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# PROCEEDINGS

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**<u>Two dimensional multi detection fire sensor, system architecture & performances</u>**

The problem of today's fire sensor systems in aircraft is the fact that false alarms occur, and that there is no possibility to monitor the efficiency of fire extinguishing nor the cargo compartment itself.

Today, in most cases one dimensional or spot-type smoke detectors are used. The only fire parameter that is detected by these sensors is smoke. A fire can be seen as a hot point (smoldering fire), a flame or smoke. In some cases, depending on the kind of fire, smoke comes later than a certain degree of radiation. One dimensional smoke detectors need to be exposed to high energetic phenomenon to reach the sensor. In other cases detection comes later again.

False fire alarms in aircraft cargo compartments can be caused by interferences detected as a fire like mist, dust, environmental conditions, particles.

Time to detection could be too long due to the fact that the technology applied covers only some aspects of a fire and the detector covers a small area of the cargo bay and not a volume.

A real status of the cargo after or while extinguishing is not yet available to the pilot. Only a binary information correlated with a remaining probability of uncertainty is transmitted to the cockpit.

In order to improve overall fire detection system efficiency in a/c while decreasing pilot stress during fire alarms procedures, we propose a new sensor technology, associated to measurement and detection signal processing to be part of a confirmation system.

Part of the research has been funded by the European Commission within the 5th Framework Programme FireDetEx.

## 1. Sensor technology & architecture

The purpose of the sensor is to identify all of the phases of a fire and therefore, consequentially, hot spots, flames and smoke.

The different phases of a fire are as follow:

Smoldering fire: period during which heating begins and gasification occurs.

Start of chemical reaction: period during which complete development of pyrolysis occurs. The ignition point sets off the beginning of combustion. Smoke emission and moderate convection are observed.

Flame: fast exothermic reaction covering the beginning of the flame and the completely developed fire:

- radiant energy generated around the flame,
- thermal convective energy,
- smoke emission (important for hydrocarbons).

For the detection of hot spots and measurement of radiant energy emitted by the flame, the use of infrared detectors is required. In addition, fire resistance of materials used in bays (lining) is 850°C over 15s. The device must therefore be capable of detecting temperatures well below the resistance of the materials.

Space coverage for detection must be close to 100%. This necessitates the use of two-dimensional sensors providing coverage of a significant solid angle.

The detector chosen will therefore be a 2D sensor.

The entire principle of thermo graphic cameras is based on the emission of the black body emission. The spectral response of the black body has been determined by Planck and is expressed in the following equation:

Eq.1 $$E_{\lambda,b}(\lambda,T)=\frac{C1}{\lambda^5\left[\exp(C2/\lambda.T)-1\right]}$$

C1=3.742x $10^8$ W μm$^4$/m$^2$

C2=1.439x $10^4$ μm.K

The response of the thermo graphic camera is the superposition of the spectral response of the black body with the spectral response of its sensor.

Transmission through particles:

Monochromatic transmission through spherical particles can be expressed by the following equation:

Hypothesis:

- Monodisperse distribution (the particles are all the same size).
- the particles are nonabsorbent (ex: water).

Eq.2 $$\tau=e^{-(\pi.N.a^2.Q).X}$$

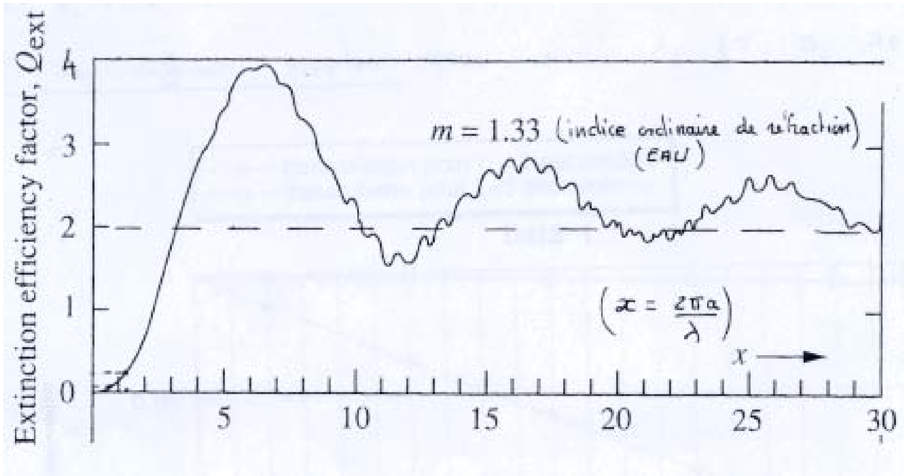
with:

- N number of particles
- a particle rays
- Q effectiveness factor
- X path
- x size indicator

Eq.3 $$x=\frac{2.\pi.a}{\lambda}$$

The effectiveness factor is determined in the graph below.

