NFPA PRESENTATION OF 16 MAY 1972

ON-BOARD CABIN PROTECTION SYSTEMS

by

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AT THE OUTSET I WISH TO EXPRESS MY GRATITUDE FOR BEING INVITED TO ADDRESS THIS AVIATION SEMINAR AT THE NATIONAL FIRE PROTECTION ASSOCIATION'S 76TH ANNUAL MEETING.

INTRODUCTION

THE AVIATION INDUSTRY HAS HAD CONSIDERABLE EXPERIENCE OVER THE PAST 20 YEARS IN THE DEVELOPMENT AND USE OF HALON 1301 PROTECTION SYSTEMS FOR THE EXTINGUISHMENT OF FIRES OCCURRING WITHIN THE ENGINE NACELLE. DURING THE YEARS OF THE FIRE-PRONE, PISTON-ENGINE AIRCRAFT, EXTENSIVE TESTING AND DEVELOPMENT WAS DONE AT THE TECHNICAL DEVELOPMENT AND EVALUATION CENTER, OR TDC, IN INDIANAPOLIS - THE PREDECESSOR OF NAFEC. AFTER THE ESTABLISHMENT OF NAFEC IN 1958, THIS WORK WAS CONTINUED ON TURBOJET AND TURBOFAN ENGINES ALTHOUGH THE OCCURRENCE OF FIRE WAS CONSIDERABLY LESS FREQUENT THAN FROM THE PISTON ENGINES. THUS, THE AVIATION INDUSTRY'S FIRST EXPERIENCE WITH THE USE OF HALON 1301 WAS FOR THE EXTINGUISHMENT OF FLAMMABLE FLUID OR CLASS B FIRES.

THIS IS NOT TO SAY THAT THERE WAS NO CONCERN OVER CLASS A FIRES. TESTS AT TDC IN THE EARLY 1950's EVALUATING 8 EXTINGUISHING AGENTS - EXCLUDING HALON 1301 - FOR EXTINGUISHMENT OF TYPICAL CARGO FIRES DEMONSTRATED AN INABILITY OF ANY OF THESE AGENTS TO PENETRATE DEEP-SEATED FIRES. EMPHASIS AT THIS TIME WAS THUS PRIMARILY DIRECTED TOWARD THE AUTOMATIC DETECTION OF FIRES ORIGINATING IN THIS AREA OF THE AIRCRAFT. HOWEVER, IN RECENT YEARS WITH THE REALIZATION THAT LOW CONCENTRATIONS OF HALON 1301 WERE EFFECTIVE IN COMBATING CLASS A FIRES AND WITH THE MANY-FOLD INCREASE IN CARGO COMPARTMENT VOLUMES, IT WAS CONSIDERED WORTHWHILE TO RESUME THE WORK ON CARGO COMPARTMENT FIRE EXTINGUISHMENT AT NAFEC.

CONSISTENT WITH THE EXPERIMENTAL FINDINGS AND THE STATISTICS ON COMMERCIAL TRANSPORT FIRES, THE FAA HAS REGULATIONS FOR POWERPLANT AND CARGO COMPARTMENT FIRE PROTECTION. DESIGNATED POWERPLANT FIRE ZONES MUST BE PROTECTED BY FIRE EXTINGUISHER SYSTEMS AND THE AIRLINES HAVE INCORPORATED HALON 1301 AS THE EXTINGUISHANT AGENT BECAUSE OF ITS FIREFIGHTING EFFECTIVENESS AND LOW TOXICITY. BECAUSE OF THE LESS

FREQUENT INCIDENCE OF FIRES IN CARGO COMPARTMENTS, THE REGULATIONS GOVERNING SUCH AREAS ARE NOT AS SEVERE AS THOSE FOR POWERPLANTS. MOST OF TODAY'S COMMERCIAL TRANSPORTS HAVE CARGO COMPARTMENTS FALLING IN THE CLASS D CATEGORY; I. E., A SMALL, SEALED BELLY COMPARTMENT. HOWEVER, THE CARGO COMPARTMENTS OF THE B-747 AND DC-10 JUMBO JETS HAVE THE CHARACTERISTICS OF A CLASS C COMPARTMENT, WHICH REQUIRE A FIRE DETECTOR AND EXTINGUISHING SYSTEM. CONVERSELY, THE APPROACH TAKEN TO PROVIDE PASSENGER CABIN FIRE PROTECTION HAS BEEN TO RESTRICT THE FLAMMABILITY OF THE INTERIOR MATERIALS. WITH THE EXCEPTION OF A FEW MATERIALS USED IN SMALL QUANTITIES, ALL INTERIOR MATERIALS WHEN TESTED VERTICALLY ARE REQUIRED TO BE SELF-EXTINGUISHING UPON EXPOSURE TO A BUNSEN BURNER FLAME.

CLASS A FIRE EXTINGUISHING TESTS AT NAFEC UTILIZING HALON 1301

HALON 1301 FIRE EXTINGUISHING TESTS WERE PERFORMED AT NAFEC DURING THE PAST SEVERAL YEARS IN A CABIN MOCKUP. TESTS WERE CONDUCTED ON URETHANE SEAT FOAM AND WOOL DRAPERY IGNITED INSIDE A 640-CUBIC-FOOT INSULATED AIRPLANE CABIN MOCKUP. THE AGENT WAS DISCHARGED THROUGH AN ASPIRATOR NOZZLE LOCATED NEAR THE CEILING OF THE MOCKUP.

ONE TEST CLEARLY DEMONSTRATED THAT A HIGH-RATE DISCHARGE OF HALON 1301 WOULD PREVENT A FLASH FIRE. THE FIRST SLIDE SHOWS THE VARIATION OF TEMPERATURE, OXYGEN, SMOKE AND CARBON MONOXIDE AT THE CEILING DURING THE BURNING OF 10 POUNDS OF URETHANE FOAM IGNITED BY A PROPANE/AIR BURNER. NO AGENT WAS USED DURING THIS BASE LINE TEST. A FLASH FIRE OCCURRED AT 2.6 MINUTES, AS EVIDENCED BY THE RAPID INCREASE IN TEMPERATURE AND CARBON MONOXIDE AND DECREASE IN OXYGEN. TYPICALLY, HIGH CONCENTRATIONS OF SMOKE PRECEDED THE FLASH FIRE BY ABOUT ONE MINUTE. NOTICE THAT THE TEMPERATURE "TOOK OFF" SHORTLY AFTER REACHING 200°F.

