Methods for Characterizing Theatrical and Real Smoke in Varying Ambient Environments for Inflight Certification of Aircraft Cargo Compartment Smoke Detection Systems

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Federal Aviation Administration (FAA) regulations require that a commercial aircraft cargo compartment smoke detection system must provide visual indication to the flight crew within one minute after the start of a fire[1]. Further FAA guidance states that the smoke detection certification test is designed to demonstrate that the smoke detection system will detect a smoldering fire that produces a small amount of smoke[2]. In an attempt to eliminate the frequency of false alarms, the FAA issued a Technical Standard Order[3] to adopt the Minimum Performance Standards of smoke detector equipment, which includes criteria for resisting alarms from nuisance sources such as water vapor, insecticide aerosols, dust and light.

False alarm resistant smoke detectors must pass the inflight smoke detection certification test in order to be implemented in aircraft. Due to health and safety concerns – artificial smoke generators are used for inflight certification testing. Aerosols created by artificial smoke generators must be similar to smoke in order for the false alarm resistant smoke detectors to alarm. Therefore, verifying which artificial smoke generators produce an aerosol with similar particle characteristics to smoke is essential for the implementation of false alarm resistant detectors in aircraft. Furthermore, standardizing the artificial smoke generators for the total quantity of aerosol production, rate of aerosol production and repeatability of aerosol production is necessary to ensure the reliability and integrity of the inflight smoke detection certification test.

In this study, methods for characterizing theatrical smoke for inflight certification of cargo compartment smoke detection systems are considered. Theatrical smoke generators use an inert gas to propel mineral oil into a heat exchanger, where the solution is vaporized and a fog similar in appearance to smoke is created. The theatrical smoke exits through a chimney incorporated with heaters to create a thermally-buoyant plume. Smoke from flaming and smoldering fires is compared to theatrical smoke by measuring light obscuration, response of scattered blue (470 nm) and an infrared (850 nm) electromagnetic radiation, temperature, and velocity. Based on the measurements of these parameters, artificial smoke generators are found to be capable of producing an inert and safe fog similar in character to various smoldering and flaming smoke sources. Key components of theatrical smoke production are found to be light obscuration, particle size and plume velocity. Light obscuration measurements in a known volume are used to quantify the total amount produced and the rate of production. Mie Scattering Theory governs light scattering by sub-micron particles where scattering intensity is a function of the wavelength of the incident light, refractive index and radius of the particle. In theory, the smoke particle size can be determined by measuring the scattering intensity from known multi-wavelength light sources. The theory is verified by comparing simultaneous

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[1] Title 14 Code of Federal Regulations (CFR) Part 25.858, 2/10/1998
[2] Federal Aviation Administration Advisory Circular 25-9A
[3] TSO C1e, 8/19/2014

measurements of multi-wavelength light scattering intensities and a scanning mobility particle sizer (SMPS). Plume velocity is shown to be a strong determining parameter of smoke transport and detection time. The plume velocity is measured by funneling the theatrical smoke generator chimney into a vane anemometer.

Varying ambient conditions are evaluated to determine the effect on the characteristics of theatrical smoke. During inflight certification testing, the cargo compartment temperature can range from 10-30°C and the pressure can range from 101kPa, while on the ground, to 69.7kPa while inflight. Testing shows that ambient temperature is positively correlated to smoke obscuration, particle size and particle concentration and is negatively correlated with plume velocity, while ambient pressure is negatively correlated to particle size, particle concentration and plume velocity.