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L-1011

JET TRANSPORT

CABIN FIRE SUPPRESSANT SYSTEM STUDY

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SUMMARY

This study presents an analytical comparison of design approaches to incorporate an integral airborne cabin fire-suppressant system into the Lockheed L-1011 commercial transport airplane. The purpose of this study is to determine feasibility, establish weight penalties, and evaluate the actual requirements for incorporating such a system in response to customer request.

Two independent systems were evaluated:

(1) Self-contained modular unit, total flooding type fire suppressant system.

(2) Ground-supplied, central-distribution system.

Both systems are based on the dispensing of Freon as the fire suppressant agent, from overhead dispersal type heads that are uniformly distributed throughout the passenger cabin and associated critical compartments.

Neither a modular nor a centralized system, of the size and complexity required for the L-1011, has been operationally developed to date. Variable contingencies involved in the dynamic control of cabin air-flow versus agent concentrations maintained within human acceptable tolerances clearly indicates that continued research must be pursued to validate the performance of an acceptable system applicable to airplane fire conditions.

It is recommended that an independent, readily installed/removable, fire protection [illegible] developed to provide airplane protection during manufacture, maintenance, overhaul, and [illegible]. This type system [illegible] limited [illegible] the airplane and provides installation [illegible] parts).

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CABIN FIRE SUPPRESSANT SYSTEM STUDY

The objective of this study is to establish the practicability and estimate weight of different concepts of fire suppressant systems acceptable for incorporation into the L-1011 airplane. Basic system requirements will be defined and system design criteria will be established. Candidate system configurations will be described and their relative merits will be compared.

TRADE-OFF CONSIDERATIONS

FAVORABLE

- Supplements survivable crashworthiness
- Provides continuous ground and unattended airplane protection

UNFAVORABLE

- Adds additional initial weight and cost to basic airplane
- Requires use of special ground support equipment (Freon supply-charging cart)

LIMITATIONS

- Human tolerances to concentrations of Freon have not been firmly established to warrant its absolute acceptance as an effective cabin fire extinguishing agent.

SYSTEM REQUIREMENTS

BASIC PARAMETERS

- System design predicates improving survivable crashworthiness conditions and provide ground maintenance and unattended airplane protection.

- Dispersed suppressant agent must effectively suppress a confined fire within a pre-determined volume (airplane compartment) for a duration of 5 minutes with all openings (doors and window exits) open, with no wind.
- Dispersed suppressant agent shall not produce detrimental effect on emergency evacuation of occupants.
- Detection and activation of the fire suppressant system shall be automatic and discharge the suppressant agent upon sensor activation in one continuous uninterrupted operation.

DESIGN CRITERIA

- Suppressant agent shall be liquified, pressurized Freon.
- Suppressant system(s) shall form one composite integral network.
- Overhead dispersal heads shall be installed in a compartment in numbers, and at intervals, determined by the total cube of the volume to be protected, and its shape.
- Dispersal design shall be dictated by the character of the area protected (i.e., the shape and size of the area, obstructions, bulkheads, doorways, etc.)
- Present design data indicates that to maintain acceptable human tolerances, concentrations of Freon shall not exceed 5 percent by volume within the volume to be protected.
- In any one compartment, all installed dispersal heads shall be connected in series so that the actuation of one results in the actuation of all.
- Automatic activation of the system; capable of manual activation.

DESCRIPTION AND DISCUSSION OF CANDIDATE SYSTEM CONFIGURATIONS

Two different independent fire suppressant system configurations are considered f potential application to the L-1011 airplane. A self-contained modular system is considered to provide the most effective protection for crew and passengers for in-flight and crashworthiness conditions. A ground-supplied, central-distribution type system is considered more effective to provide fire protection during periods of ground maintenance and unattended airplane status. In both systems, the agent shall be discharged in an extremely short period of time in one continuous uninterrupted operation and concentrations shall be automatically generated, within acceptable personnel limits. Neither system is designed to extinguish large onboard fires, such as those occurring after a crash, but to maintain a suitable situation within a given space, for a measurable period of time, which is sufficient to permit corrective action, i.e., survivable ground crash-evacuations; in-flight-initiate emergency operation procedures.