NEXT SLIDE PLEASE. A SIMILAR TEST WAS CONDUCTED USING A HIGH-RATE DISCHARGE OF HALON 1301, WITH A DESIGN CONCENTRATION OF 5.8%. THE AGENT WAS DISCHARGED WHEN THE CEILING TEMPERATURE APPROACHED 200°F AND A FLASH FIRE WAS IMMINENT AS DEMONSTRATED IN THE PREVIOUS TEST. THE FLAMES WERE EXTINGUISHED WITHIN A FEW SECONDS. IMMEDIATELY AFTER AGENT DISCHARGE THE OXYGEN CONCENTRATION DROPPED OFF SLIGHTLY AND THE TEMPERATURE DECREASED TO A VALUE SLIGHTLY ABOVE AMBIENT. THESE 2 MEASUREMENTS, AS WELL AS THE CONCENTRATION OF CARBON

MONOXIDE WHICH WAS NEGLIGIBLE, REMAINED ESSENTIALLY CONSTANT THROUGHOUT THE REMAINDER OF THE TEST, UNAFFECTED BY ATTEMPTS TO REIGNITE THE FOAM WITH EITHER THE PROPANE/AIR BURNER, A CHEMICAL FIRE OR AN INCANDESCENT CALROD; I. E., ATTEMPTS TO PRODUCE FLAMING COMBUSTION OF THE FOAM WERE UNSUCCESSFUL IN A 5.8% HALON 1301/AIR ATMOSPHERE. HOWEVER, THE CEILING SMOKE LEVEL AT THE CENTER OF THE MOCKUP VARIED SIGNIFICANTLY THROUGHOUT THE TEST, INCREASING AFTER THE ATTAINMENT OF SELF-SUSTAINING FOAM COMBUSTION, RAPIDLY INCREASING DURING AGENT DISCHARGE, DECREASING DURING OPERATION OF A FAN CAUSING DESTRATIFICATION, AND AGAIN INCREASING DURING SMOLDERING COMBUSTION UPON HEATING WITH THE INCANDESCENT CALROD. IT SHOULD BE NOTED THAT, IN AN AIR ATMOSPHERE, THE CALROD IGNITES THE FOAM AND EVENTUALLY CAUSES A FLASH FIRE. SLIDE OFF PLEASE.

AN INERTING TEST WAS CONDUCTED ON A FOLDED WOOL CURTAIN 2 1/2 FEET WIDE AND 5 FEET LONG SUSPENDED FROM THE MOCKUP CEILING. IN A UNIFORM 3.9% HALON 1301/AIR MIXTURE, THE BOTTOM HEM OF THE CURTAIN WAS SUBJECTED TO A PROPANE/AIR FLAME FOR 5 1/2 MINUTES, A CHEMICAL FIRE FOR ONE MINUTE AND CONTACT WITH THE INCANDESCENT ELEMENT FOR 5 MINUTES. ALTHOUGH SOME INTERMITTENT, DETACHED FLASHING WAS OBSERVED DURING ATTEMPTED IGNITION WITH THE PROPANE/AIR BURNER, NO SELF-SUSTAINED COMBUSTION OF THE FABRIC COULD BE OBTAINED WITH ANY OF THE 3 IGNITION SOURCES. AN IDENTICAL CURTAIN TESTED IN AIR WAS COMPLETELY CONSUMED BY FLAMES WHEN IGNITED WITH THE PROPANE/AIR BURNER.

THE EFFECTIVENESS OF HALON 1301 IN COMBATING CARGO COMPARTMENT FIRES WAS DEMONSTRATED BY CONDUCTING FULL-SCALE TESTS IN A 5000-CUBIC-FOOT C-130 FUSELAGE SECTION. THROUGHOUT THIS PROGRAM STANDARD CARDBOARD CARTONS FILLED WITH EXCELSIOR WERE USED FOR BOTH THE FIRE AND CARGO LOADS.

THE NEXT SLIDE SHOWS THE RESULTS OF A TYPICAL CARGO-COMPARTMENT FIRE TEST WITH A 10% LOAD CONFIGURATION IN WHICH AIRFLOW SHUTOFF WAS USED AS A MEANS OF EFFECTING FIRE CONTROL. DURING THE IGNITION PERIOD AND UNTIL DETECTION

OCCURRED, AIRFLOW THROUGH THE COMPARTMENT WAS MAINTAINED AT 2000 CUBIC FEET PER MINUTE. AT THE TIME OF DETECTION - WHEN THE CEILING THERMOCOUPLE DIRECTLY ABOVE THE FIRE LOAD RECORDED 300°F - THE AIRFLOW WAS REDUCED TO A TYPICAL LEAKAGE RATE OF 75 CUBIC FEET PER MINUTE. SHORTLY THEREAFTER A FLASH FIRE OCCURRED AS EVIDENCED BY THE RAPID INCREASE IN PRESSURE AND TEMPERATURE FOLLOWED BY A REDUCTION IN THE CONCENTRATION OF OXYGEN. NOTICE THAT THE FIRE EXPOSURE TIME HAS A LOGARITHMIC SCALE, WHICH GREATLY EXAGGERATES THE DURATION OF THE FLASH FIRE. DURING THE FLASH FIRE, A MAXIMUM TEMPERATURE OF 1800°F AND A PRESSURE OF 0.10 POUND PER SQUARE INCH WERE RECORDED.

A SIMILAR PLOT ILLUSTRATING THE RESULTS OF AN IDENTICAL TEST EXCEPT FOR THE UTILIZATION OF HALON 1301 IS SHOWN ON THE FOLLOWING SLIDE. SIXTY POUNDS OF AGENT CALCULATED TO PRODUCE A 3% CONCENTRATION WAS DISCHARGED IN 15 SECONDS FROM 3 OPEN-END 5/8-INCH COPPER TUBES. NONE OF THE 3 DISCHARGE POINTS WAS IN THE VICINITY OF THE FIRE LOAD. THE

ADDITION OF HALON 1301 PREVENTED A FLASH FIRE, AS EXHIBITED BY THE DECREASE IN TEMPERATURE IMMEDIATELY FOLLOWING AGENT DISCHARGE, EXTINGUISHED THE FLAMES AND CONTROLLED THE CONTINUING SMOLDERING CONDITION FOR A 2-HOUR PERIOD. SLIDE OFF PLEASE.

