G/2

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

AUTOMATIC FIRE DETECTION

by

D. Hird and P. Nash

SUMMARY

This report examines the saving of time which can be achieved by an automatic fire alarm system in calling the Fire Brigade to a fire, and interprets this time saving in terms of the increased probability of the Brigade reaching the fire before it is fully developed. It also surveys other factors which must be taken into account in examining the performance of automatic fire alarms.

File No.
December, 1956.

Fire Research Station,
Boreham Wood,
Herts.

AUTOMATIC FIRE DETECTION

by

D. Hird and P. Nash

Introduction

It has been estimated that almost half the direct annual fire losses in the United Kingdom and Eire result from 200 - 300 large fires per year. These fires generally start when the buildings are not occupied and as a result the majority of them are well developed when discovered. The task of automatic fire detectors is to prevent such a situation arising by giving sufficient warning to enable fires to be fought in their early stages.

What constitutes sufficient warning will depend largely upon the rate at which the fire develops, and the availability of fire-fighting facilities. The rate of development can vary widely in different circumstances, as will be discussed. While it is likely that automatic detection alone will often be adequate, in certain occupancies the rate of development is likely to be so rapid that automatic detection would be of little use unless accompanied by some automatic means of extinction such as sprinklers, carbon dioxide flooding or deluge systems.

Performance requirements for fire detectors

Because of the diversity of fire risks in buildings it is difficult to establish performance limits for detectors which are intended for general use, but an analysis of the time period between the start of a fire and the commencement of fire-fighting will give some guidance to the performance requirements. There are likely to be three delay periods involved: -

1. Time between the start of the fire and its discovery.

2. Time between its discovery and the call to the fire brigade.

3. Response time of the fire brigade.

If the sum of all these times is greater than the time taken for the fire to gain a substantial hold, the chance of the fire brigade being able to limit the damage in the building will be greatly reduced. The automatic fire detector is likely to reduce the delays in both 1. and 2. above, but the sensitivity of the detector will only affect the time between the start of the fire and its discovery. There is obviously little information on the delay between fires starting and their being discovered but a recent analysis of large fires[1] gives information on the delays between discovery and call and also on the response times of fire brigades. These are summarised in Tables 1 and 2.

Table 1

Delay from discovery to call

	Percentage in the following time intervals (Mins.)							
	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	-
" - Rural	11	14	27	3	11	27	5	2
Co. Boroughs	40	40	8	2	4	4	2	-

Table 2

Delay from call to arrival of fire brigade

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

Although these figures are for a relatively small number of fires they give some indication of the range of delay periods.

These delay periods must be considered in relation to the time in which the fires became fully developed. Accurate information on the rate of development of fires in buildings can generally only be obtained from experimental fires and these are naturally few, and are almost wholly confined to rooms of dwelling houses.(2). Many factors may affect this rate of development. In any given type of risk the rate of development of fire in the early stages may be materially affected by the degree of ventilation, and the chance of the source of ignition being near some readily ignitable material. The experimental fires(2) were started in such a way that their subsequent development was ensured and because of this the rates of temperature rise during the first few minutes of the fires are likely to represent the maximum that would occur in practice. From the evidence available it is probable that a fire in a normal living room of a house would be fully developed in 15 - 20 mins. if adequate air were available. If the room were lined with combustible materials the fire could be fully developed in about 5 mins. While these times are appropriate to the enclosure in which the fire started, this enclosure may often represent a larger part of the building, or may be situated in such a way that a fire fully developed within it may seriously hamper personal escape and endanger the rest of the building. The minimum times of development for most buildings may therefore be considered to lie within this range with the hazardous occupancies such as department stores and furniture warehouses at the lower end and the majority of engineering factories, restaurants, etc. at the upper end. Comparing this range with the delays indicated in Tables 1 and 2, it is possible to gauge the effectiveness of fire detectors by considering the percentage of fires which could be reached by the Fire Brigade before the fire is fully developed both with and without automatic detection systems. These results are shown in Figs.1, 2 and 3 for non-rural and rural Counties, and County Boroughs. The effect of increasing the sensitivity of the detectors is illustrated, the assumptions made in these calculations being outlined in the Appendix. The following broad conclusions can be drawn from this analysis:-

(a) In the more hazardous occupancies (fire fully developed in less than 10 mins.) even if fires could be detected immediately they started, there would be many incidents in which effective fire-fighting could not be started before the fire was fully developed. This indicates that for these occupancies automatic sprinkler installations could reduce the fire damage whereas automatic fire detection alone might not, although it might give sufficient warning to save life.

