Optical Fire Detection for Engine Nacelle and Auxiliary Power Units

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Kidde Aerospace & Defense
A Hamilton Sundstrand Company

The Companies of Kidde Aerospace & Defense

Kidde Aerospace & Fenwal Safety Systems

Wilson, NC USA
Fire/Overheat/Smoke/Optical Detection, Controls
Extinguishing, System Integration & Service

Kidde Dual Spectrum

Goleta, CA USA
Vehicle Protection, Service

Kidde Graviner Ltd

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Fire Detection, Oxygen, Vehicle Protection, Service

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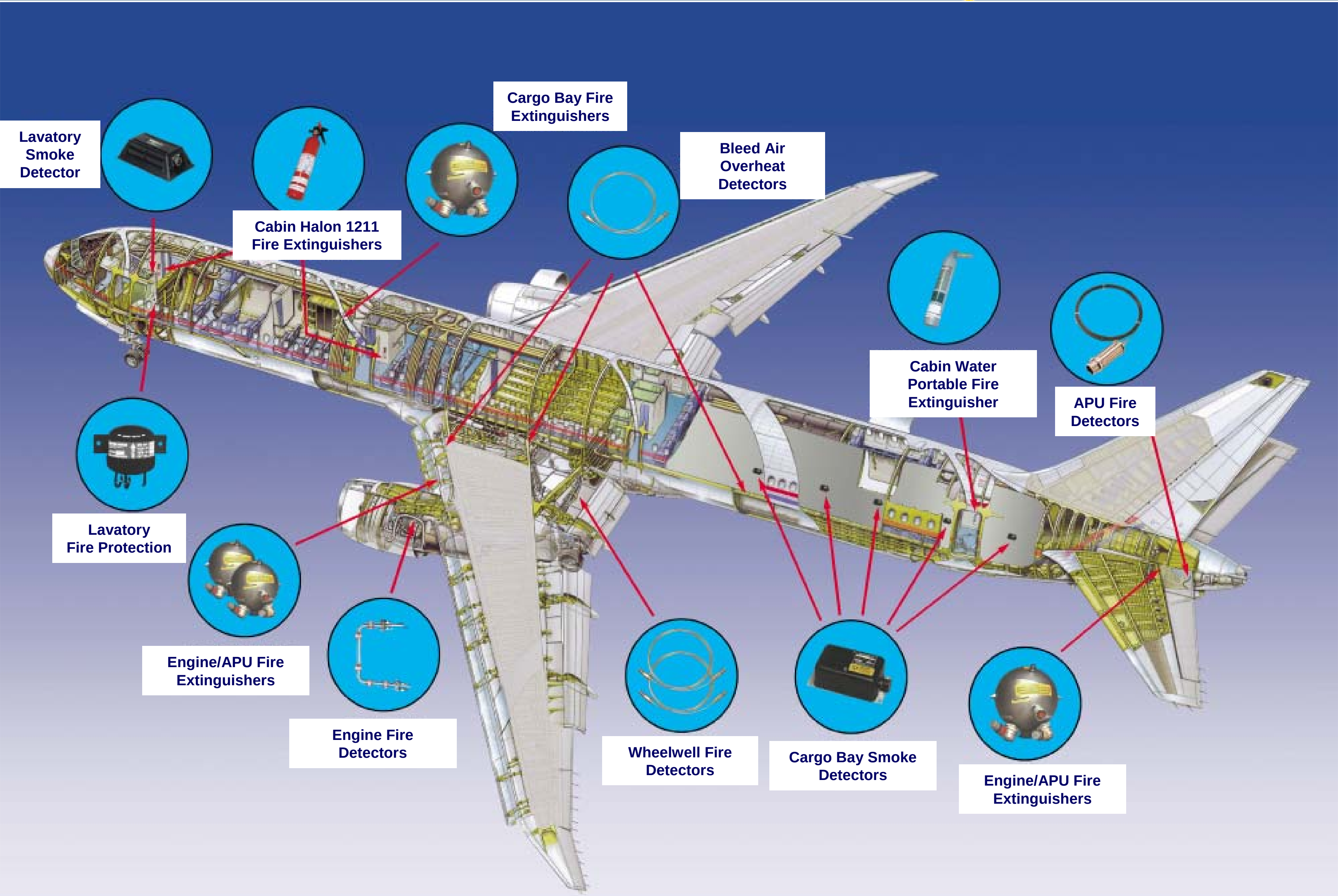


Summary

- All Commercial Aircraft Types Require Engine / APU Fire Detection
  - Exception: some general aviation that do not carry revenue generating passengers
- History
  - Continuous Element (Predominant)
  - Thermal Switches
  - Optical (High end, Military)
- Increasing Interest in Faster Recognition of Damage Causing Fires
  - Composites
    - Hard to Extinguish
  - Stealth
  - Maintainability
    - Light Weight
    - Larger Coverage With Less
    - Cost
  - Response Time

