

## Interpretation of 'sensitivity' for ClassiFire™

With the increase in the number of high value properties, the requirement for very high sensitivity aspirating smoke detectors is becoming ever larger. People or organisations wishing to protect such property are likely to select an aspirating system that has a reliable sensitivity that increases as the effect of a source of combustion spreads throughout the area. This form of detection can be so sensitive when correctly designed and set-up that an overheated wire will be detected long before any serious damage occurs.

At a superficial level, the selection of which manufacturers detector to use is often made according to a manufacturers stated maximum sensitivity, and this leads to a problem. At very high sensitivity the probability of a false (nuisance) alarm increases and in certain applications the stated maximum sensitivity cannot be used without serious risk of many nuisance alarms. In order to allow for this high sensitivity aspirating systems have the ability to adjust their alarm level(s). This is the same as saying that their effective sensitivity can be varied. It is difficult to predict the best balance between sensitivity and an acceptable likelihood of nuisance alarm when designing a system, and this must be done when commissioning such a system. Also, if such a balance is manually decided upon, it is difficult to predict if and how it will vary over the next few weeks, let alone years, of the installations life.

The problem is that in most sites where high sensitivity protection is required there is already a small but significant amount of smoke in its normal use. This is known as 'ambient' smoke. Ambient smoke is rarely if ever at a steady level and will normally and constantly vary in density due to; mechanical processes, ventilation system changes or the simple act of opening and closing doors or windows. While this fluctuating ambient level will usually not be enough to trigger an alarm, it contributes to the probability of generating nuisance alarms. It adds to the smoke level from a combustion source, varying the increase in density required to trigger an alarm. The installation will trigger an alarm when the sum of the two exceeds the alarm level. The additional combustion product that is required from a fire in order to trigger a fixed alarm setting will consequently vary with the ambient smoke density. It should also be appreciated that as the additional amount required gets smaller, the installation becomes more prone to producing nuisance alarms. Thus, if the alarm level is fixed to a certain smoke density, then the sensitivity to smoke from a potential combustion source varies and the probability of nuisance alarm will also vary.

Variation in quiescent or ambient smoke level poses a problem for the installation engineer when the required sensitivity of the equipment is not very much greater than the ambient smoke levels of the site. If the alarm level is set too low, there are likely to be nuisance alarms. This would typically cause the installation to be considered so unreliable as to be nearly useless. If on the other hand the levels are set too high then the system is unlikely to give an alarm at the smoke level required to detect an incipient fire.

Contrary to the common sense of protection, nuisance alarms are the worse of the two alternatives. They create a great nuisance to the authorities and the site proprietor. They cost money and, worst of all, can lead to any signalled

alarms being ignored; they earn the manufacturer of the equipment a bad name, even though he considers them to be not under his control. Frequently the installation engineers solution is to make a rapid assessment of the nature of the area to be protected and the quiescent (ambient) level and set the alarm level so high that it is very unlikely to give a nuisance alarm, at the time or in the future. In this situation the equipment is not being used to its full potential and certainly not providing the level of protection that the customer thought he was getting by examining the manufacturers maximum sensitivity figures for the detection equipment.

As we have already discussed, there is a correlated relationship between 'sensitivity' and 'nuisance alarms'. The higher the sensitivity, the higher the nuisance alarm rate and visa-versa. It may therefore be appreciated that a far more attractive situation for the customer (and installer) would be to be able to fix the probability of nuisance alarm rather than the sensitivity and for the system to be able to maintain a predetermined nuisance alarm rate irrespective of environmental fluctuations.

ClassiFire™ is a patented method of automatically setting and maintaining the *sensitivity* of a detector. It is a statistically based system of analysis and can also be accurately described as an Artificial Intelligence system as it automatically makes decisions about appropriate alarm thresholds based upon historical information.

Sensitivity can be described either as the 'absolute level of smoke density required to trigger an alarm or as the 'increase in smoke density above a quiescent state' required to trigger an alarm. Throughout the following explanation we are referring to the 'increase above a quiescent state'. ClassiFire is based on the relationship between *sensitivity* and *probability of nuisance alarm*, aiming to achieve a constant *probability of nuisance alarm*.

## Detailed explanation of ClassiFire™

ClassiFire recognises that a *sensitivity* setting is a function of *probability of nuisance alarm*, where the function  $f()$  is as described below. This relationship exists such that, if the *probability of nuisance alarm* increases then the *sensitivity* must. Conversely, if the *sensitivity* increases the *probability of nuisance alarm* must increase. On the face of it, if the *sensitivity* is fixed then the *probability of nuisance alarm* is fixed. However the function  $f()$  is constantly varying. The result of this is that if the *sensitivity* is fixed then the *probability of nuisance alarm* must vary. If the *probability of nuisance alarm* is fixed then the *sensitivity* must vary.

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### $f()$

The function  $f()$  varies with the conditions in the area that the detector is installed. The varying factors are; the *level* and *range of variation* of the quiescent smoke level. This is similar to noise, which varies over a wide band of frequencies simultaneously. ClassiFire measures these variables (*level* and

*range of variation*) and constructs the function  $f()$ . They are both constantly altering with time so the measurements have to be made continuously and assessed over a meaningful time period. ClassiFire chooses to take measurements at the rate of once per second and to construct the function  $f()$  for a period of approximately 12 hours previous to the present. The effect of a measurement taken at the present time gradually decreases as time passes. It is difficult to describe the point at which measurements cease to have any effect at all; theoretically it is at an infinite time but, in this instance, it is in the region of 12 hours. This function then allows the probability to be calculated of a measurement exceeding a given level. Conversely, it allows a level to be calculated which has a given probability of being exceeded. The classifier (ClassiFire) system can thus find a level that will only be exceeded with a given probability. This is, of course, assuming normal background smoke levels. If a level is set at 1 chance in one million then when it is exceeded, the probability is that it is exceeded by an abnormal source of smoke or there is a 1 in a million chance that it is caused by the background smoke variations.