Fig.3




For particles of this size, transmission is significantly degraded with the wavelength. Attenuation will be increasingly greater as particles are bigger, keeping in mind that particle sizes are from 0.01 to 100µm.

Selection of a technology for the FDVS program:

The choice of a technology is influenced by:

- The environment : On-board 2D sensors, due to the necessity of protecting them from the outside environment (moisture, pressure, temperature), look through a window (the 2D sensor is placed in a heated, pressurized zone or in a wathertight case fitted with a viewing window.

- The precision of measurement at temperature : For measurements of temperatures in range of fire , 2D sensor working in VSW (Very Short Wave 0.4-2.7 µm) spectrum yield more precise results than do traditional infrared cameras. The uncertainty on the emissivity affects results of VSW 2D sensor measurements less.

In addition, given that the emissivity of metallic materials tends to increase as wavelength decreases, this brings yet another advantage to measuring the temperatures of these materials with VSW 2D sensor when they are operating at temperatures greater than 500°C.

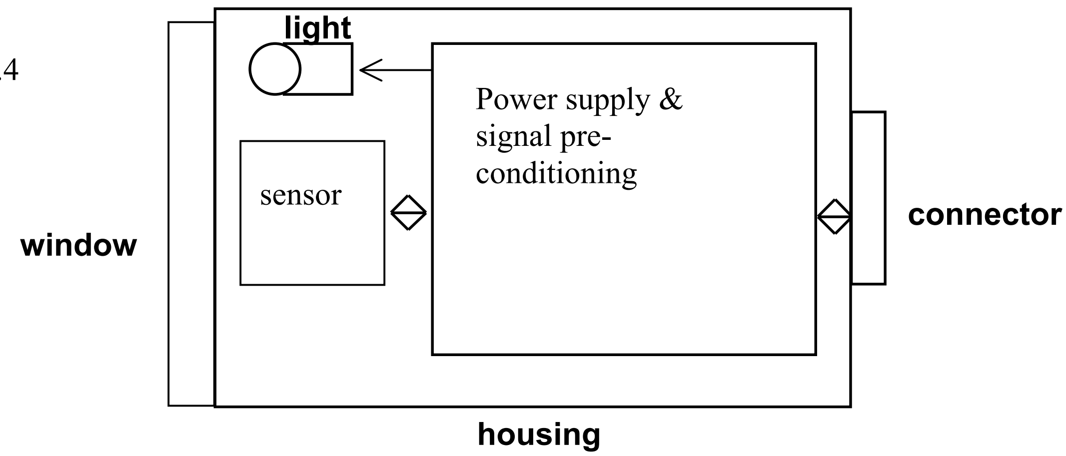
- The transmission (taking the size of smoke or fog particles into account), which is better in the VSW band and which therefore provides a better smoke detection.

- The cost: the cost ratio between the three sub-bands is approximately the following:

VSW= x1, SW=x50, LW=x150

CVSU architecture

Fig.4



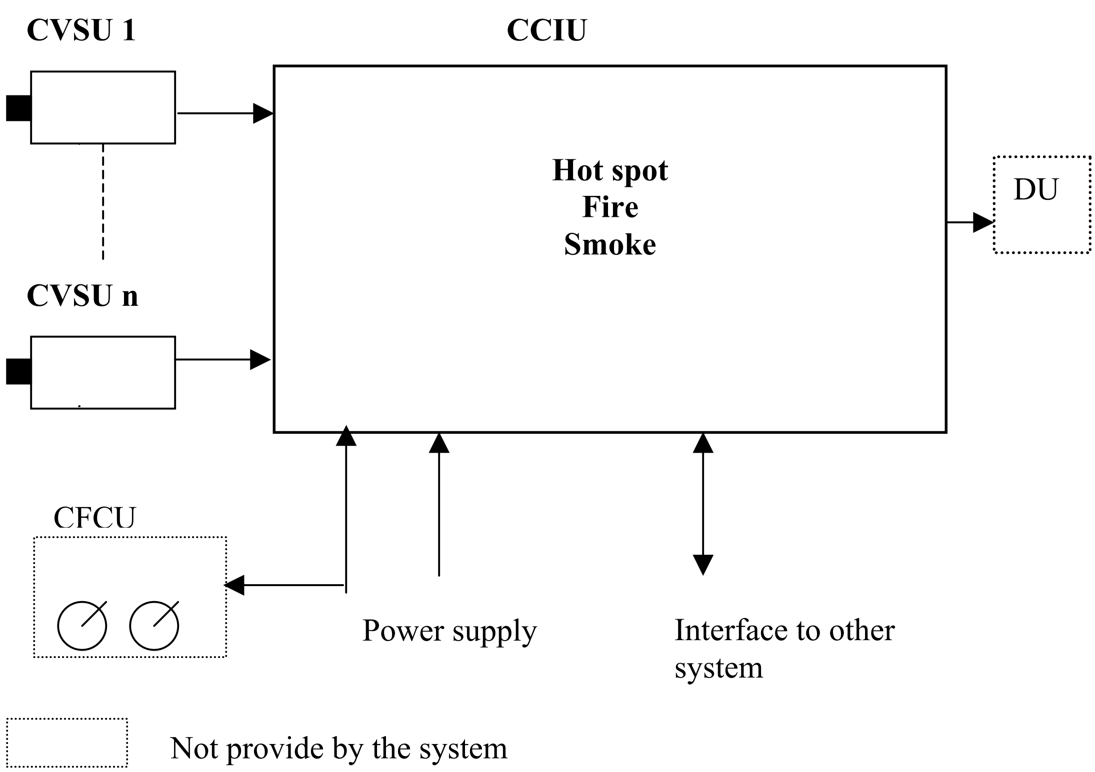
The sensor is composed of :

- 1 two dimensional  sensor and its lens,
- 1 power supply, signal pre-conditioning
- 1 sealed housing with front window & connector

**2- System architecture**

Schematic diagram of the system.

Fig.5




The FDVS system is composed of two different equipment, CVSU& CCIU:

- Cargo Viewer & Sensor Unit (CVSU) is the hot spot, fire & smoke sensor but also provide images for the visualisation in the cockpit. The CVSU makes detection, visualises the cargo (image capture), lights the cargo. The CVSU includes a power supply, a 2D sensor and its signal pre-conditioning, a viewing window. The CVSU has an electrical interface to the CCIU. The CVSU is interfaced to the power supply of the a/c and mechanically with the lining of the cargo compartment & structure.

- Cargo Camera Interface Unit (CCIU) is the computation of the system. It controls and interfaces with sensors and processes all signals delivered from the sensors. It interfaces to other systems: primary fire/smoke detection system, a/c flight warning system, power supply, maintenance system, extinguishing system. The CCIU processes information's (visualisation mode, detection mode), acquires information from sensors, switches the sensors, processes hot spot, smoke & fire information's, realises self control and reporting to maintenance system (BITE), processes warning, exchange data with other systems ( primary smoke/fire system, power supply, maintenance system, ventilation system, flight warning system, extinguishing system).The CCIU realises the Man Machine Interface, controls the image on relevant display unit, controls the lights on its front panel. The CCIU is interfaced to the power supply of the a/c and mechanically to electronic bay.

In case of warning from the primary system the FDVS system provides automatically to the cockpit display, a cargo compartment view including computation information.

- Display Unit (DU) located in the cockpit performances

Maximum time response to hot spot event < 10 s
Maximum time response to smoke event < 10 s
Maximum time response to fire event < 60 s

AIRCRAFT INSTALLATION

An example of the aircraft installation could be:

Fig.6 top view

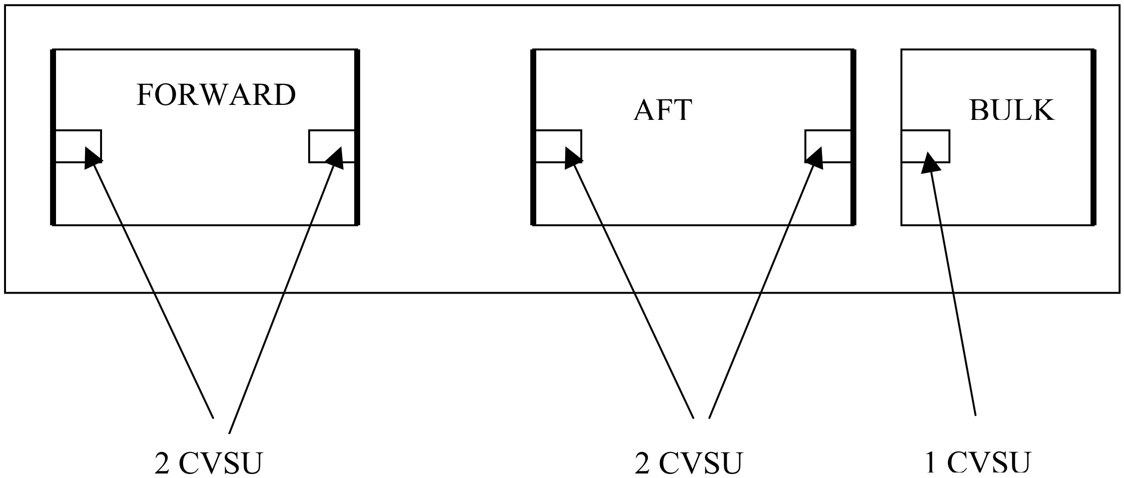
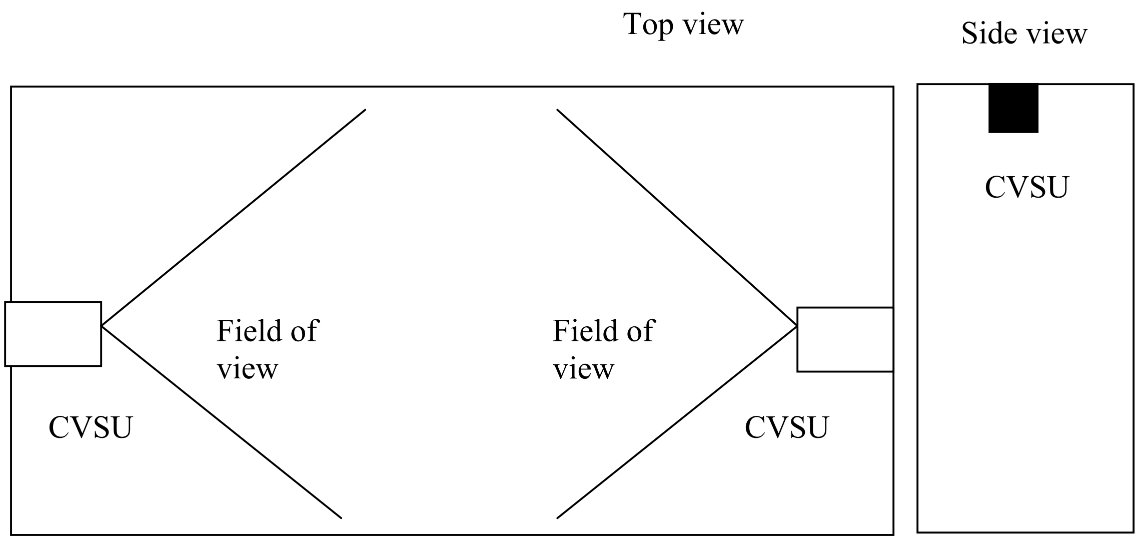



Fig.7

CARGO COMPARTMENT




The position of the cargo compartment visualisation sensors within the cargo compartment is optimised:

- Any phenomenon in the field of view of the two sensors is automatically detected and the detection coverage is 100%,

- Time of detection is always the same and it is very short (no need to reach the sensor).

This configuration allows monitoring phenomenon between containers & between containers and lining (ceiling).

**3- Measurement & detection signal processing**

HOT SPOT Principle:

The principle is that of a thermographic camera and not that of a simple pyrometer. The camera provides a heat image associated to a temperature scale, and the result obtained yields a thermogram.

Hot spot detection is based on analysis of the hot spot's luminance (energy) in the dark.