Optical vs. Thermal

- Thermal
  - Response Requirements
    - 5 sec. to 2000°F flame
  - Benefits
    - Overheat detection
    - Contamination not an issue
  - Limitations
    - Convective heat transfer
    - Little false alarm immunity
    - Hard to remove / maintain
    - Explosions too fast
- Optical
  - Response Requirements
    - <<5 sec. Depending on the event
  - Benefits
    - Weight reduction / FOV
    - Cost
    - Maintainability
    - Response time
      - Explosion detection
  - Limitations
    - Overheat detection
    - Contamination

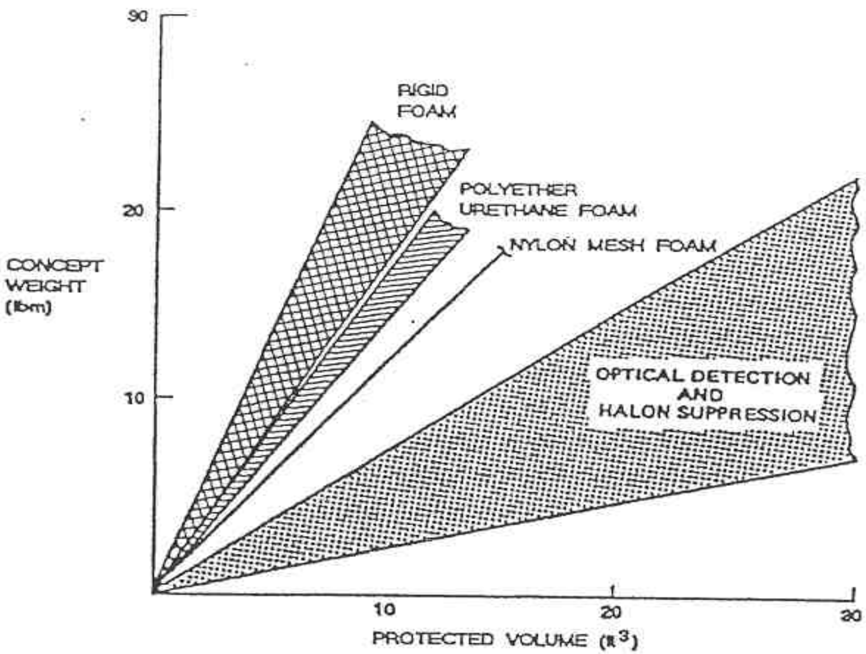
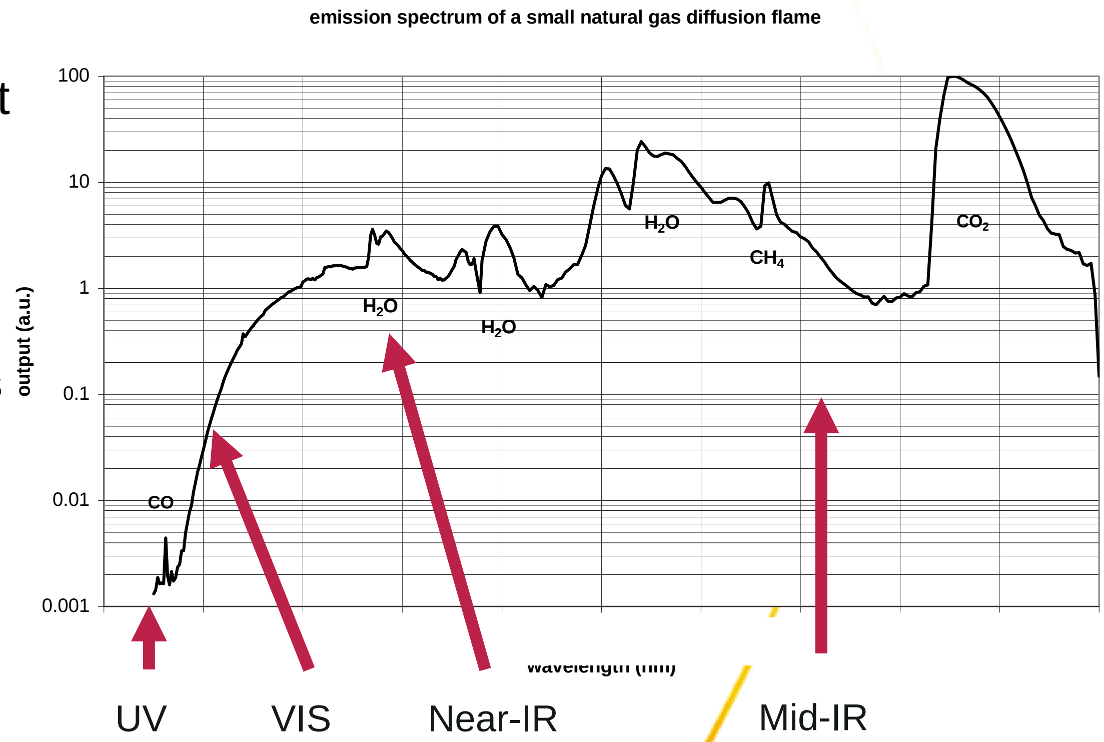