HALON 1301 FIRE SUPPRESSION SYSTEMS

EXTINGUISHMENT TESTS AT NAFEC OF CABIN AND CARGO FIRES, PLUS COMPREHENSIVE STUDIES OF POWERPLANT FIRE PROTECTION, REPRESENT A SMALL PERCENTAGE OF THE EXTENSIVE WORK WITH HALON 1301 FOR APPLICATIONS OUTSIDE AIRCRAFT INSTALLATIONS. THIS WIDE EFFORT AND INTEREST WAS CLEARLY EVIDENT AT LAST MONTH'S 2-DAY SYMPOSIUM SPONSORED BY THE NATIONAL ACADEMY OF SCIENCES ENTITLED, "SYMPOSIUM ON AN APPRAISAL OF HALOGENATED FIRE EXTINGUISHING AGENTS," WHICH INCLUDED SESSIONS ON TOXICOLOGY, APPLICATIONS AND ENGINEERING. MOREOVER, TOMORROW AFTERNOON'S SESSION ON "EXTINGUISHING AGENTS/SYSTEMS" INCLUDES 5 PRESENTATIONS CONCERNING HALON 1301 SYSTEMS AND FURTHER DEMONSTRATES THE EVER-INCREASING APPLICATION OF THIS AGENT. CONSEQUENTLY, IN ORDER TO CONTROL FIRES WHICH MIGHT ORIGINATE WITHIN AIRCRAFT INTERIORS AS HAVE OCCURRED IN THE PAST DURING CONSTRUCTION, MAINTENANCE AND SERVICING, THE NFPA'S COMMITTEE ON AVIATION HAS TENTATIVELY PROPOSED THE "RECOMMENDED PRACTICE ON

AIRCRAFT INTERIOR FIRE PROTECTION SYSTEMS," NFPA NO. 421-T, UTILIZING EITHER HALON 1301 OR HIGH-EXPANSION FOAM.

IN ADDITION TO AIRCRAFT POWERPLANT FIRE PROTECTION, HALON 1301 FIRE SUPPRESSION SYSTEMS ARE ALSO IN USE OR ANTICIPATED FOR USE IN AIRCRAFT FUSELAGES. THE B-747 AND DC-10 CARGO COMPARTMENTS REQUIRE FIRE SUPPRESSION SYSTEMS. HALON 1301 WAS SELECTED AS THE EXTINGUISHANT. FOR THOSE OF YOU IN THE AUDIENCE WHO ARE SYSTEM-WEIGHT CONSCIOUS, IT SHOULD BE NOTED THAT THE STORAGE CONTAINERS IN THE DC-10 ONLY WEIGH 1/4 OF THE WEIGHT OF AGENT BEING STORED. DURING ASSEMBLY OF THE B-747, DC-10 AND L-1011 JUMBO JETS, THE INTERIORS ARE PROTECTED BY PORTABLE, AUTOMATIC, HALON 1301 FIRE SUPPRESSION SYSTEMS. BECAUSE OF THE OBVIOUSLY GREATER POTENTIAL FIRE HAZARDS INHERENT DURING MILITARY FLIGHT OPERATIONS, SERIOUS CONSIDERATION IS BEING GIVEN TO HALON 1301 INTERIOR PROTECTION. A SYSTEM DEVELOPMENT PROGRAM CONSISTING OF BOTH GROUND AND IN-FLIGHT TESTING WAS RECENTLY COMPLETED ON THE E-2 AIRCRAFT AT THE PATUXENT RIVER NAVAL AIR STATION. LOCKHEED IS INCORPORATING A TEMPORARY, OVERHEAD, FIXED-PIPE SYSTEM CONSISTING OF 4 NOZZLES FOR PROTECTION OF THE P-3 AIRCRAFT DURING ASSEMBLY. THE AIR FORCE IS CONTEMPLATING A HALON 1301 FIRE SUPPRESSION SYSTEM FOR THE CARGO COMPARTMENT AND BAY AREAS OF

THE C-5A AIRCRAFT AND FOR THE CREW CAPSULE OF THE B-1 AND F-111 AIRCRAFT.

NAFEC TEST PROGRAM FOR HALON 1301 PASSENGER CABIN FIRE SUPPRESSION SYSTEM

I WOULD NOW LIKE TO DESCRIBE A TEST PROGRAM RECENTLY STARTED AT NAFEC WHICH CONSISTS OF EVALUATING 2 HALON 1301 FIRE SUPPRESSION SYSTEM CONCEPTS FOR INCORPORATION INTO THE PASSENGER CABIN OF A COMMERCIAL TRANSPORT. HALON 1301

WAS THE EXTINGUISHANT SELECTED BECAUSE OF ITS EFFICIENT AND EFFECTIVE FIRE SUPPRESSION CAPABILITY AND LOW TOXICITY IN THE CONCENTRATION REQUIRED FOR CLASS A FIRE EXTINGUISHMENT.

NEXT SLIDE PLEASE. THE FIRE SUPPRESSION SYSTEMS WILL BE INSTALLED WITHIN THE PASSENGER CABIN OF A DC-7 FUSELAGE, WHICH IS TYPICALLY FURNISHED WITH DOUBLE SEATS, CARPETING, CURTAINS, HATRACK, HEADLINER, DROP CEILING, ETC. THIS TEST ARTICLE IS HOUSED INSIDE A HEATED BUILDING AT NAFEC.

NEXT SLIDE PLEASE. FOR THIS TEST PROGRAM, THE CABIN SPACE TO BE PROTECTED EXTENDS FROM THE FORWARD SLOPE BULKHEAD TO THE AFT PRESSURE BULKHEAD, AND IS COMPOSED

OF THE SO-CALLED "B" LOUNGE, 2 LAVATORIES, THE MAIN PASSENGER CABIN AND THE AFT LOUNGE. THE VOLUME OF PROTECTED CABIN AIR SPACE WAS CALCULATED TO BE 4000 CUBIC FEET.

NEXT SLIDE PLEASE. THE 1ST FIRE SUPPRESSION SYSTEM CONCEPT TO BE EVALUATED IS THE MODULAR APPROACH. FOUR IDENTICAL MODULES WILL BE MOUNTED ABOVE THE DROP CEILING ALONG THE SYMMETRY PLANE OF THE FUSELAGE. ONLY THE AGENT SPREADERS WILL BE VISIBLE FROM WITHIN THE CABIN. THE MODULES WILL BE INSTALLED AT FUSELAGE STATIONS 223, 434, 647, AND 858, WITH EACH MODULE PROTECTING AN EQUAL VOLUME OF THE CABIN. RECOGNIZING THAT THE OBJECTIVE OF THE TEST PROGRAM IS TO EVALUATE A SYSTEM CONCEPT, THE EXTINGUISHING MODULES TO BE TESTED ARE NOT OPTIMUM FOR INSTALLATION IN PRODUCTION AIRCRAFT. A STANDARD, 13"-DIAMETER SPHERICAL AGENT CONTAINER WILL BE USED.

