Fire detection system call points types selection based on the gas and smoke environment physical parameters dynamic study in different premises

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Abstract. Fire detection system call points types selection is determined by the gas-smoke environment prevailing physical parameter in fire case and by this parameter change dynamic as combustion develops. Obtaining of practically important information about the gas-smoke environment prevailing parameters during a fire, their changes dynamic and the time when they reach the threshold values for call points for real objects is possible on the numerical studies results basis using the FDS program complex modeling heat and mass transfer and gas dynamic processes occurring during a fire. The performed calculations made it possible to obtain the temperature dependences, smoke optical density and carbon monoxide concentration in the near-ceiling area on time since the ignition start for a number of characteristic rooms for various purposes. The call points type choosing ambiguity for rooms with different fire load indicators is shown. The calculated data can serve as a basis for choosing the fire detection system call points types, as well as for setting up and effective functioning of multi-sensor and multi-criteria fire detectors.

1. Introduction

The automatic fire detection system (ASD), commonly referred to as the fire alarm system (FAS) [1, 2] in regulatory documents, is a key technical device that redounds both to the timely people safe evacuation and to the earliest possible start of fire extinguishing, which makes it possible to minimize material losses from fire. The ASD functions are sending messages about the fire that has occurred to the facility duty section and to the central fire control service, launching a system for people alarm about the evacuation necessity, launching automatic fire extinguishing installations (if they are available at the facility). Modern ASDs are built on the basis of so-called call points (hereinafter – CP) with sensor elements (measuring sensors) that control one or more fire characteristic physical parameters values [1, 3, 4]. Most often, this is the temperature and smoke optical density in a gas-smoke environment, as well as the carbon monoxide (CO - "sweetdamp") concentration in it, (the corresponding sensors are thermal, smoke and gas). These parameters current values and their increase rate in time from the ignition beginning with the same room geometric dimensions and the substances and materials mass involved in the combustion (fire load) depend on the type and characteristics of the available fire load. Each of these types has its own indicators for the combustion heat, the linear fire escalation velocity, the mass combustion rate, the smoke-producing ability, the specific combustion products emission [5, 6]. As a result, the changes patterns in above-mentioned gas-smoke
environment parameters on the burning time will be individual for each of fire load types. Accordingly, the threshold values occurrence time (for detectors) of gas-smoke environment parameters (maximum absolute values or parameters increasing velocities) will also differ [1, 7, 8], which are recorded by sensors as a fire evidence. Therefore, the CP types choice is determined by the gas-smoke environment prevailing physical parameter during a fire and by the changes dynamic in this parameter as the fire develops.

2. Materials and Methods

Obtaining information about the prevailing gas-smoke environment parameter in fire case, this parameter changes dynamic and the time it reaches the threshold value is a necessary, practically important preliminary stage for CP type choosing and effective ASD adjustment. Experimental determination of such parameters on real objects in fire conditions is significant dangerous, can lead to significant material costs and catastrophic consequences. An alternative is to conduct a numerical experimental study and fire parameters determination for objects of interest based on modern means of mathematical fire modeling, programming and computer technology.

In this paper, such a study is carried out on the FDS software package basis [9, 10, 11], which has become the most widely used in the parameters calculating world practice in a fire due to known justifications for the results reliability obtained acceptable for practice [12, 13, 14].

3. Experimental section

As a numerical experimentation result based on the FDS software package, it is possible to obtain the gas-smoke environment physical parameters dependences on time from the fire beginning for any object with known indicators characterizing the fire load. Such calculated data can serve as an evidentiary basis for the subsequent call points types selection and the ASD construction.

As examples, Figures 1-8 show the calculated dependences of temperature, smoke optical density and carbon monoxide concentration in the near-ceiling area (controlled by CP sensors) [15] on the time from the fire start for a number of characteristic rooms for various purposes with known fire load indicators [5, 6]. The parameter values are given in relative values T (temperature), D (smoke optical density) and C (CO concentration), which were determined by the percentage ratio of the current calculated parameter value to this parameter threshold value, identified by the corresponding sensor as the fire detection time. Thus: \( T = \frac{T_c - T_i}{T_{th} - T_i} \), where \( T_c, T_i, T_{th} \) are, respectively, the current, initial and threshold temperature values. D and C were similarly defined. Concurrently, it was thought that \( T_i = 20^\circ \text{C}, D_i = 0 \text{ Np/ m}, C = 0 \text{ kg/m}^3 \). At \( T, D, C = 100\% \), the medium parameters reach the absolute threshold values for the corresponding CP sensors. The all rooms geometric dimensions were assumed to be the same with a length and width of 10 m, a height of 3.2 m.