Figure 5. Protection System Weight Comparisons

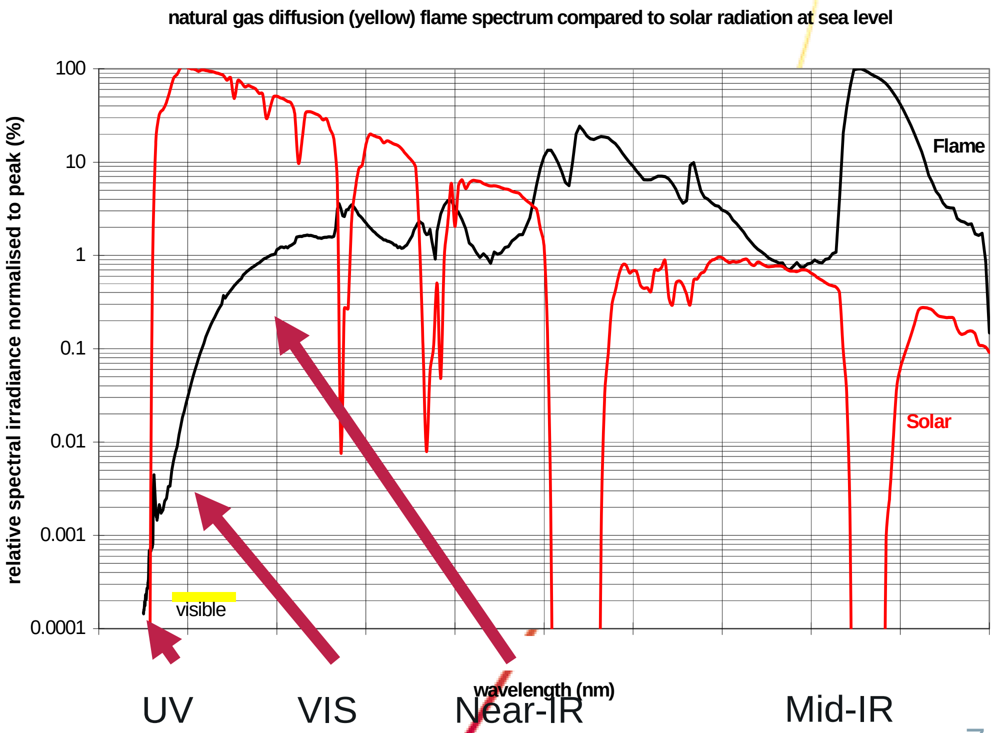
Optical Fire Detection – Flame Characteristics

- Flame Radiation
  - Black body radiation
    - Related to flame temperature and amount of particulate matter
  - Discrete emissions
    - UV
      - Electronic transitions from atoms, molecules and free radicals
    - IR
      - Rotational/vibrational transitions from combustion products (CO_2/H_20)



Optical Fire Detection – False Alarm Sources

- Other radiation sources
  - Difficulty with optical flame sensing is not detecting fire but avoiding false alarms
  - False alarm sources include solar radiation, fluorescent lights, incandescent lights
  - Select flame sensing wavelength based on intensity of signal from flame *and* discrimination against false alarm sources
    - Mid-IR; strong flame emission, weak solar and light sources
    - < 400nm; flame emission present, non-flame sources are very weak in this region



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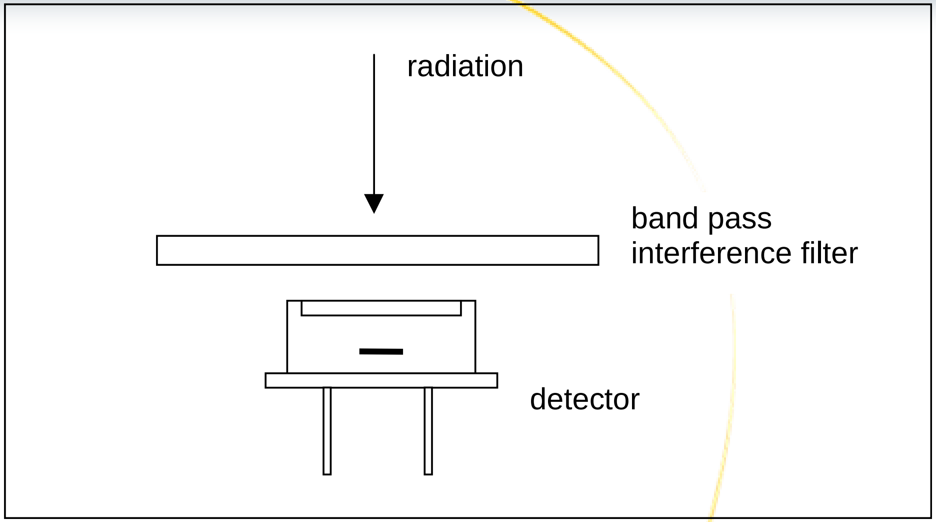
Infrared Optical Fire Detectors – Background