THE NEXT SLIDE SHOWS A MODULE ESPECIALLY DESIGNED FOR INSTALLATION ABOVE THE DROP CEILING OF A PASSENGER CABIN, WHICH HAS SIMILAR DESIGN FEATURES TO THE MODULES TO BE TESTED EXCEPT FOR THE CONTAINER SHAPE, THE QUICK-DISCONNECT CLAMP AND THE DISCHARGE TUBE. EACH TEST MODULE CONTAINS THE FOLLOWING COMPONENTS: (1) A PRESSURE GAUGE NOT SHOWN ON

THE SLIDE: (2) AN INITIATOR WHICH SERVES TO EXPLOSIVELY RUPTURE A FRANGIBLE DISC FOR AGENT RELEASE (THE DISC IS DESIGNED TO RUPTURE HYDROSTATICALLY SHOULD THE CONTAINER PRESSURE EXCEED NORMAL OPERATING LEVELS); (3) A FILL VALVE; AND (4) A SPREADER DESIGNED TO PROVIDE A HORIZONTAL AGENT DISCHARGE PATTERN WELL ABOVE THE HEADS OF ANY OCCUPANTS WITHIN THE CABIN AREA. IT IS FELT THAT THIS IS ONE METHOD TO MINIMIZE ANY PSYCHOLOGICAL OR PHYSICAL EFFECTS ON PASSENGERS AND YET ACHIEVE MAXIMUM AGENT DISTRIBUTION TO EFFECTIVELY PROTECT THE CABIN. THE SYSTEM WILL HAVE THE CAPABILITY FOR EITHER AUTOMATIC DISCHARGE OF AGENT, USING THERMAL DETECTORS, OR MANUAL ACTUATION. A CONTROL PANEL WILL CONSIST OF A SYSTEM ON LAMP VERIFYING INTEGRITY OR CONTINUITY OF SYSTEM WIRING, A SYSTEM FIRED LAMP, AND A MANUAL ACTUATION SWITCH.

NEXT SLIDE PLEASE. THE SECOND FIRE SUPPRESSION SYSTEM CONCEPT TO BE EVALUATED IS THE FIXED-PIPE APPROACH. TWO MODULES LOCATED AT OPPOSITE ENDS OF THE FUSELAGE WILL HAVE A COMMON DISPERSER RUNNING ALONG THE CEILING FOR THE ENTIRE LENGTH OF THE PROTECTED CABIN. THIS SYSTEM WILL HAVE THE SAME CONTROL PANEL AND THE CAPABILITY FOR EITHER MANUAL OR AUTOMATIC ACTUATION AS THE PREVIOUSLY DESCRIBED MODULAR SYSTEM.

THE NEXT SLIDE ILLUSTRATES THE FIXED-PIPE DISPERSER. IT CONSISTS OF 2 CONCENTRIC, PERFORATED TUBES WITH AN OUTER COVERING OF 1/4-INCH THICK OPEN CELL FOAM. THE HOLE SIZES AND THEIR SPACING ON THE INNER TUBE ARE SUCH THAT A UNIFORM DISTRIBUTION OF AGENT IS ACHIEVED THROUGHOUT THE PASSENGER CABIN. THE OUTER TUBE WILL HAVE LARGER HOLES SO THAT THE DISCHARGE INTO THE CABIN IS AT LOW VELOCITY, ELIMINATING OR REDUCING BOTH AGENT JET IMPINGEMENT FORCES AND HIGH CONCENTRATIONS FOR PROLONGED PERIODS NEAR PASSENGERS. IN ORDER TO MINIMIZE SOUND DURING DISCHARGE WHICH MIGHT CAUSE PASSENGER APPREHENSION ACCOMPANIED BY ELEVATED ADRENALIN LEVELS, THE FOAM WILL PROVIDE A SOUND-DEADENING PASSAGEWAY AND QUIET THE DISCHARGE FROM THE HIGH-VELOCITY INNER HOLES. SLIDE OFF PLEASE.

THE EXPERIMENTAL STUDY IS DIVIDED INTO 3 PARTS AND CONSISTS OF THE EVALUATION OF A FIRE SUPPRESSION SYSTEM IN TERMS OF: (1) AGENT DISTRIBUTION AND OTHER FACTORS AFFECTING PASSENGER COMPOSITION OR COMPOSURE; (2) SAFE AUTOMATIC EXTINGUISHMENT OF CABIN FIRES; AND (3) PROTECTION AGAINST AN EXTERNAL FUEL FIRE ADJACENT TO A FUSELAGE RUPTURE.

THE DISTRIBUTION OF AGENT THROUGHOUT THE PASSENGER CABIN, UNDER NO-FIRE TEST CONDITIONS, WILL BE MEASURED USING

2 STATHAM HALON 1301 ANALYZERS, WHICH WILL PROVIDE A TOTAL OF 24 CONTINUOUS CONCENTRATION MEASUREMENTS. THE INSTRUMENT RESPONSE TO 95% FULL-SCALE READING IS WITHIN 0.10 SECOND.

AN OUTLINE OF THE FIRST PART OF THE TEST PROGRAM IS SHOWN ON THE NEXT SLIDE. MEASUREMENTS WILL BE MADE THROUGHOUT THE PASSENGER CABIN OF THE CONCENTRATION OF HALON 1301 AND THE OCCURRENCE OF OTHER AGENT DISCHARGE CHARACTERISTICS AFFECTING HUMAN COMPOSURE FOR BOTH THE MODULAR AND FIXED-PIPE SYSTEMS. EFFECTIVENESS AND SAFETY WILL BE DETERMINED BY MEASURING AGENT CONCENTRATION WITH THE LISTED 5 FACTORS RECEIVING PRIMARY CONSIDERATION: (1) MIXTURE HOMOGENEITY, (2) SYSTEM REPEATABILITY, (3) AGENT CONCENTRATION AT REMOTE LOCATIONS, (4) EFFECT OF OPEN EXITS, AND (5) AGENT CONCENTRATION NEAR PASSENGERS.