It is proposed that the self-contained fire suppressant system (Figure No. 1) utilize independent modules, similar to Fenwal, Inc. design (Figure No. 1, View A). This 30 pound module is completely self-contained and includes: suppressant agent storage container (400 psia); sensor(s) (thermal and products of combustion); actuator; dispersal head; trickle charged battery power-pack and detonator. The module is charged with 20 pounds of liquid Freon, which is sufficient to achieve a 5 percent volume of 1,000 cu. ft.

Based on the Fenwal 30 pound module, the airplane passenger compartment requires 15 modules installed along the overhead centerline at approximately 8-foot intervals (Figure No. 1). In associated compartments; i.e., flight compartment (330 cu. ft.): forward electronic compartment (654 cu. ft.); air conditioning bay (464 cu. ft.); lavatories forward and aft (581 cu. ft.); underfloor kitchen (1717 cu. ft.); electrical load compartment (273 cu. ft.) and hydraulic center (210 cu. ft.) combinations of the passenger compartment module and/or modules of smaller Freon capacity will fulfill the requirements.

Automatic actuation of the system is accomplished by use of sensors that shall be strategically located throughtout the airplane and wired directly to the module detonators. Provisions for manual system actuation shall be incorporated and monitored in the flight compartment. The thermal sensors shall be rated to initiate system activation at 190° - 200° F temperatures.

The ground supplied fire suppressant system proposed (Figure No. 2) disperses suppressant agent from a "plugged-in" external supply source (ground service cart).

Overhead dispersal heads, connected to the supply source through a central network of aluminum tubing, and sensors are located throughout the airplane, in much the same manner, as outlined for the self-contained system. The tubing is adequate to withstand the initial surge of the rapid discharge and must be sized to promote high volume, even flow. To maintain equal pressure gradients throughout the discharge system, the I.D. of the tubing must be reduced on a scale determined by the distance from the source of Freon. This will provide an even distribution of the agent to various areas of the same compartment, or to the several compartments serviced by the distribution system.

This system may be adapted into multi-complexes, as shown on Figure No. 2 or combined into one common supplied system. To convert the system to an airborne application requires the airplane installation of a central agent supply source for each of the two complexes.

Based on the airplane volume of approximately 19,000 cu. ft. and the requirement of 20 pounds of Freon per 1,000 cu. ft. of volume, it is established that 380 pounds (20 x 19) of liquid Freon is required to achieve the desired concentration of 5 percent for a discharge rate of 2 seconds or less. Therefore, each system complex requires 190 pounds of agent to be stored in a cylinder that weighs approximately 140 pounds for a total airplane weight of 660 pounds (i.e., 2(140 + 190) = 660).

If additional requirements for ground fire protection are generated by a particular set of circumstances, the existing integral systems (self-contained or ground-supplied) can be supplemented with completely self-contained portable modules (Figure No. 3). A Fenwal portable module, in this category, weighs approximately 65 pounds and contains 30 pounds of liquid Freon. Installation consists of placing the module in the desired position on the floor and extending its built-in telescoping sensor and dispersal head up to the overhead.

FIRE SUPPRESSANT AGENT ANALYSIS (FREON, TYPE 1301)

Freon (FE 1301) is a liquified compressed gas which boils at -76°, and has a vapor pressure of approximately 213 psia at standard room temperature (70° F). Chemically, it is bromotrifluoromethane ($CBrF_3$). Freon 1301 is considered to be a highly effective fire extinguishing agent for Class A fires (wood, paper, textile) where quenching extinguishing is required, Class B fires (flammable liquids) where smothering extinguishing is required, and Class C fires (electrical) where non-conductive extinguishing is required. Tests indicate that as an extinguishing agent, it is significantly more effective than other chemicals now in use. Lockheed has successfully used this agent in engine and other unoccupied compartments on aircraft since 1953.