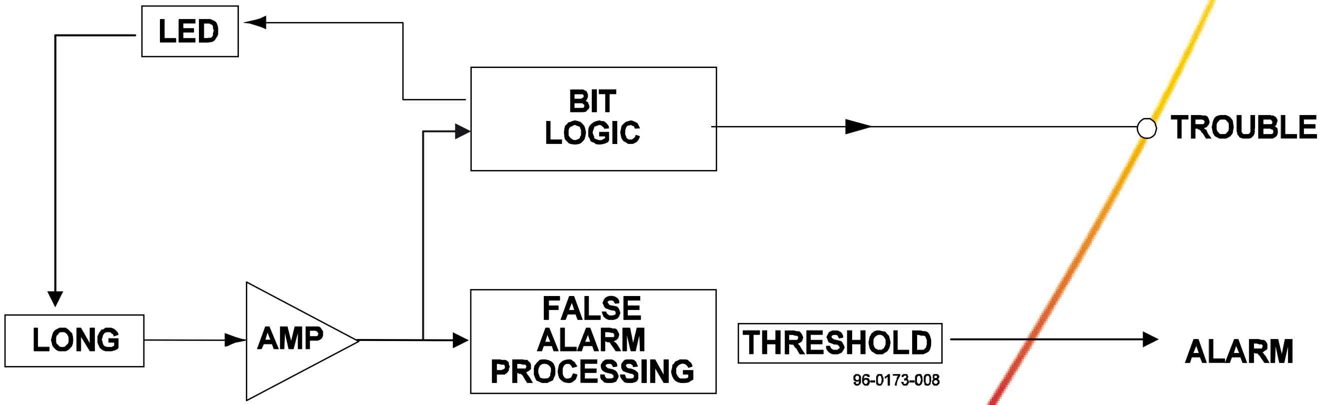
- With the development of relatively cheap detectors and interference filters for the middle infrared, infrared flame detection has become common
- These detectors can also be made solar blind
- They are routinely used both in accidental flame detection and in combustion control systems
- They can operate at temperatures up to 125ºC or higher

Infrared Optical Fire Detectors – Single IR Sensors

Detector options

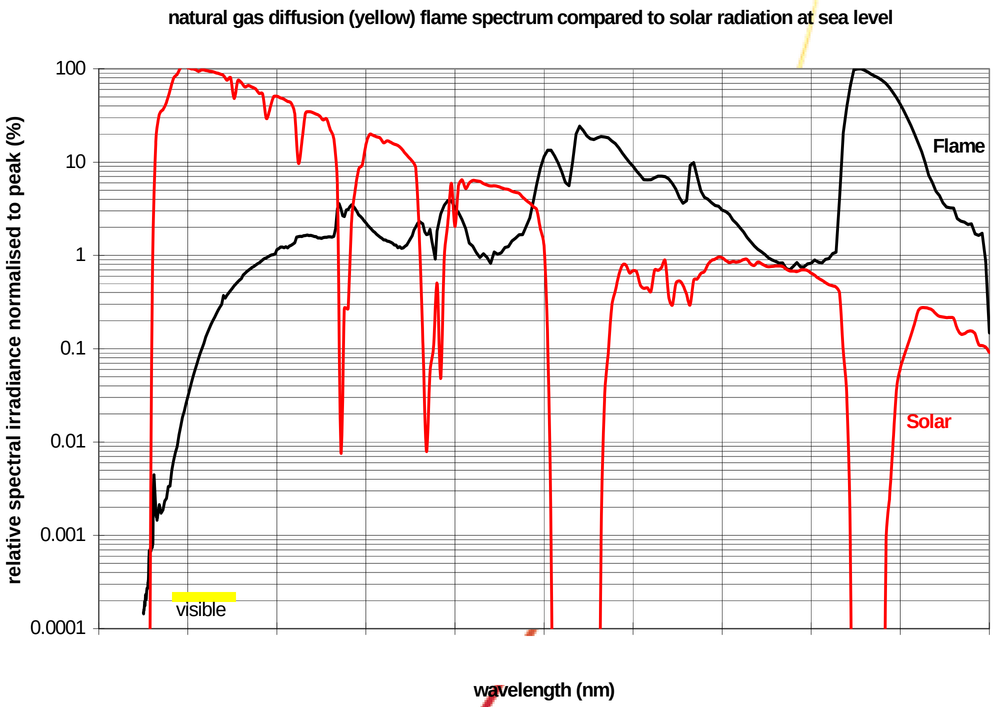
- Thermal detectors, wide wavelength response
  - good for monitoring rate of change for IR radiation
- Semiconductor detectors, selective wavelength response
more temperature sensitive
  - photoconductors, e.g. PbS, PbSe
  - photodiodes e.g. InAs