(b) There are a large number of buildings where automatic detection of a fire would enable the Fire Brigade to attend before the fire was fully developed, and thus to reduce the resultant fire damage.

(c) The effectiveness of a fire detection system does not depend on the sensitivity of the detector alone but must be considered in relation to the type of risk and the degree of fire cover.

Factors governing the operating time of detectors

There are three factors which will govern the operating time of a fire detection system in the event of a fire. The first is the ambient conditions likely where the detectors are installed. Thus the maximum likely ambient temperatures and temperature variations will set the lower limits for heat-sensitive detectors, whilst the greatest smoke density likely will govern the lower limits for smoke detectors. The second is the sensitivity of the detector, which will depend on such factors as the area and the mass of the sensitive element of heat sensitive detectors. The third factor affecting the operating time is the spacing of the detectors. Experiments with fires of various sizes under flat ceilings have shown(3) that the relationship between the temperature rise (Θ) near the ceiling, and the radial distance from the fire, r, is of the form $\Theta = A\,r^{-n}$,

where A = constant
n = 0.4 - 0.6

Thus if the spacings of any type of heat sensitive detectors are reduced, they will be subjected to higher rates of rise of temperature in the event of fire, and their operating times will be reduced.

Of these three factors which govern the operating time, the first, the lower limits set by ambient conditions, will obviously vary considerably particularly in buildings where industrial processes are carried on, but will be common to detectors of the same types. The second factor, the sensitivity of the detectors, has to be determined by test under conditions representative of those likely to occur in an actual fire. For heat-sensitive detectors these conditions have been shown(4) to be an increasing air temperature and velocity.

It has been shown that a suitable method of test for sensitivity would be to subject the detectors to an increasing air temperature at a chosen constant velocity, and an apparatus has been designed for this purpose.

The third factor, the spacing of the detectors, is closely related to their sensitivity and might well be used as a basis for grading detectors.

The grading of heat sensitive detectors

There are at least two ways in which detectors could be graded after their sensitivity had been determined.

1. The spacing of all heat sensitive detectors could be the same and differences in operating time on the sensitivity test would be reflected in corresponding differences in operating time in the event of fire.

2. The spacing of detectors could be related to their operating time under given conditions. For this some standard of protection must be established. One possibility is to take the automatic sprinkler as a standard and deduce the spacing of detectors so that they will operate under given fire conditions in some chosen fraction of the time taken by sprinklers at 10 ft. spacing. This is the method adopted by the National Board of Fire Underwriters. These 'equivalent spacings' can be deduced from the curves of operating times versus rate of rise of temperature, which can be obtained on the sensitivity test, and the relationship between temperature (Θ) and distance (r) from a fire under a flat ceiling.

$$\Theta = A\,r^{-\frac{1}{2}}.$$

Other factors in the testing of fire detectors

Fire detectors are required to be capable of operation after long periods of installation, sometimes with little or no regular inspection and maintenance, and often, in industrial premises, in corrosive or dust-laden atmospheres.

The corrosive conditions occurring in industrial premises are known to vary widely, and their effects on the materials and protective treatments used for detectors may also be expected to vary. It is possible to get a good general indication of the corrosion-resistance of the various detectors and to indicate any weak points of design or protection, by using a test described in Part 3 of British Standard 1391 : 1952. In this test, which was developed by the Chemical Research Laboratory, the specimen is subjected to a humid atmosphere of sulphur dioxide, at a temperature of 45 degrees Centigrade for an agreed test period.

The possible effects of atmospheres laden with dust or oily fluff may often be deduced by an inspection of the design of the detector. Small clearances between moving parts, and the use of open contacts tend to reduce the chances of operation, after a period of installation. While these points should be considered at the design stage, it is thought that the only satisfactory way of ensuring operation is by regular inspection and maintenance.

The effects of vibration on fire detectors may be to produce false alarms, or mechanical failure by fatigue. An analysis has been made of typical vibrations in buildings(5), and it has been shown that vibrations likely to occur lie in the amplitude range 0 - 0.01 in. and in the frequency range 0 - 50 cycles per second.

