Monitoring Of Air Quality Parameters For Construction Of Fire Risk Detection Systems

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Abstract. The analysis of fire developmental process is given, which showed that there are seven stages of fire development, a set of phenomena (factors, signs) of fire risk condition, characterized by a set of defined parameters, corresponds to each stage. Observed that the registration of high staging factors (high ambient temperature, content of CO_2, etc.) means the registration of actual low staging fire (thermal destruction of materials gases, fumes, etc.) - fire risk situation. It is shown that the decrease of registered factor staging leads to construction of fire preventive and diagnostic systems as the lower is registered stage, the more uncertain is connection between the fact of its detection and a fire. It is indicated that with development of electronic equipment the staging of fire situations factors used for detection is reducing in whole, and also it is noted that for each control object it is necessary to choose (identify) the optimal factor, in particular, in many ways the optimal factor for aircrafts are smokes and their TV image.

Introduction

Fire risk detection by monitoring of air quality parameters is widely used in equipment and depends on the character of the controlled object and its service conditions. Optical parameters of air quality allow estimating mediately air quality changes connected with signs indicative of development of the condition usually defined as signs of fire situation development.

In general the fire (F) development to the uncontrolled state passes up to seven stages [1]. Early low stages of F development can be determined as fire risk condition, a fire hazard situation, for various reasons such a state could not develop in a F.

Usually to the first stage is referred [1] the ingress of burning gases into the atmosphere of controlled room - due to the fault condition of gas main lines etc., fire stage (FS) registration is performed by means of gas sensors.

The second stage of F development is connected with temperature rise of substructure components' surfaces of equipment and apparatus, increasing of infrared radiation intensity, entering of combined-cycle thermal degradation products of non-metallic: structural, insulating, decorative and other materials into the atmosphere. Due to low concentrations of combined-cycle thermolysis products at this stage dominates the condensation mechanism of the formation of aerosols with particles of 0.01 - 0.1 micrometer, such aerosols mostly unobserved visually.

The third stage is associated with a further rise of warm-up temperatures of non-metallic materials and corresponding increase of flux densities of combined-cycle products of thermal (thermaloxidative) decay materials. There is a coagulation of initial condensation particles along with steam products of thermolysis condensation; as a result the aerosol particle spectrum expands towards larger particle sizes. Thus, at the third stage the thermo destruction aerosols are optically active and as a rule can be observed visually.

Subsequent stages associated with the appearance of glow at the hotbed of fire, flame formation, production of considerable quantity of carbon dioxide, rise of environmental air temperature and so on, and so forth, also, as a rule, are characterized by stronger probability of process development to fire condition than mentioned initial stages of its development. All F detection methods are based on the registration of physical phenomena parameters (factors, fire risk signs) accompanying different developmental stages.

Thus, registration of early stages' factors (leakage of burning gases, rise of temperature and IR radiation of equipment surfaces, smoke generation, etc.) is referred, as noted above, to FS detection, and detection of factors of late stages, as a rule – to F detection.

In the construction of detection and alarm systems for fire risk condition of controlled object it is natural aspiration for detection of low F developmental stages - for FS detection.

About fire factor

About an optimal fire factor for construction of fire detection devices. Though the decrease in staging of recorded factor leads to increase in uncertainty of fire risk estimation. It is clear since the decrease in factor staging is an approximation to the normal state of controlled object, and the state arbitrary close to normal one is characterized by arbitrary small fire risk (FR) probability. The latter means that an attainment of threshold level by any low staging factor does not mean 100% probability of fire development after the event. In this case only some supposed FS is fixed which must be explored further to draw conclusions and implement the necessary protective measures.

In fact the decrease in staging of recorded factor leads to increase in probability of false actions of detection device, if any factor recording device is considered from the viewpoint of reliable F detection tasks. We understand the F detection device as traditional system of some sensors, where for F «determination» it is enough that the signal of at least one sensor to cross the threshold.

These devices more likely should be defined as F prevention or FS diagnostic devices.

The set forth describes only one aspect of constructing early F detection devices issue based on the registration of law staging factors - the probability of detecting a real fire risk situation decreases.

Another difficulty is that at the same level factor corresponding to certain fire developmental stage fire risk and fire safe situations are possible. This difficulty results from the fact that the factor level (intensity) is associated with the fact of real fire risk statistically, because object modes are extremely various in the general case and are implemented randomly in time.

Let us explain the last by example. Assuming that some object over a long period of time is controlled in temperature area of equipment and devices parts in different including the emergency states associated with a real FS. Then using collected statistics the minimum levels of fire-hazardous temperatures and the corresponding threshold settings for temperature sensors of FS detection system are determined. Seemingly now the system can prevent the F warning of FS occurrence. However in the majority of cases system action (actuation) doesn't mean FS occurrence, i.e. it is false. Moreover, in the object, particularly the complex one, such emergency situations unsuspected during the survey are possible, where FS occurs and quickly, irreversibly develops to F at temperatures less than the threshold ones, i.e. there is FS and F skip occurs.