Infrared Optical Fire Detectors – Theory of Operation

- Flames output radiation in the Mid-IR but hot body radiation may cause false alarm at short range
  - Additional wavelengths (Near IR or UV) selected to provide immunity
- Thermopile plus filter detects at Mid-IR
- Photodiode detects at Near IR
- Flame recognition algorithm which ensures flame flicker detected and minimises the impact of steady state background signals



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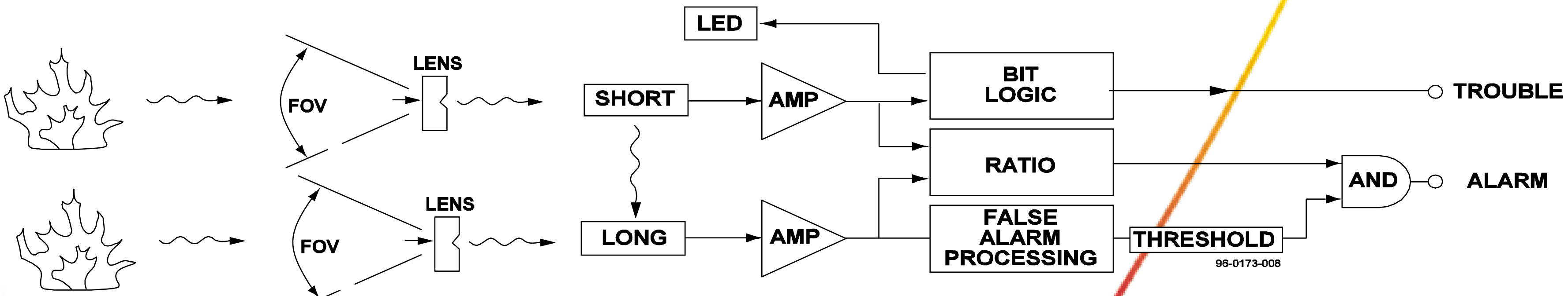
Infrared Optical Fire Detectors – Dual IR Sensors

- Detector "sees" fire (does not need to be placed in the fire)
  - Field of view -120° solid cone
  - Response time
    - Explosive event
      - < 5ms response
    - Pool / Spray fire event
      - 2-5 s
      - Detection requires flame flicker

- False alarm immunity
  - Improved performance through optical filtering recognises peak emissions from hydrocarbon flames
  - "ANDING" technology used to optimise detection performance

