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Abstract

Aviation regulation requires a fire detection system in designated fire zone to ensure safety operation. This fire detection system shall be reliable and accurate in order to avoid false fire warning which could lead to operation abort. This need is at key importance for any users operating helicopters for example in offshore operation. In addition to the safety requirement, Eurocopter also pay attention to installation requirements in order to optimise on one hand the system performance and on the other hand accessibility to helicopter equipment inside these compartments.

In the frame of the NH90 program, Eurocopter investigated optical flame detection technology. These systems are based on flame radiation sensing and analysis, and allow a distance detection in a solid angle around 90°. This latest characteristic allows to pass over common installation constraints using a reduced number of detector and avoiding the link between the detectors and the equipment to be surveyed. Accessibility and relevant coverage are then facilitated. Eurocopter gained experience by testing different detectors with single and dual spectrum in engine and main gear box compartments. Eurocopter has specified and installed a dual spectrum ultraviolet and infrared optical flame detection system for the NH90 helicopter.

The purpose of this paper is to provide the summary of the installation constraints of a fire detection system on the helicopter and to present Eurocopter experience gained by using optical fire detection system on NH90.

Terms & Definition

- MGB : Main Gear Box
- OFD : Optical Fire Detector
- FMB : Fire management box
- UV : Single wavelength in ultraviolet
- IR : Single wavelength in infrared
- IR-IR : Dual spectrum detector in Infrared
- UV-IR : Dual spectrum detector in ultraviolet and infrared

Optical fire detection system principle

Flame characteristics

The optical fire detection systems set on alarm when they are exposed to the radiant energy emitted by a flame. By this way they are collectively called optical flame detector (OFD). Detectors and associated circuits can be conceived to be selective with regard to some factors such as the spectral sensibility, the level of energy of the detector, the rate of rise of the illumination energy or the frequency fluctuations in this illumination (flickering of flame).

Generally, the main parameters characterising flames are the following ones:

- Large intensity of the brilliance in the infrared
- Brilliance in the totality of the light spectrum
- Low frequency oscillation of the flames
- Specific emission spectrum

So the characterisation of the flame is performed essentially by the detection of an intensity of brilliance in one or several given wavelengths coupled for some detectors with a frequency analysis characterising the phenomenon of flame flickering during combustion.

If the products of the combustion shine in all the brilliant spectrum, the atmosphere in which are diffused these products play the role of a filter with its own transmittance (ref 1). On the other hand the atmosphere presents a variable transmittance according to its appropriate constituents, which gives a series of parameters of influence. The main of which are: the distance of distribution in the environment, the temperature, the relative humidity and the distance of visibility in the environment.

Of this fact the combination between the pure brilliance of the products of the combustion and the atmospheric absorption reduces considerably the useful bands of the emission spectrum in the data processing.

In conclusion, the useful zones for the optical analysis of flame are reduced to some wavelengths for the ultraviolet brilliance around 220nm, and the infrared brilliance around 2.8 μ m, 4 μ m, 4.35 μ m and 5 μ m. For the infrared, the wavelength 4.35 μ m is privileged because it corresponds to a maximum of emission of the products of combustion (CO₂) with a minimum of absorption of the atmosphere in this wavelength, which allows to have a high-level signal. For the same reason the frequency of the source is analysed in this wavelength to characterise the flicker phenomenon.

These characteristics define the possible options and the inherent limitations to discover this brilliance. Indeed some sources approach the flame spectrum in the chosen wavelength and according to the signal analysis (Frequency analysis, Threshold comparison) spurious fire detection can appear.

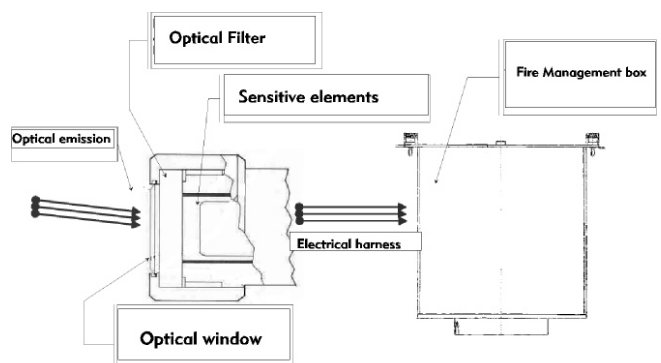
Of this fact and according to the complexity of the environment in which the system of detection operates, it becomes necessary to make sure that no source may causes interference in the chosen wavelength (case of the single band systems) or to multiply the surveyed wavelengths to refine the analysis (case of the systems multiple bands) to cancel the potential negative effect on system reliability.