DURING THE FIRST SEVERAL TESTS UTILIZING EACH OF THE TWO FIRE SUPPRESSION SYSTEMS, MEASUREMENTS WILL ALSO BE MADE OF 4 OTHER FACTORS AFFECTING PASSENGER COMPOSITION OR

COMPOSURE: (1) OVERPRESSURE, (2) NOISE, (3) SCATTERING OF LIGHTWEIGHT OBJECTS, AND (4) TEMPERATURE.[4] THESE FACTORS WILL BE MOST SIGNIFICANT WHILE THE AGENT IS BEING DISCHARGED THROUGH THE DISPENSER AND WILL PREDOMINANTLY HAVE A PSYCHOLOGICAL, RATHER THAN PHYSIOLOGICAL, EFFECT UPON PASSENGERS. OF CONCERN HERE ARE THE FINDINGS OF LABORATORY EXPERIMENTS WITH ANIMALS INHALING 7.5% HALON 1301, IN THE PRESENCE OF HIGH CIRCULATING LEVELS OF ADRENALIN, WHEREIN SERIOUS CARDIAC ARRHYTHMIAS RESULTED. THIS RISK CANNOT BE FORECAST ACCURATELY IN HUMANS BECAUSE THE STATE OF THE SUSCEPTIBILITY OF THE PERSONS EXPOSED TO HALON 1301 WILL VARY.[4] IF THE FIRE SUPPRESSION SYSTEM IS DESIGNED SUCH THAT ACTIVATION IN ITSELF DOES NOT PRODUCE PASSENGER APPREHENSION AND ASSOCIATED ELEVATED ADRENALIN LEVELS, THEN NO SERIOUS HEALTH HAZARDS ARE TO BE ANTICIPATED FROM SHORT EXPOSURES TO HALON 1301 CONCENTRATIONS OF 7%. IN THE CASE OF A FIRE CAUSING ALARM, FOR MOST FORESEEABLE SITUATIONS, THE RISK ASSOCIATED WITH THE FIRE HAZARD IS ASSUMED TO BE GREATER THAN THAT CAUSED BY THE RELEASE OF AGENT. SLIDE OFF PLEASE

THIS TEST PROGRAM IS PRIMARILY GEARED TOWARD SYSTEM EVALUATION; HOWEVER, IT IS MORE THAN LIKELY THAT SOME SYSTEM DEVELOPMENT WILL BECOME NECESSARY TO OBTAIN AN

OPTIMUM DESIGN. THE IDEAL SYSTEM SHOULD FULFILL THE FOLLOWING 3 REQUIREMENTS: (1) ACHIEVEMENT OF DESIGN HALON 1301 CONCENTRATION THROUGHOUT THE PROTECTED AREA IN THE MINIMUM AMOUNT OF TIME; (2) ABSENCE OF HARMFUL, ELEVATED HALON 1301 CONCENTRATIONS NEAR ANY PASSENGERS DURING THIS PERIOD; AND (3) SYSTEM DISPERSER DESIGN WHICH WILL NOT CAUSE ALARM DURING AGENT DISCHARGE. ON THE BASIS OF THESE 3 REQUIREMENTS, THE OPTIMUM FIRE SUPPRESSION SYSTEM WILL BE SELECTED FOR FURTHER EVALUATION.

NEXT SLIDE PLEASE. THE 2ND PART OF THE TEST PROGRAM CONSISTS OF A SERIES OF TESTS DURING WHICH TYPICAL CABIN FIRES WILL BE AUTOMATICALLY EXTINGUISHED. THE PRIMARY REQUIREMENT OF AN AUTOMATIC FIRE SUPPRESSION SYSTEM IS TO RAPIDLY EXTINGUISH THE FIRE BEFORE HARMFUL TOXIC GAS LEVELS FROM THE DECOMPOSITION OF AGENT OR BURNING MATERIALS CAN ACCUMULATE. AUTOMATIC SYSTEM ACTIVATION WILL BE EFFECTED BY EITHER ONE OF 2 THERMAL DETECTORS - UNIT OR CONTINUOUS COMPARATOR - COOPERATIVELY WIRED INTO THE SYSTEM. THE UNIT DETECTORS WILL BE MOUNTED AT THE MODULE LOCATIONS AND SET TO ACTIVATE AT 160°F. THE CONTINUOUS COMPARATOR DETECTOR, INCORPORATING EXISTING TECHNOLOGY AND PRODUCTS, IS A NEW CONCEPT STILL IN THE

DEVELOPMENTAL STAGE.

IN ORDER TO DETERMINE IF THE DETECTOR SENSITIVITY PROVIDES SAFE EXTINGUISHMENT OF CABIN FIRES, THE FOLLOWING EXTENSIVE INSTRUMENTATION IS PLANNED: CONTINUOUS PARAMAGNETIC OXYGEN ANALYZERS; CONTINUOUS INFRARED CARBON MONOXIDE ANALYZERS; SMOKE METERS WHICH CONTINUOUSLY MEASURE LIGHT TRANSMISSION; CONTINUOUS INFRARED HALON 1301 ANALYZERS BELIEVED TO BE THE 1ST EVER MADE IN THIS COUNTRY; THERMOCOUPLES TO MEASURE THE TEMPERATURE OF THE FIRE; COLOR MOTION PICTURE COVERAGE TO TRACE THE VISIBLE PROGRESS OF THE FIRE; AND PERIODIC MIXTURE SAMPLING TO DETERMINE THE CONCENTRATIONS OF HYDROGEN FLUORIDE AND HYDROGEN BROMIDE - THE PREDOMINANT HALON 1301 DECOMPOSITION PRODUCTS RESULTING FROM PYROLYSIS. THE CONCENTRATIONS OF HF AND HBr ARE THE MOST IMPORTANT MEASUREMENTS TO BE PERFORMED DURING THIS SERIES OF TESTS, SINCE THEIR TOXICITY HAS BEEN PRIMARILY RESPONSIBLE FOR THE RELUCTANCE TO INSTALL HALON 1301 EXTINGUISHING SYSTEMS IN OCCUPIED ENCLOSURES.[1] HF AND HBr WILL BE DETERMINED USING SPECIFIC ION ELECTRODES. SLIDE OFF PLEASE.