One of Freon's most outstanding qualities as an extinguishing agent is its low toxicity. In a letter to Haskell Laboratory for Toxicology (du Pont Co.), dated 22 September 1967, the National Research Council, National Academy of Sciences, reported:

> "Personnel can be exposed without significant hazard for a maximum of 5 minutes to normal air at 1 atmosphere admixed with up to 6 percent concentration by volume of bromotrifluoromethane as a fire extinguishing agent. This assumes appropriate engineering design to sense the fire and to deliver the agent so as to extinguish the fire promptly in order that the pyrolysis products are minimized."

Tests by du Pont (Report No. S-35, "Human Exposure to Freon 1301") indicates that "exposure to a concentration exceeding 7 percent for extended periods, greater than 5 minutes, could produce toxicities that might result in impaired bodily functions." When Freon comes in contact with fire and burns, highly toxic hydrofluoric acid is formed. To reduce, or eliminate, formation of pyrolosis agents, the sensors are quick to respond to small fires and rapid discharge (2 seconds or less) of the agent retards rapid fire growth. Effective concentrations of Freon (3 to 5 percent) within a confined area (compartment), have proven to not create hazardous effects on occupants, in relation to breathing and visual acuity, that would interfere with their evacuation from the compartment. Continued research is being conducted to fully verify human compatibility and the toxicity effects of Freon.

The chemical stability of Freon makes it satisfactory for use with practically all metallic, plastic or elastromeric materials presently used in fire extinguishing systems. It is believed that Freon extinguishes fire by chemical action. The halogen compound (Freon) reacts with the combustion products thereby terminating the chain reaction involved in combustion.

WEIGHT ANALYSIS (ESTIMATED)

Airplane Self-Contained System:

	POUNDS	
Liquid Freon (19,000 cu. ft.)	380	
Modules* (50 percent Weight of Freon)	190	
Wiring (310 ft. - #16)	5	
Airplane Total	575	Pounds

* Value obtained from Fenwal Stds.

Airplane Ground Supplied Central-Distribution System:

Dispersal Heads (32 @ 0.5 pounds each)	16.	
Thermal Sensors (32 @ 0.2 pounds each)	6.5	
Smoke Sensors (18 @ 1.0 pounds each)	18.	
Smoke Sensor Amplifiers (3 @ 0.75 pounds)	2.25	
Al. Tubing (380' @ 0.074 pounds per foot)	28.	
Wiring (616' @ 0.013 pounds per foot)	8.	
Miscellaneous Plumbing	8.	
Airplane Total	86.75	Pounds
Storage Cylinders (2 @ 140 pounds each)	280	
Liquid Freon (@ 190 pounds ea/cyl)	380	
Ground Sys. Total	660	Pounds

CONCLUSIONS AND RECOMMENDATIONS

Comparison studies of the fire suppressant system for airplanes the size of the L-1011 indicate that the self-contained modular Freon fire suppressant system as represented by Figure No. 1 provides the best overall independent integral installation. This system provides both airborne and on-the-ground protection, and represents the most efficient system in regards to: maintenance, reliability, adaptability, and flexibility. The self-contained system does present a sizable weight penalty or initial cost compared to the centralized system. The fire suppressant effectiveness of both systems is considered to be equal, as is the recharging and accidental discharge factors.

Since this is an analytical feasibility study, it is recommended that additional research and application testing be conducted before Freon 1301 can be warranted for use as a cabin fire-suppressant agent. Also, the reliability of fire detection and initiation must be improved upon to preclude the possibility of inadvertent system discharge during normal flight conditions.