FIRE Principle:

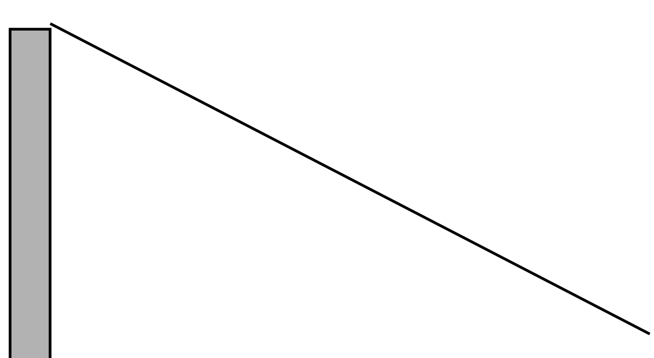
Fire detection is based on analysis of the fluctuation of the flame (energy, frequency) in the dark

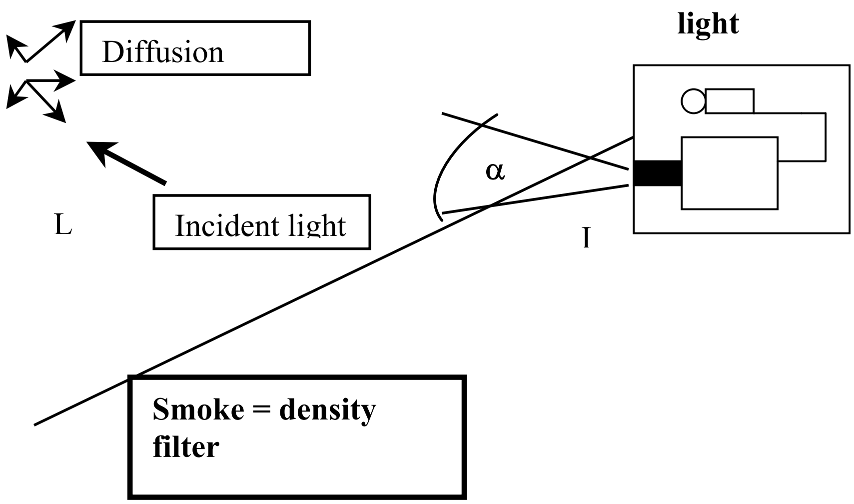
SMOKE Principle:

Smoke detection is based on reflection-transmission of a reflecting body.

The principle is the following:

Fig.8






The relation of the transmission is the following:

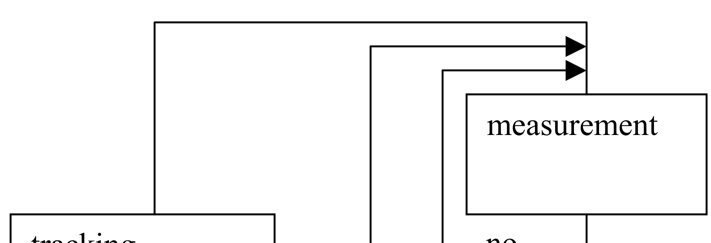
Eq.3 $\xi = \frac{I}{I0} = 10^{-Attx/10}$

I0 reference signal (no smoke)

I signal received

Detection & tracking principle:

Fig.9



**4- Lab test**

The fire detection & visualisation system is able to recognize the fire tests TF1 through TF6 following EN 54 part 9.
Interferences like sun, rising sun, sun with chopper, do not affect (no warning) the fire detection & visualisation system.
These tests are successful in :
- a certified EN54 test chamber.
- a downscaled cargo compartment volume in an empty cargo compartment.
- a downscaled cargo compartment volume in a partially loaded cargo compartment.
- a full scale cargo compartment fully loaded.

Fog or condensation interferences do not produce a warning.
Environmental not correlated with a real fire conditions has no effect on processed images.

Other trial

One trial was made on AIRBUS A330 a/c with 120g FAA powder and full cargo compartment loaded: FDVS sensor detection time was 5s and optical smoke did not detect. The test was stopped after 15mn.
Trials were made on AIRBUS A330 a/c with 240g FAA powder and full cargo compartment loaded: FDVS sensor detection time was 3s and optical smoke detector time was 2mn & 5s.

Trial were made on AIRBUS A300/600ST to monitor the upper and lower cargo compartment in un-pressurised conditions.

Environment tests

Trial will be made in 2001 to mix temperature variation & pressure variation with a real fire to make sure that technology has the same potential on real environment.