With increasing threshold of the system decreases the possibility of false alarms and increases the probability of FS skip. Therefore for low staging factors in a certain range of their values an "overlap" of fireproof and fire risk modes (Fig. 1) takes place predetermining the ambiguity of such systems.

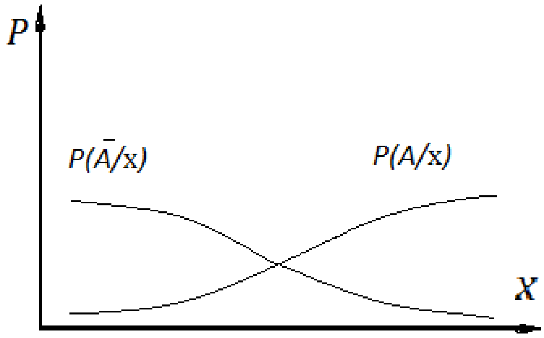

Figure 1 - "Overlap" of fire proof and fire risk modes: *P(Ā/x)* – probability of fireproof modes; *P(A/x)* – probability of fire risk modes; *x* –factor of FS

False action and skip of FS equally reduce efficiency of the systems. The efficiency (E) of the system can be defined like this:

$$E = \frac{P(A) - F - P_P}{P(A)}, \qquad (1)$$

where *P(A)* – probability of FS; *F* – probability of system false action; P_P– probability of FS skip.

Obviously, in light of the above-mentioned, there is an optimal threshold level of low staging factor, where E is maximal. Dependence of E on threshold level has a shape shown at Fig. 2, i.e. E even at the maximum does not exceed 23 - 24%, and given the fact that it is rather critical to the threshold, the actual quantity of E is much lower which is confirmed by the statistics of right and wrong actions of such systems.

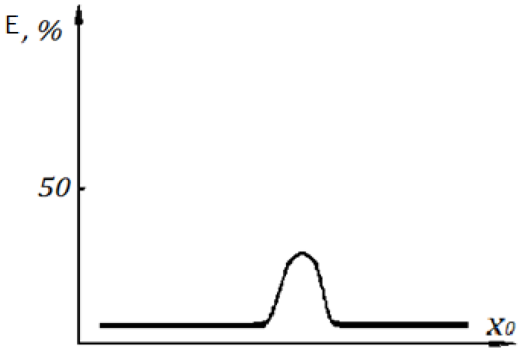

Figure 2 - Dependence of FS detection efficiency by traditional systems on threshold setting of registered factor x_o

Stated above applies to the registration of low staging factors (to FS registration) likewise relates to the registration of high staging factors (to actual F registration): the same impact of the threshold level on the probability of false action and F skip, the same dependence character of E on the threshold level etc.

For simplicity let's assume that the ways and means are found to eliminate inferiority of described systems and they work with 100% value of E. This means that the system based on the registration of factor associated with some stage, with a 100% probability detects exactly this stage of fire risk developmental process.

Hindsight at the development of fire detection means and alarm system in whole confirms the stated interpretation of their direction of development. Suffice it to say that the first fire sensors, fire alerts were based on the elements sensitive to factor of late stages - temperature rise of controlled environment (fusible alloys, bimetallic strips etc.). With the development of semiconductor optical detectors the sensors reacting to fire glow appeared. The development of gas- analytical instrument making put on the agenda the use of CO_2 gas analyzers. Currently intensively develops the "next" stage of FS development - smoke formation stage. There are also examples of the construction or attempts to construct FS detection systems based on registration of the second stage factors of F development: relatively moderate overheating, increasing of infrared radiation intensity, inflow of small concentrations of thermal destruction gases into the atmosphere.

Principles of design, construction and characteristics of the elements sensitive to different factors, F and FS devices and detection systems are described in numerous sources starting with the works of the 1960-s in the last century [2-5] and ending with such works as [6-8].

For specific transportation facilities, such as aircraft (AC) the F registration is unacceptable: too late would be the registration of a noticeable increase in ambient temperature, the presence of significant amounts of CO_2, flame, glowing fire source. Whereas reliable registration of fumes, submicron aerosol or thermal destruction gases, an abnormal temperature increase and heat radiation in certain areas of equipment and devices means, as noted above, the detection of FS when the fire hazard process is still controllable.

In the stated range of factors the smoke, being a FS factor, is the closest one to F, therefore, its definition is related to F. In light of the above mentioned the use of smoke factor assumes the smallest, compared with other factors, amount of additional preventive and diagnostic procedures and therefore it is more preferable of all low staging factors. In addition the smoke factor applied to the AC has a significant advantage: it can be detected by a relatively small number of sensors, as the smoke circulates throughout the space of the AC in an air stream (as aerosols and thermal destruction gases). While in order to control the radiation and surface and equipment temperatures even in the most critical areas an immeasurably larger number of radiation and temperature sensors are needed.