THE 3RD AND FINAL PART OF THIS EXPERIMENTAL ENDEAVOR IS THE MOST CONTROVERSIAL AND PROBABLY THE MOST DIFFICULT

FROM THE STANDPOINT OF CONTROLLING VARIABLES. IT CONSISTS OF DETERMINING THE DEGREE OF PROTECTION PROVIDED BY AN AUTOMATIC, HALON 1301 FIRE SUPPRESSION SYSTEM AGAINST AN EXTERNAL FUEL FIRE ADJACENT TO A FUSELAGE RUPTURE. ANALYSIS OF SURVIVABLE TRANSPORT CRASHES INDICATE THIS TO BE A FREQUENT POST-CRASH SITUATION. HOWEVER, THERE ARE SEVERAL OTHER SURVIVABLE CRASHES, WHICH DO NOT FALL INTO THIS CATEGORY, WHERE AUTOMATIC FIRE SUPPRESSION MAY HAVE SAVED THE LIVES OF SOME PASSENGERS. ONE SUCH ACCIDENT OCCURRED AT SALT LAKE CITY. THE FIRE ENTERED THE CABIN "IMMEDIATELY" OR "1 TO 2" SECONDS AFTER IMPACT AND WAS ESSENTIALLY CONFINED WITHIN THE FUSELAGE. AUTOMATIC FIRE SUPPRESSION COULD HAVE EXTINGUISHED THIS INITIAL FIRE AND PERHAPS INERTED THE CABIN SO AS TO PREVENT, AS ONE WITNESS ESTIMATED, FLAMING THROUGHOUT THE ENTIRE CABIN WITHIN 90 SECONDS AFTER IMPACT. ANOTHER MORE RECENT ACCIDENT OCCURRED AT EAST HAVEN, CONNECTICUT. TOXICOLOGICAL STUDIES INDICATED THAT CARBON MONOXIDE INHALATION INCAPACITATED MOST OF THE PASSENGERS AND PREVENTED THEM FROM TAKING THE NECESSARY ACTION TO EVACUATE THE AIRCRAFT. AT THE HEARING, THE MALE SURVIVOR TESTIFIED THAT HIS INITIAL ATTEMPT TO EVACUATE WAS THROUGH THE LEFT WINDOW EXIT AND WAS THWARTED BY THE EXTERNAL FIRE WHICH BURNED

HIS HANDS AND ALSO IGNITED INTERIOR FURNISHINGS. THE FLAME PROGRESS THROUGH THE CABIN FROM THIS IGNITION IS UNKNOWN AND WILL NEVER BE DETERMINED. ALSO, IT IS NOT EVIDENT WHETHER THE CO RESPONSIBLE FOR PASSENGER INCAPACITATION WAS PRODUCED BY THE BURNING CABIN MATERIALS OR THE EXTERNAL FUEL FIRE. THE IMMEDIATE TOTAL-FLOODING DISCHARGE OF HALON 1301 WOULD HAVE EXTINGUISHED THE INITIAL BURNING OF FURNISHINGS AND PROVIDED ADDITIONAL TIME FOR PASSENGER EVACUATION BY INERTING THE CABIN ENCLOSURE; CONVERSELY, FLAMES ENTERING THROUGH THE OPEN WINDOW COULD CONCEIVABLY DECOMPOSE THE AGENT TO A LEVEL WHICH WOULD ACTUALLY HAMPER EVACUATION. THESE UNCERTAINTIES SURROUNDING THE USEFULNESS OF HALON 1301 CABIN FLOODING DURING A POST-CRASH CONDITION CAN ONLY BE RESOLVED BY CONTROLLED EXPERIMENTATION, THUS THE UNDERTAKING OF THE 3RD PART OF THIS TEST PROGRAM.

THE FINAL SLIDE SHOWS THE TEST SETUP SIMULATING A SURVIVABLE CRASH WITH AN EXTERNAL FUEL FIRE ADJACENT TO A FUSELAGE RUPTURE. SINCE THE TEST ARTICLE IS HOUSED IN A LARGE BUILDING, THE EFFECT OF VARIABLE AMBIENT WINDS ARE NEGATED. A SECTION OF THE ALUMINUM FUSELAGE SKIN, WHERE THE SIMULATED RUPTURE WILL BE CUT, WILL BE REPLACED OR

COVERED BY A STAINLESS STEEL SECTION. THIS ELIMINATES THE ENLARGEMENT OF THE OPENING BEYOND THE ORIGINAL SIMULATED RUPTURE. THIS IS PROBABLY A MINOR VARIABLE COMPARED TO THE FIRE INTENSITY, BUT ALLOWS FOR REPEATED TESTING WITH A CONSTANT RUPTURE AREA. THE FUEL PAN WILL BE LARGER THAN THE RUPTURE SUCH AS TO EXPOSE THE CABIN TO A SOLID SHEET OF FLAME WITH AN AREA EQUIVALENT TO THE SIMULATED RUPTURE. THE WIDTH OF THE FUEL PAN WILL BE DICTATED BY THE DESIRE TO OBTAIN A SEVERE FUEL FIRE, APPROACHING A HEAT FLUX OF 10 BTU/FT^2-SEC AND A TEMPERATURE OF 2000^{o}F, WITHOUT ENDANGERING THE BUILDING. THERE IS CONSIDERABLE EVIDENCE TO SUPPORT THE CONTENTION THAT, FOR THE POST-CRASH SITUATION DEFINED IN THIS STUDY, THE GOVERNING VARIABLE AFFECTING PASSENGER ESCAPE IS THE CABIN DRAFT CONDITION EVOLVING FROM OPEN EXITS AND AMBIENT WIND SPEED AND DIRECTION. BEARING THIS IN MIND, THE 1ST TEST WILL CONSIST OF AUTOMATIC TOTAL CABIN FLOODING WITH ALL EXITS CLOSED. IF THE 1ST TEST RESULTS SHOW ANY PROMISE, A 2ND TEST WILL BE CONDUCTED WITH AN OPEN EXIT REMOTE FROM THE FIRE AS MIGHT OCCUR DURING PASSENGER EVACUATION. IF THESE TESTS INDICATE THAT THE HALON 1301 IS PROVIDING SOME DEGREE OF PASSENGER PROTECTION, LATER TESTS WILL INVOLVE

OPEN EXITS, AND STILL LATER TESTS A LARGE FAN SIMULATING AMBIENT WINDS. INSTRUMENTATION WILL BE BASICALLY THE SAME AS THAT USED DURING THE 2ND PART OF THE TEST PROGRAM, EXCEPT FOR THE INCLUSION OF HEAT FLUX TRANSDUCERS AND AIR VELOCITY SENSORS FOR MEASURING THE CABIN DRAFTS. SLIDE OFF PLEASE

IN CLOSING, I WOULD LIKE TO AFFIRM MY BELIEF THAT AN AUTOMATIC, HALON 1301 FIRE SUPPRESSION SYSTEM IS NOT A PANACEA GUARANTEEING PASSENGER EVACUATION FROM ALL SURVIVABLE TRANSPORT CRASHES WITH ACCOMPANYING FUEL FIRES. THERE HAVE BEEN SURVIVABLE CRASHES WHERE THE EXTENT OF STRUCTURAL DAMAGE WOULD PREVENT THE BUILDUP OF HALON 1301 CONCENTRATIONS REQUIRED FOR FIRE EXTINGUISHMENT OR INERTING. THE PURPOSE OF THIS 3RD SERIES OF TESTS IS TO DETERMINE THE CONDITION UNDER WHICH AN AUTOMATIC, HALON 1301 FIRE SUPPRESSION SYSTEM IS NO LONGER AN ASSET TO PASSENGER EVACUATION.