Conclusions

It is concluded that an automatic fire detection system can give a valuable saving of time in calling the Fire Brigade to a fire, as compared with personal detection and warning. This saving does not depend only upon the sensitivity of the system, but also upon the type of risk involved, and the degree of fire cover.

References

1. Millar, D.W. and Fry, J.F. Fires causing a large monetary loss. F.R. Note No.222/1956.

2. Fire Research 1950. London 1951. H.M.S.O.

3. Fire Research 1955. London 1956. H.M.S.O.

4. Pickard, R.W., Hird, D. and Nash, P. The thermal testing of heat sensitive fire detectors. F.R. Note No.247/1955.

5. Vibrations in buildings. Building Research Station Digest No.78. June 1955. H.M.S.O.

APPENDIX

The effect of automatic fire detectors on the percentage of fires which can be reached by Fire Brigades before the fire is fully developed, for different rates of development of fire.

From the information available it is not possible to associate a given rate of rise of temperature in the early stages of a fire with the subsequent rate of development of the fire. Initial rates of rise of temperature between 5°C/min. and 80°C/min. have been recorded in experimental fires and in this analysis it has been assumed that all fires give the same initial rate of rise of temperature of 30°C/min. at 10 ft from the fire. A number of proprietary detectors have been tested by the Joint Fire Research Organization and the most sensitive and the least sensitive of these indicate the range of sensitivity likely. With a rate of rise of temperature of 30°C/min. these detectors operated in $1\frac{1}{2}$ min. and 4 min. respectively. The ideal fire alarm is considered to have zero operating time. If it is assumed that the detectors are connected directly to a Fire Station and there is thus no delay between discovery and call, the percentage of fires which can be reached before the fire becomes fully developed, with different fire detectors, can be calculated from Table 2. and the operating times given above. To obtain some estimate of the percentages with no fire detection system, two additional curves have been included in Figs. 1 - 3. In one, the delay between the start of the fire and its discovery is assumed to be the same as the operating time of the least sensitive detector and in the other a delay of 10 mins. has been assumed. Each of these curves also includes the delay from discovery to call given in Table 1.