Common interference sources can be:

- sun Light
- Source of heat (radiator.)
- Bow (flashes of lighting)
- "warm" Objects
- Light sources

Functional system

The flame detectors are constituted by an optical window defining the opening of the detection (solid angle) and which complies with the wavelength to be analysed. Secondly an optical filter allows to restrict the brilliance crossing the window in the wavelengths selected for the analysis. One or several sensitive elements allow to transform the optical brilliance into electric signal for the analysis.



The treatment of the signal can take place in the detector or in the deported box. For all the optical systems using at least one band in the infrared, the wavelength privileged of 4.35 μ m is of used. If the system contains several wavelengths in the infrared, the possible logic of analysis consists of a comparison of the levels of energy received for each of it with a comparison to a threshold by band or a ratio between bands, compared with a threshold.

For the systems combining several wavelengths (ex : UV-IR detector), it is the answer in each of the domains which is the object of an analysis identical to the one presented in the case of the single band detector.

Helicopter installation

Installation requirement

While satisfying the required performance, the main installation constraint of any fire detection system are at least :

- To ensure accessibility to the surveyed component, specially for maintenance purpose.
- To ensure protection of the fire detection system during maintenance operation and in the installation life time.
- To ensure correct accessibility for inspection of the fire detection system itself
- To take into account fire detection system physical limitations such as radius of curvature and distance between two clamp assembly for the wire detection
- To perform the compartment temperature analysis for temperature threshold determination of temperature sensing detectors
- To perform the fire hazard analysis to clearly identify the equipment to be surveyed taking into account the system safety/reliability analysis.
- To optimise the detectors number for an appropriate coverage of the equipment to be surveyed...

According to the specificity of the helicopter installation the number of possible fire detection system can be reduced. Nevertheless the optical fire detection system appears to be the one which offer the capability to take into account most of these requirements. The main point to be taken into account is to have the most opened area between the detector optical part and the equipment to be surveyed. At the early stage of the compartment design this can be taken into account knowing that the performance of the optical system offer benefits.

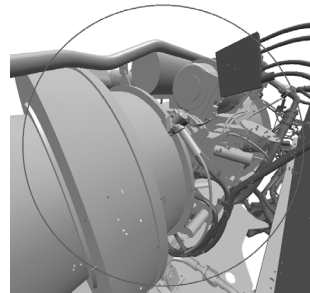
Therefore engine and main gear box components inspection and removal shall as far as possible not be affected by the presence of the fire detection system. The detection based on optical system turns out to be an adequate system for the surveillance of large volumes (distance detection) or of an important number of equipments to be surveyed in a domain which can be more restricted (solid angle of 90 ° and more). On the other hand the optical systems are able to detect flame like a torch for which the temperature rise could not be detected quickly by temperature sensing detector if the flame is not directly in contact with it.

For these reasons the optical systems answer to the requirements of a fire detection system on helicopter in the engine compartments and the main gear box but also in cargo bay.

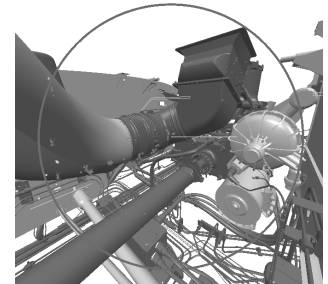
Main advantages of optical systems

- **Vast domain of surveillance:** with a solid angle of 90 ° and a distance of detection which can reach a dozen meters, the optical fire detection allow to surveyed a large area with a reduced

number of detectors. This advantage is effective for the survey of MGB zones, engine compartments and the cargo bay. However, it is necessary to have a design which provide relatively free area away the optical field of the detector.