- Built in Test provides indication of contamination



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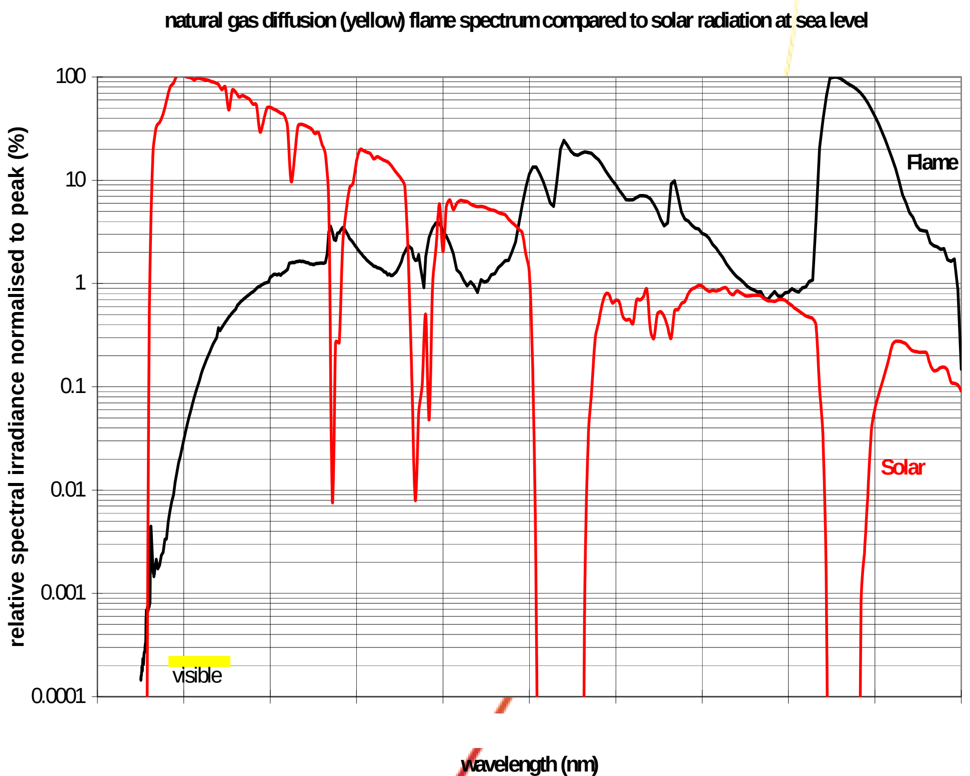
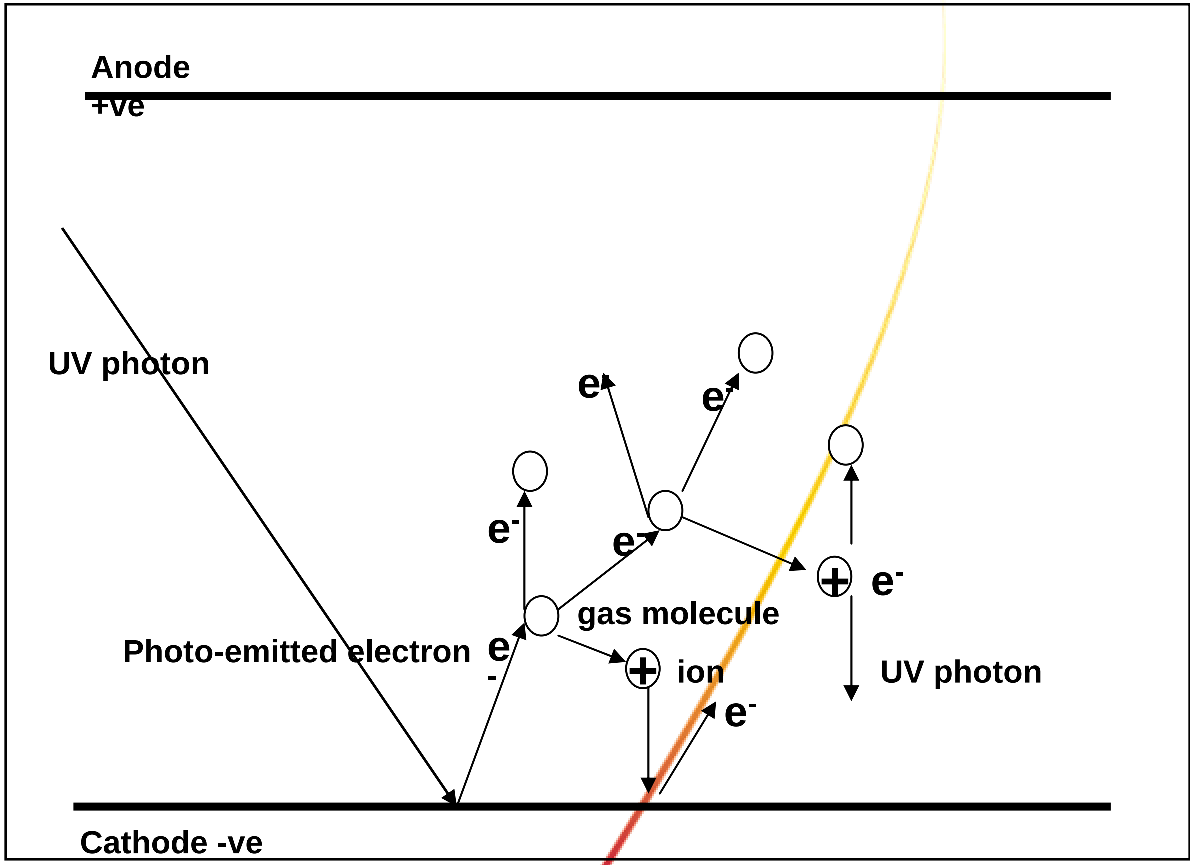
Ultraviolet Optical Fire Detectors – Background

- The first flame detectors operated in the visible and near infrared regions of the electromagnetic spectrum but suffered from frequent false alarms
- Solar blind ultraviolet detectors were developed in the 1960s
- They are routinely used both in accidental flame detection and in combustion control systems
- They can operate at temperatures up to 200ºC or higher