THANK YOU FOR YOUR KIND ATTENTION. ARE THERE ANY QUESTIONS?

SLIDE #1

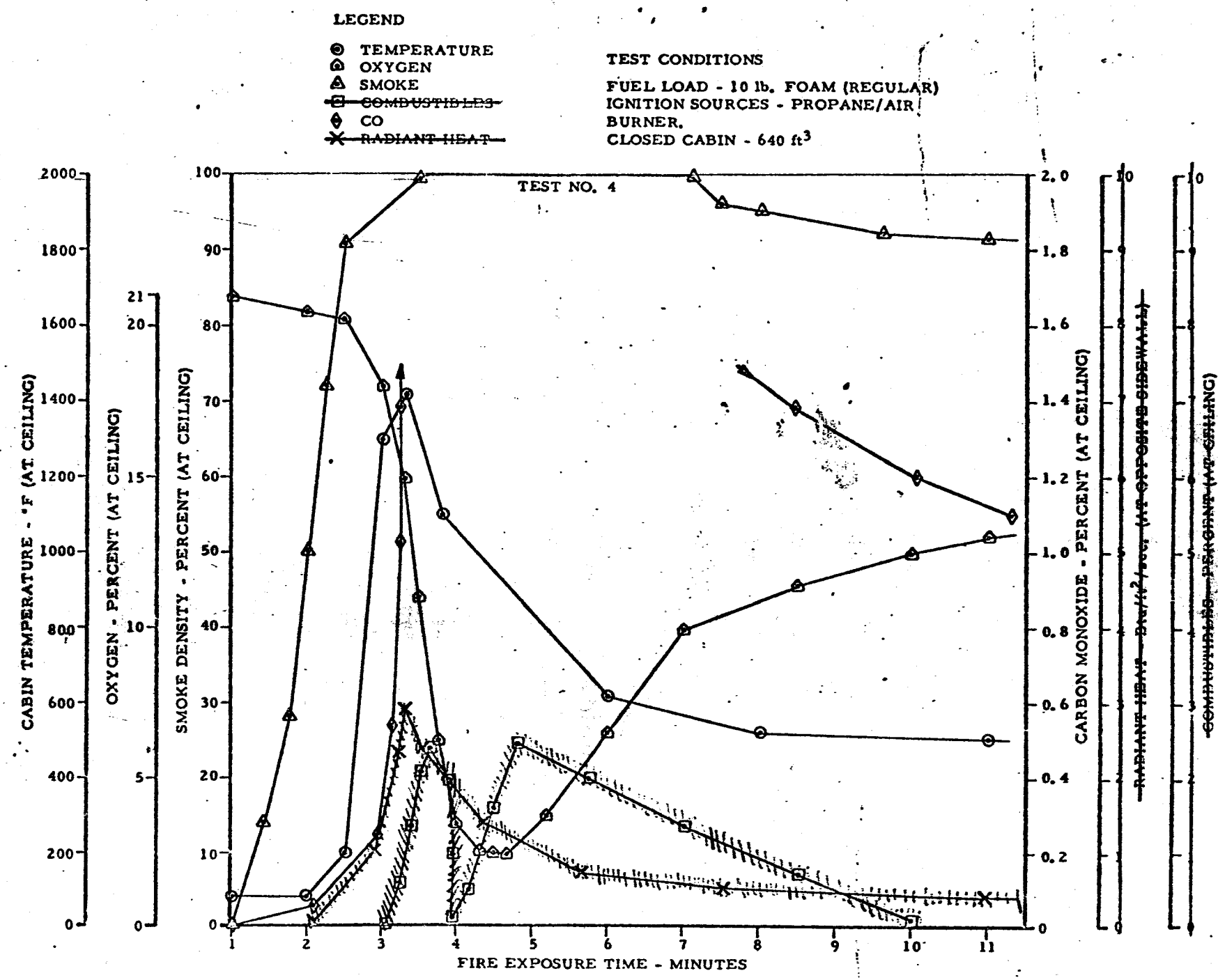


FIG. 2 REGULAR URETHANE FOAM FIRE PARAMETERS IN CLOSED CABIN

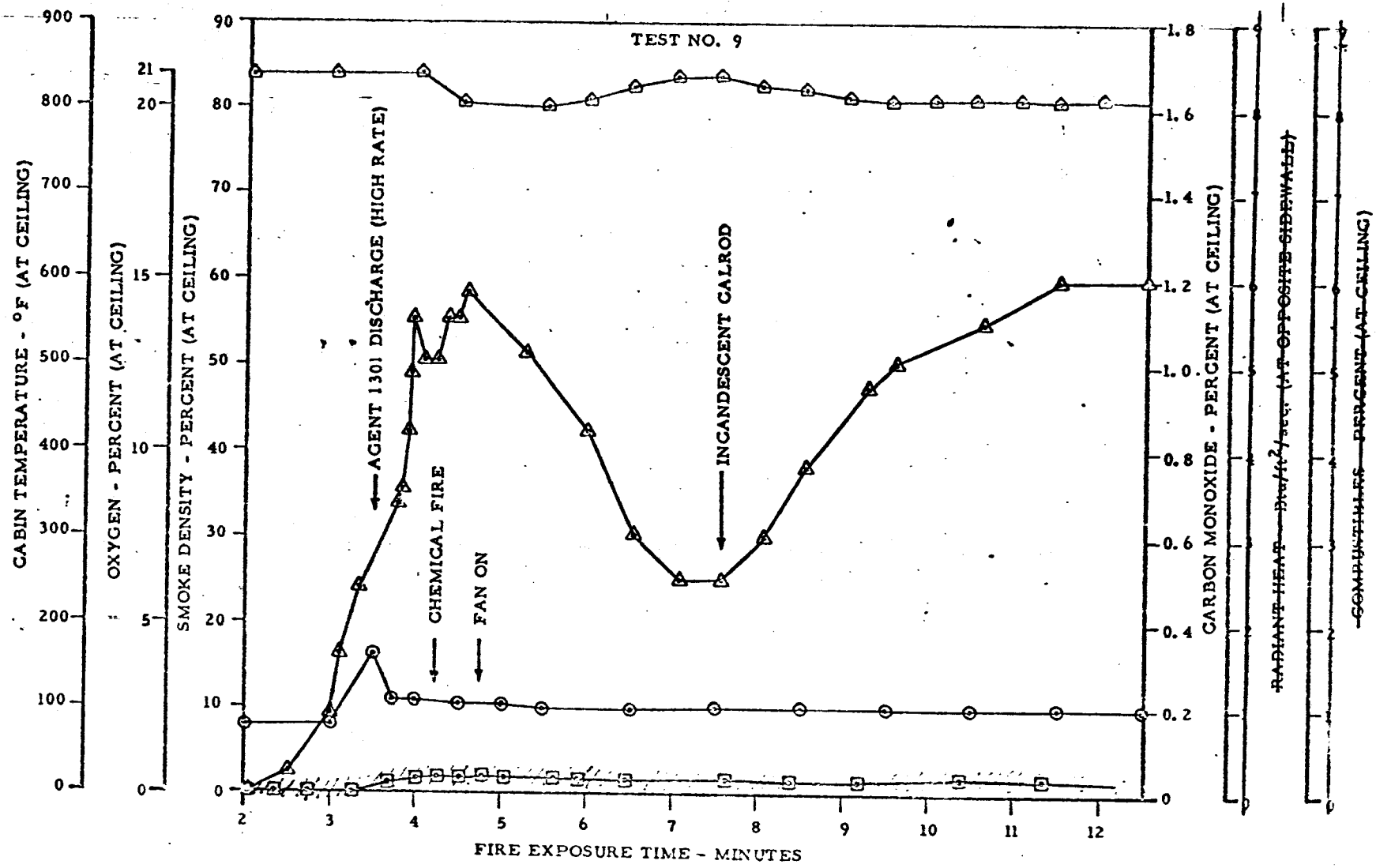
SLIDE #2

LEGEND

- TEMPERATURE
- OXYGEN
- SMOKE
- ~~COMBUSTIBLES~~