Engine compartment



MGB compartment

- **Distance detection:** The additional point of the surveillance of a large area is the capacity of distance detection which provide the ability to pass over the some installation constraint. It is not necessary that the flame passes on the detector to activate an alarm. This allows to save time in the fire detection and to have more flexibility in the system installation.
- **Detection of flame:** unlike other systems (heat and \ or smoke detectors), the optical systems characterise the brilliance of flames. In the case of systems using pure UV wavelength or at least a UV wavelength, fire detection systems can be insensible to the rise of temperature caused by engine start or lack of compartment ventilation. This point allows to pass over from the delicate calibration of the temperature sensing system according to the installation area. This allows to increase the commonality of the fire detector reference improving the spare parts management.
- **Fast detection:** the detection can be made in some milliseconds. However to ensure a reliable detection a delay is added in the alarm actuation. Generally the optical systems are actuated between 2 and 5 seconds what is fully compliant with certification requirements. This performance allows to discover a fire from its birth while other systems (wire, bimetal) require the distribution of the fire up to the place where is located the sensor or to reach an average temperature threshold. In addition optical technology is adapted to the detection in the case of blown flames. On the other hand there is no persistence in the effect of the fire (rearming time) allowing a fast response in case of a new fire ignition.
- **Improved installation on the helicopter:** the optical detectors are directly settled on the structure of the helicopter without compulsory mechanical link with the surveyed equipment. This point notably allows to leave a free access to the engine and to the MGB components for the maintenance purpose compared to the fire wire which needs to be installed closed to the various equipment. Indeed, using a wire detection often lead to installed the wire along the engine itself, or along a dedicated support which have to be removed before engine maintenance operation, or

on compartment deck and opening cowling used as maintenance platform where they can be inadvertently damaged by operators.

Main optical systems constraint

- **Cleaning of optics:** detection can be partially reduced by a fouling of their optical window. This is why, it is necessary to foresee a periodic cleaning of the optical windows. Nevertheless this periodicity can be increased by a better control of the integrity of detectors with an optical test.
- **Opened area :** Optical fire detection system installation requires a quite opened area in the compartment in order to ensure the detection performance.

Helicopter experience

Eurocopter gained experience in optical fire detection system in the frame of the NH90 program. This technology was selected taking into account installation requirement and availability of optical technology.

At the early stage of development single IR technology was available and selected as far as according to the flame characteristic the 4.35µm wavelength appears to be the basis of analysis. Nevertheless after installation in engine compartment some false fire warning appeared during engine starts. The temperature rise of the engine compartment combined with the ventilation initiation could lead to emission in the selected wavelength (temperature rise of body part) and frequency oscillation (ventilation). Therefore the discrimination criteria were met leading to transient false fire warning. This phenomenon was also clearly identified when testing the detector with an oscillated hot warm plate.

Further investigation lead Eurocopter to improve knowledge of optical flame detector using available public data (ref 2) and to evaluate other optical detectors: Single UV, Dual IR and a modify dual spectrum UV-IR. Some tests were first performed on bench using different source in order to proceed to a first characterisation of the detectors performance (ref 4) :

test	Expected	UV-IR	UV	IR	IR-IR
Light flame	Yes	Yes	Yes	Yes	Yes
Laboratory flame	Yes	Yes	Yes	Yes	Yes
A fuel flame	Yes	Yes	Yes	Yes	Yes
Sun light	No	No	Yes	No	No
Domestic light 12V/45W	No	No	No	Yes	Yes
incandescent (75 à 100W)	No	No	No	Yes	Yes
UV tube	No	No	Yes	No	No
Stroboscopic light	No	No	Yes	No	No
Warmed metallic plate (600°C)	No	No	No	Yes	yes

This first approach allowed to verify that the pure infrared detector were sensitive to the brilliance of warm bodies and that the addition of a second IR band did not solve this problem. The UV-IR detector which keeps the privileged infrared band in infrared while adding a complementary discrimination in the ultraviolet band gave satisfactory results.

In logical complement to this experience, Eurocopter proceeded to the installation of detectors UV, UV-IR and IR-IR in an engine compartment of the NH90. Hot engine starts were performed in order to identify the performance of the detector. The helicopter results have confirmed the test performed on bench. Pure infrared technology was not adapted to the NH90 while detectors using ultraviolet band provided satisfactory results.

Ultraviolet is commonly the tracked wavelength to detect explosion or high intensity flame such as the one seen in the afterburner of military aircraft. On the other hand the commonly used wavelength of the infrared remains an interesting parameter to detect the flame due to the specificity of the flame characteristic (flicker and CO₂ absorption band). Potential parasite sources for the UV band are unlikely to be found in engine and MGB compartment (UV light, Arc welding...). Therefore the combination of UV-IR offers the best compromise between performance and reliability.

Conclusion

The UV-IR detector was selected for NH90 helicopter and is developed by L'HOTELLIER. After one year of flight, no false fire warning occurred and the system is to be qualified by end of 2002. The NH90 helicopter is the first helicopter using the first aeronautic UV-IR optical flame detector.

Reference

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- [2] Characteristics of optical fire detector false alarm sources and qualification test procedures to prove immunity, phase II, volume I, II and III. Authors : D.A. Goedke and H.G. Gross. Wright Laboratory
- [3] Eurocopter Test report
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