The stated material determines the predominant interest in the registration of fumes as the basis for the construction of reliable FS detection devices.

The results of researches and developments in the sphere of early FS detection in the world

The stated logic of the construction of FS detection systems predetermined, in fact, by the works similar to [1], is kept up to date. For example, in [9,10] there are descriptions of early FS detection devices, on the basis of the second stage of FS development (increase in temperature and intensity of the infrared radiation at the place of potential source of fire), in the [11-15] - on the basis of the third stage of FS development (smokes). However, in some cases, the term "early detection of fire" is used also for the systems based on registration of the later stages of the F development; in the [16-18], "early detection of F" is based on an open flame detection devices, for example, using the characteristics of flame flickering and moving, [17], [19] – based on the registration of CO content in a controlled environment. In the [20] the diamond sensor, developed in Japan for registration of the ultraviolet radiation from the potential fire source before the fire and smoke could reach dangerous levels, is discussed.

In the [21] it is reported on the F detection systems where after smoke content registration the intelligence systems for control of engineering equipment work automatically notify a fire fighting service, in which the flame detection is made using closed television (TV) system with subsequent transfer of an image to the control station of fire service. These measures may be regarded as mentioned preventive and diagnostic procedures allow clarifying the subsequent trajectory of FS development. In the [22] a multi-level approach to the development of automated fire alarm systems based on TV - images processing technology is offered. During high-speed scanning of controlled space, firstly the areas containing an image of burning objects with high probability are allocated.

Then the areas with the colorimetric characteristics corresponding to red color are tracked. Application of neural network provides a separation of burning and not burning areas.

At the same time more and more clearly appears the trend to use in the alarm F detection devices of complex of F features - signs of its early and late developmental stages. Using the signs of late stages intended to remove some uncertainty in the future F development after signs of early stages are found, for example, temperature rise or smoke.

So, already in 2004 in the [23] an overview of the entire spectrum of F alarm systems is provided, starting with systems based on the registration of one of the initial stages, for example, smoke stage, ending with flame detectors based on detection of IR - and UV - radiation, as well as systems using complex information and provided with intelligent functions. These intelligent systems for early F detection are presented in the [23-26]. Despite the complexity of different-type information merge technology and accounting of information-statistical characteristics of F developmental process, the use of complex information about F, in any case, should help to improve the reliability of F detection.

At the same time - in experiments with early FS detection based on the registration of its late-stage features or successive indication of early stages firstly, then the late ones, and subsequent merge of different-type information - almost always the question remains: what sign must be the "primer" starting the entire chain of events indicating the succession of signs of all the later stages of FS development - up to the fusion of different-type information and formation of an integrated solution about F? In other words, what feature of the stages to be understood as an optimum one: gases of initial thermal destruction of electrical and other materials, temperature, thermal (infrared) radiation, smoke, the presence of traces of carbon monoxide or, as in the [22], as such initial feature should then learn the detected (based on the technology of TV image) areas of controlled spaces containing moving images?

Analysis of more than thirty articles mentioned above and dedicated to the systems of early F detection based on the complex of signs shows that the most commonly the "primer" one the sign of smoke formation is called. And in combination with a sign of smoke formation in the complex systems are mentioned the results of TV images processing of smoke flows or moving flame.

Thus, at the present time as the most appropriate F sign to identify FS and F affirms a sign of smoke formation- including the systems built on the basis of indication of both early and late stages of F followed by the merging of different-type information and formation of integrated solution about FS of controlled object.

Conclusion

1. Fire-risk process – from the operating mode of the object to the F - develops in several stages.
2. A set of physical and chemical phenomena, or factors (signs) of fire risk condition, characterized by a set of certain parameters, corresponds to each stage.
3. Registration of high staging factors means, as a rule, the registration of F, low ones - FS.
4. Decrease in the staging of registered factor leads to the need of building, in fact, fire preventive and diagnostic systems: systems solutions for low staging factors should be analyzed additionally, as the lower is registered stage, the more uncertain is the connection between the fact of its detection and F. It is confirmed by current trends in the construction of intelligence F detection system systems.
5. Detection of the actual FS as situations described by a certain set of physical and chemical parameters, traditional systems implement ineffectively.
6. With the development of electronic equipment the staging of factors used to detect the FS is decreasing generally.
7. By many characteristics an optimal feature (factor) of F to identify FS for aircrafts in particular is smoke.
8. Analysis of the researches and developments of F and FS detection systems performed abroad in 2002- 2013 shows that the most appropriate initial ("primer") feature to detect the FS and F by a set of F signs is smoke.

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