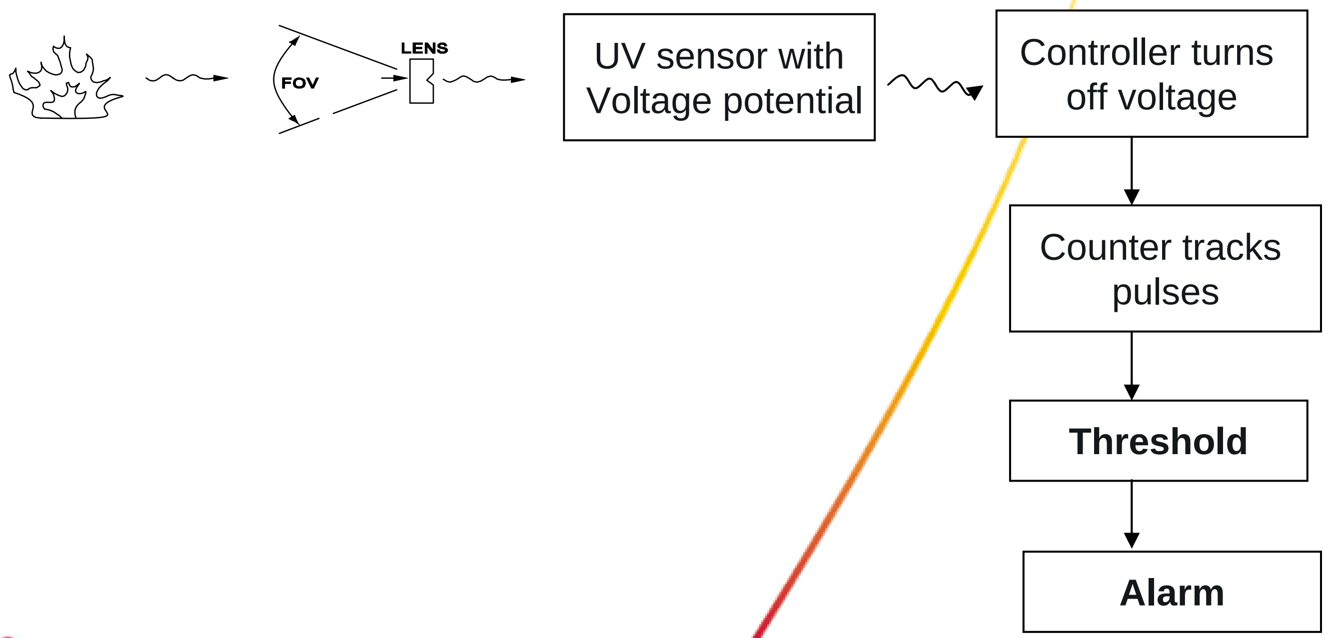
Ultraviolet Optical Fire Detectors – Theory of Operation

- UV radiation causes UV sensor to conduct by emission of electrons from cathode
- High voltage field between cathode & anode causes the avalanche effect
- UV tube continues to conduct while voltage is applied
- Counts registered by the control unit; voltage is removed to allow the tube to de-ionise



Ultraviolet Optical Fire Detectors – Sensor

- Photocell is also sensitive to high energy cosmic radiation, background count exists; background count employed for BIT
- Count rate in presence of a flame > 40/s
- When any tube channel senses a count in a set time frame, a fire signal is communicated (current system logic)

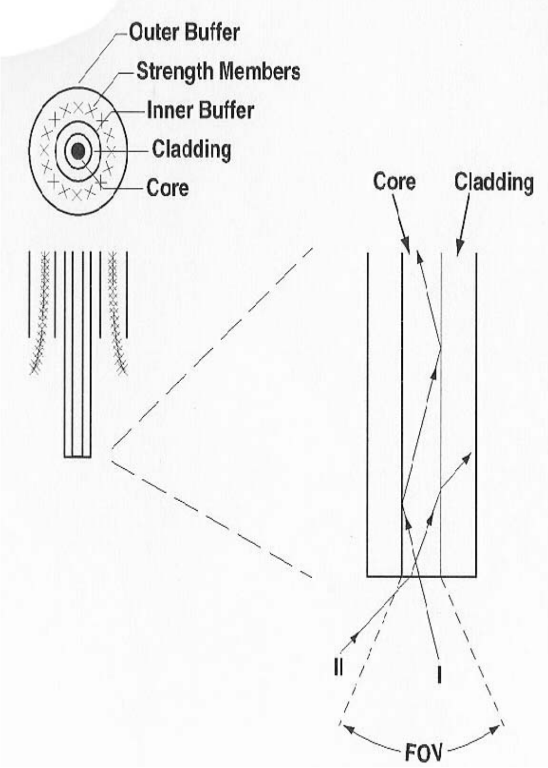


Fiber Optics Fire Detectors - Background

- Smallest: Each detection point requires less volume
- Lightest: Each detection point weighs less
- Highest Reliability: Removes electronics from severe, high-temperature areas. Fiber Optics has ~4X MTBF as electronics in same environment.
- High Operating Temperature 250 – 1000ºC
- Optical Performance (fire response, false-alarm immunity) is competitive
- Economical: Fewer points may be required, comparable or lower cost per point