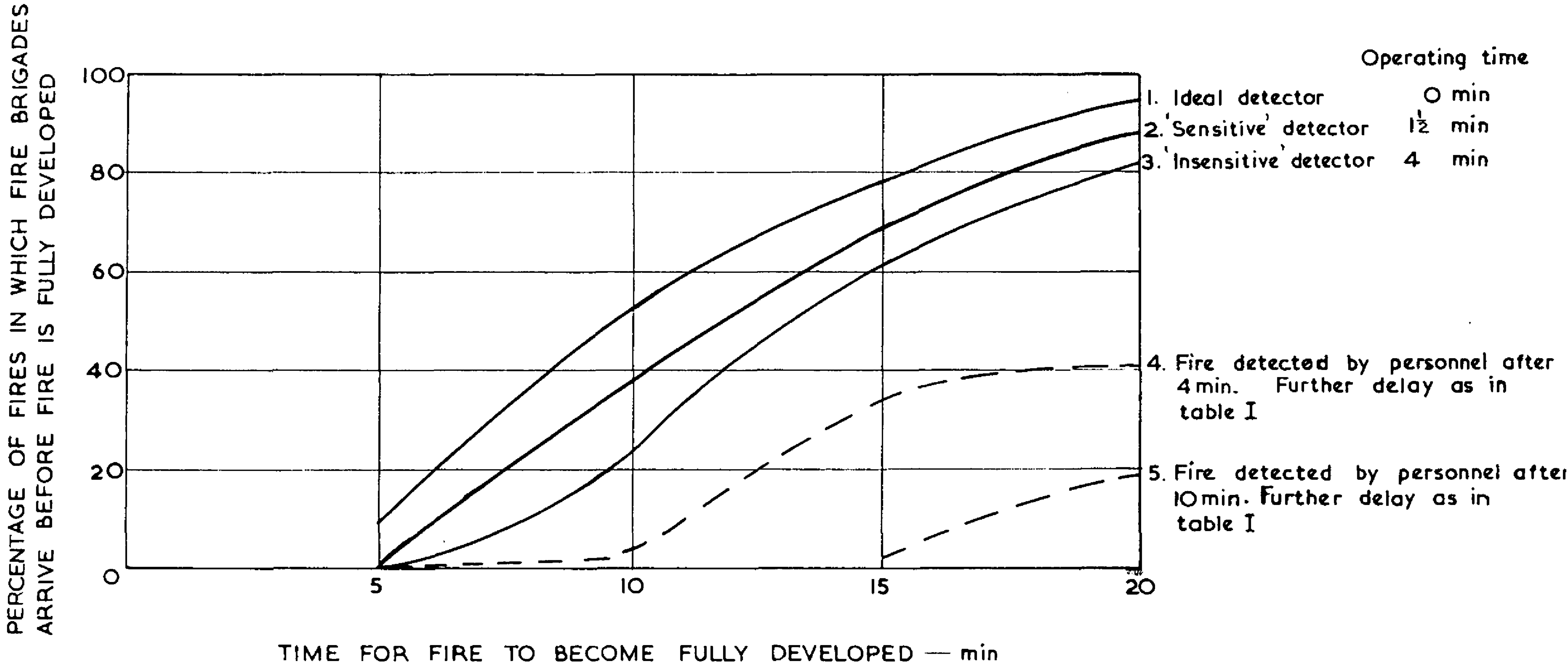

FIG. 1. EFFICIENCY OF AUTOMATIC FIRE DETECTORS — RURAL COUNTIES

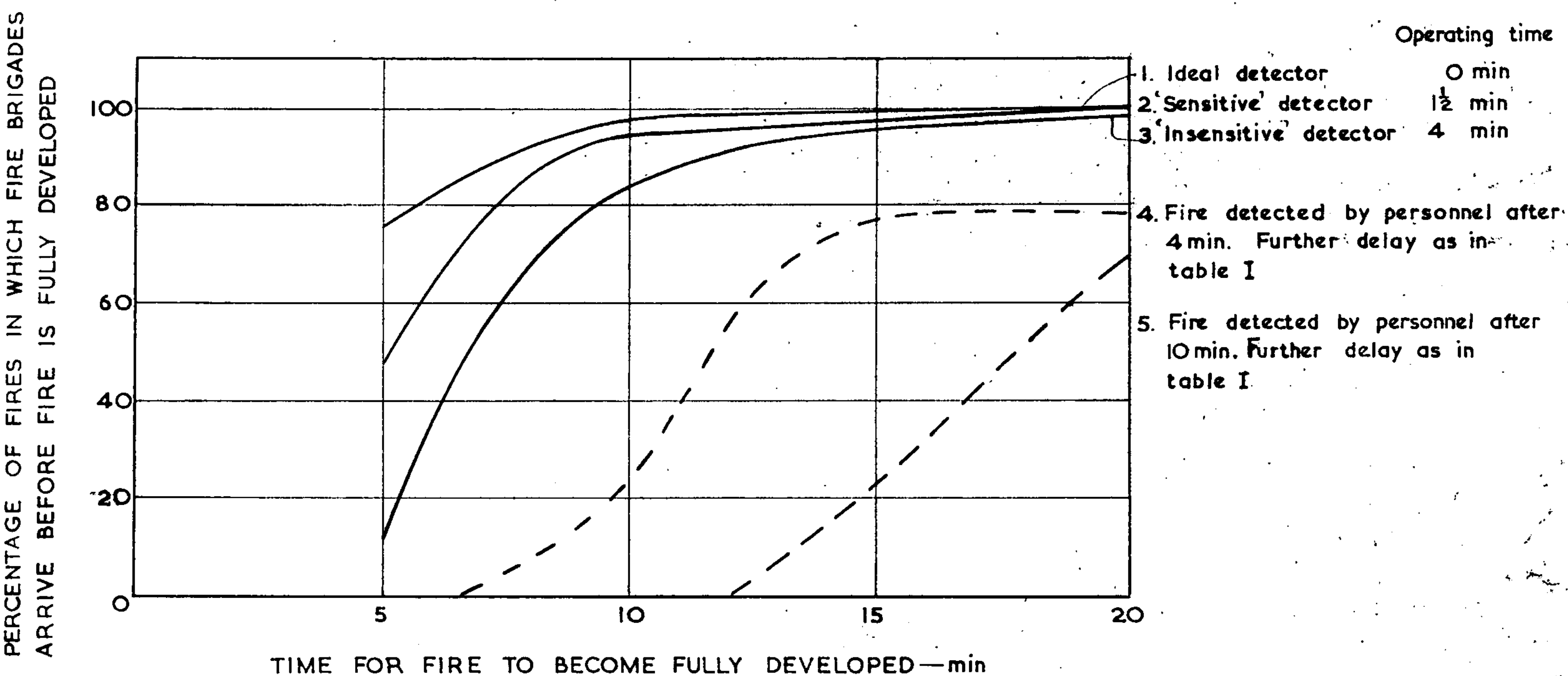