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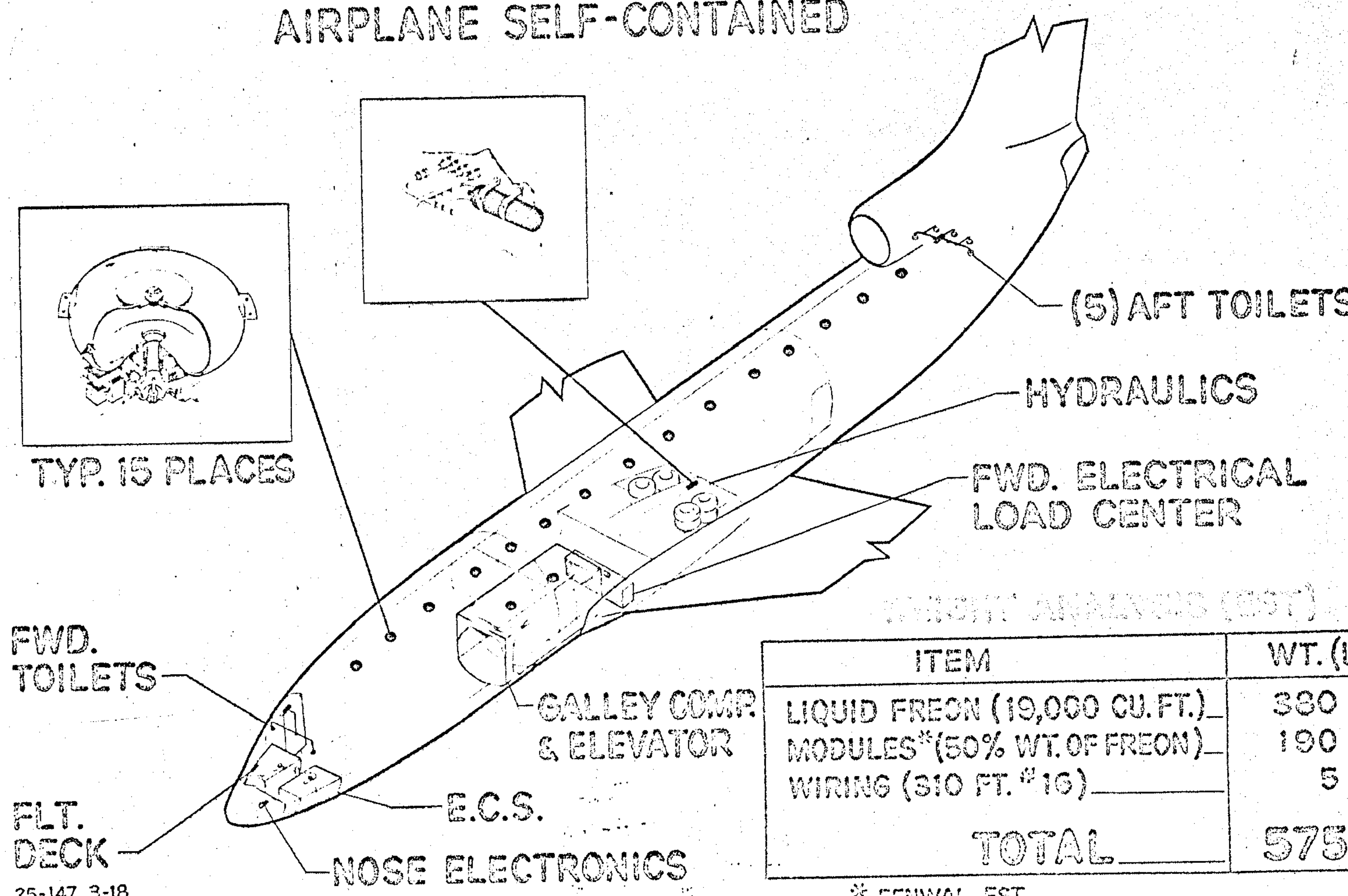
L-1011 FIRE SUPPRESSION SYSTEM

JET TRANSPORT

AIRPLANE SELF-CONTAINED



WEIGHT ANALYSIS (EST.)

ITEM	WT. (LBS.)
LIQUID FREON (19,000 CU. FT.)	380
MODULES* (50% WT. OF FREON)	190
WIRING (310 FT. #16)	5
TOTAL	575 LBS.

* FENWAL EST.