Fiber Optics Fire Detectors - Background

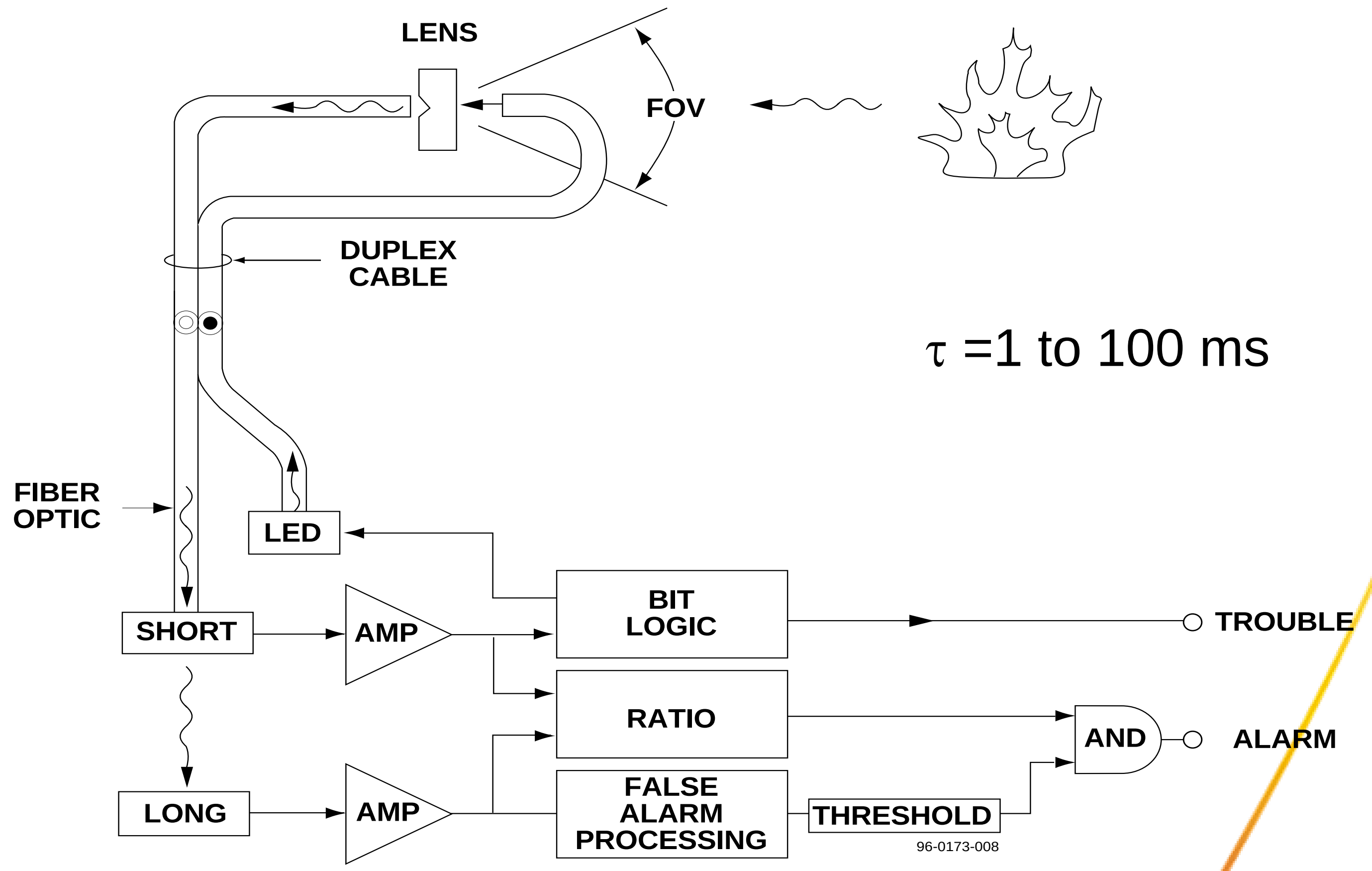
- The Fire Sensors described here are Fiber-Optically coupled:
  - A fiber-optically coupled flame detector senses radiation transmitted by an optical fiber.
  - The fiber optic acts as a light conduit via total internal reflection



The detector senses flame radiation that is transmitted by the fiber optic core/cladding

I. Light inside the FOV angle is totally internally reflected by the fiber optic yielding a sensor signal.
II. Light outside the FOV angle leaks from the core and yields little or no sensor signal.

Fiber Optics Fire Sensors – Current Technology



τ =1 to 100 ms

Optical Detection Not The Standard

- Obstacles
  - Overheat coverage
  - Certification
    - Fire hardening (1000ºC)
    - FAA
  - Fear of the unknown
    - Radiation emitting background (false alarms)
    - Temperature profile (unknown engine temps)
    - EMI
    - Vibration environment