FIG. 2. EFFICIENCY OF AUTOMATIC FIRE DETECTORS — NON-RURAL COUNTIES

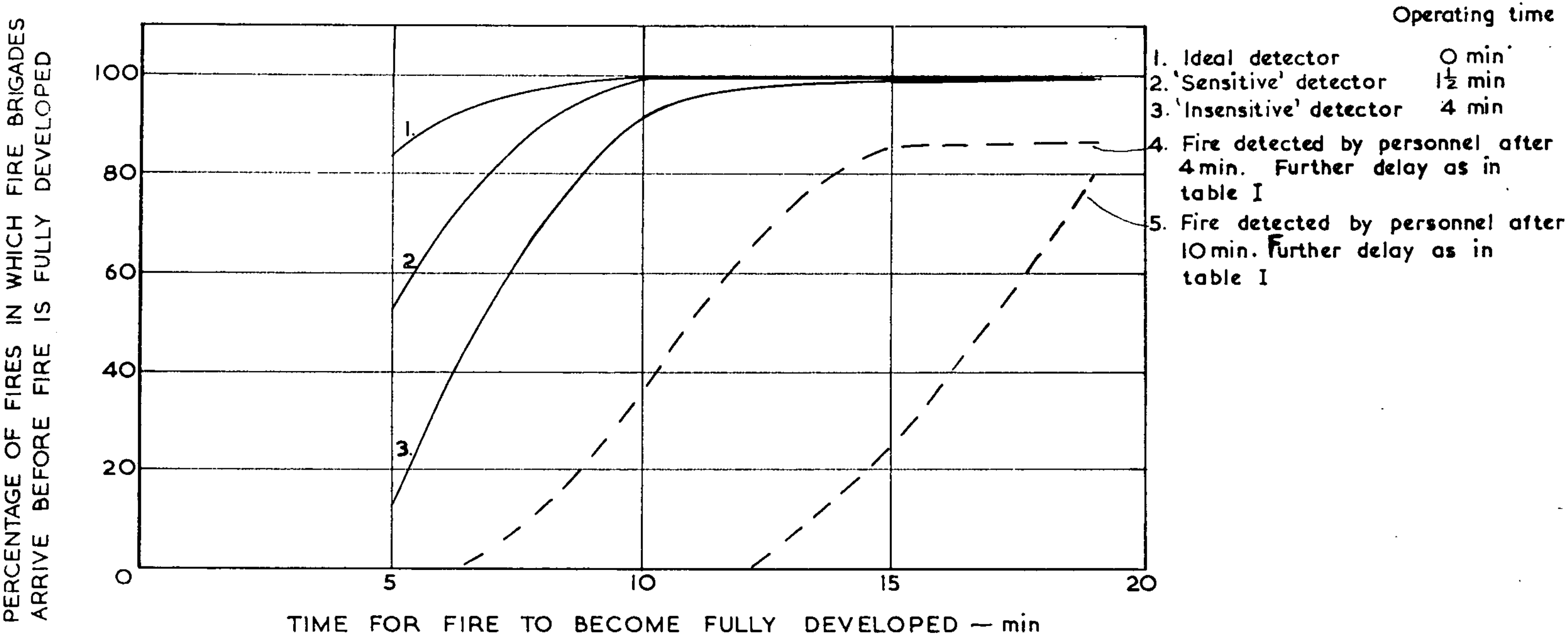

FIG. 3. EFFICIENCY OF AUTOMATIC FIRE DETECTORS — COUNTY BOROUGHS