ClassiFire uses this level as the Alarm threshold of the detection system. In practice it is constantly running and adjusting the alarm level in line with the previous hours of measurements. Consequently the *sensitivity* is not a fixed level but the *probability of nuisance alarm* is fixed.

This technique contrasts starkly with other detectors, where the alarm level is dependent upon an accurately calibrated level and an alarm signal level that is accurately proportional to smoke level in the protected area. In these detectors it is critical that the variations in the sensitivity of the sensor and the gain of the amplifiers and the intensity of the light source are kept at a minimum. This is difficult and costly to achieve; it is, even then, subject to faults, failures and drifting. In the ClassiFire method all the calculation of sensitivity is performed in the microprocessor that calculates the function  $f()$ . So long as the signal provided by the sensor and its amplifiers is large enough for the processor to analyse, the derived sensitivity setting will be the same. Increasing the sensitivity of the sensor or the gain of the amplifier will not effect the derived sensitivity or probability of nuisance alarm. Thus ClassiFire removes a common source of sensitivity variation (analogue circuitry) from the detector and places the onus of accuracy in the digital processor's mathematical capabilities which is a more readily achievable task.

Another advantage of ClassiFire is that it is constantly adjusting its alarm level (s) to suit the environment. Other detectors, which have settings fixed at their time of installation, can subsequently randomly increase or decrease their effective sensitivity and probability of nuisance alarm.

## **Interpretation of 'sensitivity' for Air Sampling systems**

An Air Sampling detection system is one in which the air from the area to be protected is sampled by means of air being drawn through sampling holes into a pipe network. The air so obtained is taken through a central very high sensitivity smoke detector. The common alternative is a series of Point Detectors, which have to be mounted at various points within the area and joined together by wiring. The advantage of the Air Sampling system over Point Detectors is that the smoke detector can be very much more

sophisticated than a Point Detector because they are fewer and they need not be designed within such tight commercial restraints, neither are they limited in their sensitivity by regulations. Also the central detector and the installation of the necessary pipework is cheaper to install and maintain than the Point Detectors and their wiring.

There are other advantages to an Air Sampling system, such as increased sensitivity as the pre-combustion product from a fire spreads in the area and are drawn to the central detector from an ever increasing number of sampling points, thus reducing dilution and increasing effective sensitivity. It is true that some point detectors can emulate this, but it adds to their cost and complexity.

There are some disadvantages to Air Sampling systems. The central detector does not know which particular part of the area a smoke signal originates from. However, a separate system for each area to be identified, is often an option where this is required. The advantages of an Air Sampling system frequently make it the preferred choice however. Drastic failure of the central detector in the aspirating unit would remove protection from the entire area it covers. In order to counteract this disadvantage, it is essential that the economic advantage available to increase sophistication be used, at least partially, to achieve very high reliability.

With a conventional Point Detector system, if all the detectors have an alarm level which operates at a given smoke density, the air at any or all parts of the area must reach that alarm level in order to trigger an alarm. This is not the case with an Air Sampling system. The central detector needs to be about 100 times more sensitive than a Point Detector so that the pipe network can have a hundred sampling holes where the sensitivity at each hole is the same sensitivity as a Point Detector. This is easily achievable with some, although certainly not all aspirating detectors. This method assumes that air passing through the detector-sensing element is equally drawn from all holes. A few moments taken to appreciate the principle would be well spent. The reason for this is that the smoke sample at one hole must be considered diluted by unpolluted air at all the other holes. With a 100 sampling hole system this will provide a 1:99 dilution ratio. This dilution factor is a crucial factor and one that is usually not detailed in some manufacturers data for good reason. It should be noted that if the smoke sample is taken in at two of the hundred holes, the sensitivity is doubled and if at four of a hundred holes, it is quadrupled etc. If it is taken in by all the hundred holes, then the sensitivity is 100 times the sensitivity of a Point Detector. As the smoke spreads, the central detector sees steps of increase as it reaches more sampling holes. It is this attribute which often makes it a preferable selection (in terms of sensitivity) to that of a Point Detector system.

If an Air Sampling system is designed to protect a given area, and twenty sampling holes are distributed throughout the area to sample the air at strategic points then the sensitivity-per-hole should safely be assumed to be  $1/20^{\text{th}}$  of the sampling detectors sensitivity to allow for possible dilution. If the design is then changed, doubling the number of holes to forty and keeping all other factors the same, the effect will be to reduce the sensitivity-per-hole to  $1/40^{\text{th}}$  of the central detector sensitivity. However the overall sensitivity will not be changed. ***The central detector still has the same sensitivity and it is***

***still covering the same area.*** The difference will be that the smoke sample must spread over two of the forty-hole design to equal the sensitivity of one of the twenty-hole design and the holes will be closer. In other words, the rise in smoke level will be perceived by the central detector to take smaller steps at a faster rate in its rise as the smoke spreads. A given sub-area within the main area is covered to the same degree as with the twenty-hole design. From this it is evident that the degree of coverage is governed by the sensitivity of the central detector and the extent of the area it covers and not by the sensitivity-per-hole of the design. It follows that, in designing an installation for a specific area, once the extent of the area and the detector sensitivity has been defined, the degree of coverage may be deduced. If it is found to be insufficient then the extent of the area must be decreased (i.e. the number of detectors increased). The number of holes used in the pipework covering the area is immaterial to this question and is only pertinent to how evenly the area is covered.