4. Discussion

The presented calculated results make it possible to identify the prevailing physical parameters of the gas-smoke environment and estimate the time they reach the threshold values for call points. For most rooms, such a prevailing parameter is the smoke optical density, both in maximum value terms and in increase rate terms. However, for some rooms, the prevailing parameter may be the gas-smoke environment temperature or the CO concentration in it. For example, in the examples presented (Fig. 1-8) for the residential apartment premises (Fig. 1), kitchen (Fig. 2), the rubber products warehouse (Fig. 4), the outerwear wardrobe (Fig. 7) the prevailing parameter is the smoke optical density. In this case, the temperature thresholds are reached later, and the CO concentration is reached even later. This is explained by the relatively large values these premises fire load smoke-generating capacity (especially for the rubber products warehouse), the combustion heat moderate value (on which the temperature rise rate depends) and the relatively low CO specific emission values [5, 6]. For the book depository premises (Fig. 3) and a wheat flour warehouse (Fig. 8) the prevailing parameter is the CO concentration. The smoke optical density in these rooms reaches its threshold values later and even later the temperature reaches its threshold values. This is explained by the significant CO specific
emission values for these premises characteristic fire load [5, 6]. At the same time, in the wheat flour room (Fig. 8), the smoke optical density threshold value is achieved with a relatively small lag from the CO concentration compared to the book depository room (Fig. 3), since the fire load in the first of the rooms is characterized by a much greater smoke-generating capacity than in the second one. In the cotton raw materials warehouse (Fig. 5) and flax products warehouse (Fig. 6), the prevailing parameter is the gas-smoke environment temperature. These premises fire load at moderate combustion heat values is characterized by the smoke-generating capacity and specific gas emission small values [5, 6]. It should be noted that with the values of the smoke-generating capacity close to each other, the CO specific emission values for the cotton raw materials warehouse are higher than for the flax products warehouse. Therefore, the CO concentration threshold value in the cotton raw materials warehouse (Fig. 5) is reached before the smoke optical density, and in the flax products warehouse - on the contrary (Fig. 6).

**Figure. 1.** The relative values dependence of gas-smoke environment parameters in the near-ceiling area on the time from the ignition moment in the living room (apartment)

**Figure. 2.** The relative values dependence of gas-smoke environment parameters in the near-ceiling area on the time from the ignition moment in the cooking room (kitchen)

**Figure. 3.** The relative values dependence of gas-smoke environment parameters in the near-ceiling area on the time from the ignition moment in the book depository room

**Figure. 4.** The relative values dependence of gas-smoke environment parameters in the near-ceiling area on the time from the ignition moment in the rubber products warehouse
Figure. 5. The relative values dependence of gas-smoke environment parameters in the near-ceiling area on the time from the ignition moment in the cotton raw materials warehouse

Figure. 6. The relative values dependence of gas-smoke environment parameters in the near-ceiling area on the time from the ignition moment in the linen garment warehouse

Figure. 7. The relative values dependence of gas-smoke environment parameters in the near-ceiling area on the time from the ignition moment in the wool and synthetics outerwear wardrobe

Figure. 8. The relative values dependence of gas-smoke environment parameters in the near-ceiling area on the time from the ignition moment in the wheat flour warehouse premise

Although information about the gas-smoke environment prevailing parameters in fire case can most often be a justification for the CP type choosing - monosensor (thermal, smoke or gas) or multisensor (including a combination of two or more sensors) [1] with the setting of the corresponding fire detection sensor channel (thermal, smoke or gas), however, such information does not always allow to choose the detector type unambiguously. For example, for some rooms, the presence of finely dispersed liquid or solid aerosol particles in the air is possible due to the water boiling, the kitchen equipment operation, the food burning, etc., as well as the smoke or dust entry into the room from the outside. In these cases, the smoke sensor will falsely detect a fire. An effective way to overcome the false fire detection problems is the use of new multi-sensor CP modifications - multicriteria detectors [16, 17] that perform intelligent controlled fire parameters processing, on the basis of which they make decisions about fire detection signal transmitting. Information inserting about the possible changes dynamic in fire parameters at the protected object into the multicriteria CP storage device is necessary.
The preliminary calculations results, examples of which are presented above, can be used as such information. During operation, such a detector compares the gas-smoke environment parameters recorded values with the predicted values in the storage device and, if they are sufficiently close, records the fact of the fire that occurred.

5. Conclusions

Obtaining information about the gas-smoke environment physical parameters current values in fire case and the their changes dynamic as combustion develops is possible as a performing numerical studies result of heat-mass-exchange and gas-dynamic processes occurring in fire case on the FDS software package basis [9, 10, 11].

This information can be used for the fire detection system detectors types reasonable choice [1], as well as for setting up and effective functioning of multi-sensor [1] and multicriteria [16, 17] fire detectors.

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