FIGURE 1. FIRE SUPPRESSION SYSTEM - AIRPLANE SELF-CONTAINED

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L-1011 FIRE SUPPRESSION SYSTEM

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GROUND SUPPLIED SUPPRESSANT

WEIGHT ANALYSIS (EST.)

AIRPLANE SYSTEM

QTY.	ITEM	WT. (LBS.)
32	DIFFUSER HEADS	16
32	THERMAL DETECT.	6.5
18	SMOKE DETECT.	18
3	SMOKE DETECTOR AMPLIFIER	2.25
380 FT.	TUBING	28
616 FT.	WIRING	8
	MISC. PLUMBING	8
	AIRPLANE TOTAL	86.75

GROUND SYSTEM

QTY.	ITEM	WT. (LBS.)
2	CYLINDERS + CART	280
	LIQUID FREON	380
	GROUND SYS. TOTAL	660

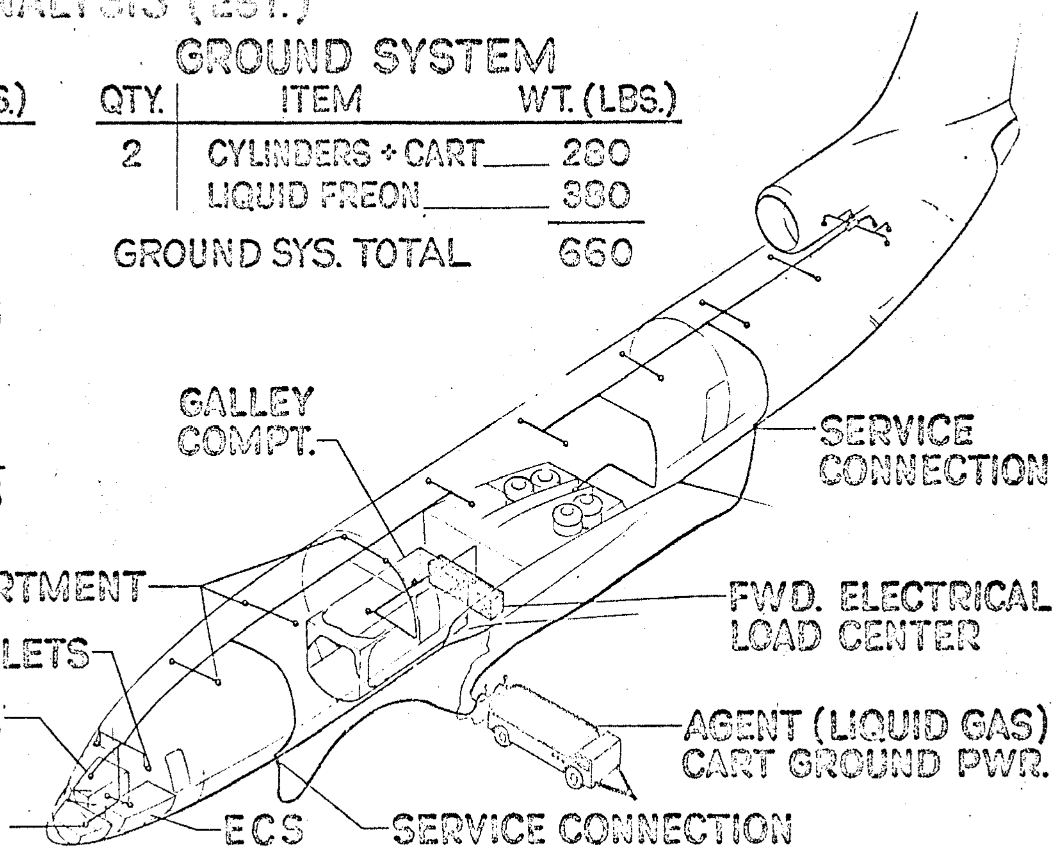

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FIGURE 2. FIRE SUPPRESSION SYSTEM - GROUND SUPPLIED SUPPRESSANT