- CO (NEG.)
- ~~RADIANT HEAT (NEG.)~~

TEST CONDITIONS

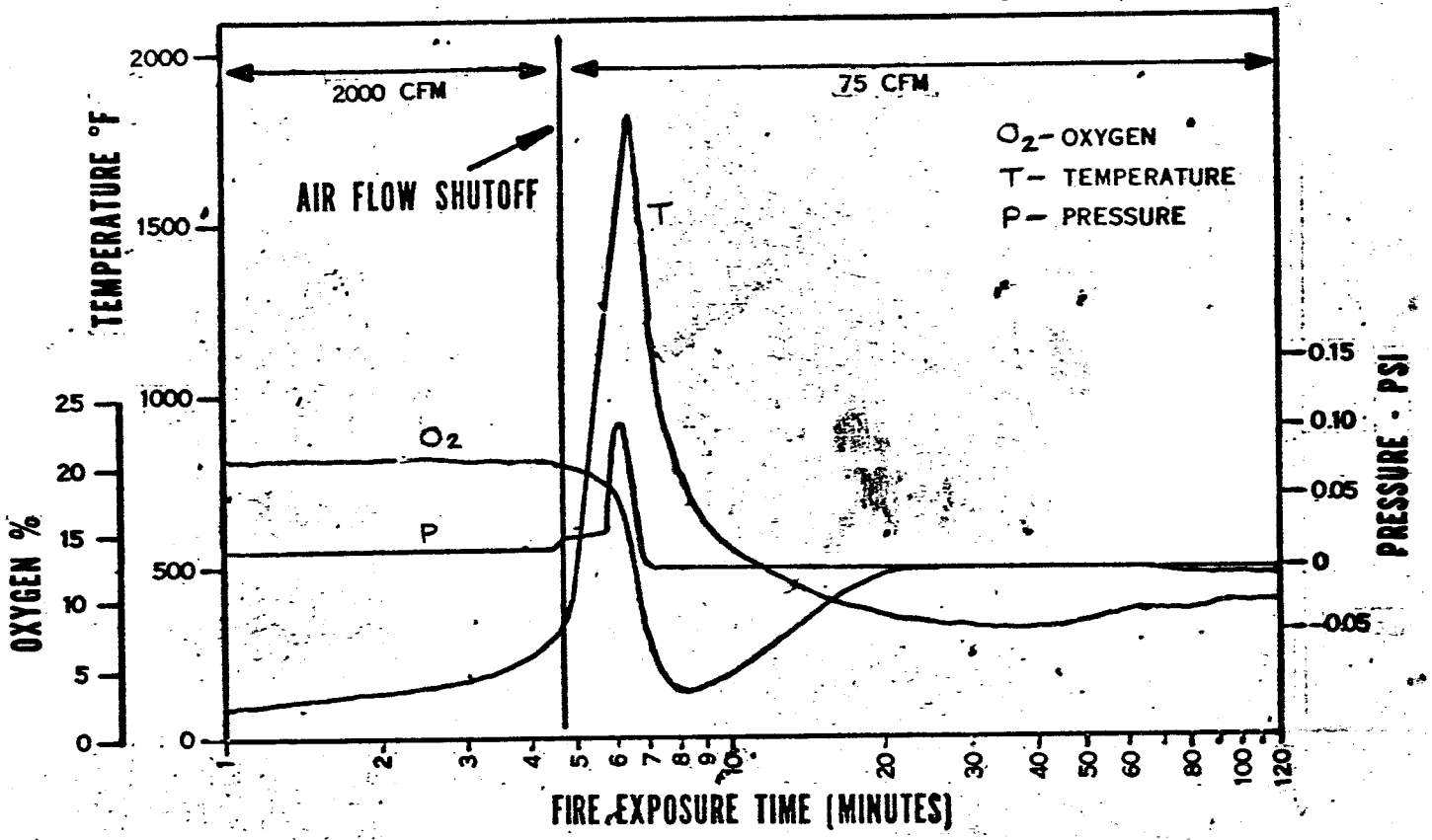
FUEL LOAD - 10 lb. FOAM (REGULAR)
IGNITION SOURCES - PROPANE/AIR BURNER, CHEMICALS AND INCANDESCENT CALROD
EXTINGUISHING AGENT - CF_3Br 1301 (5.8% BY VOL.)
CLOSED CABIN - 640 ft^3



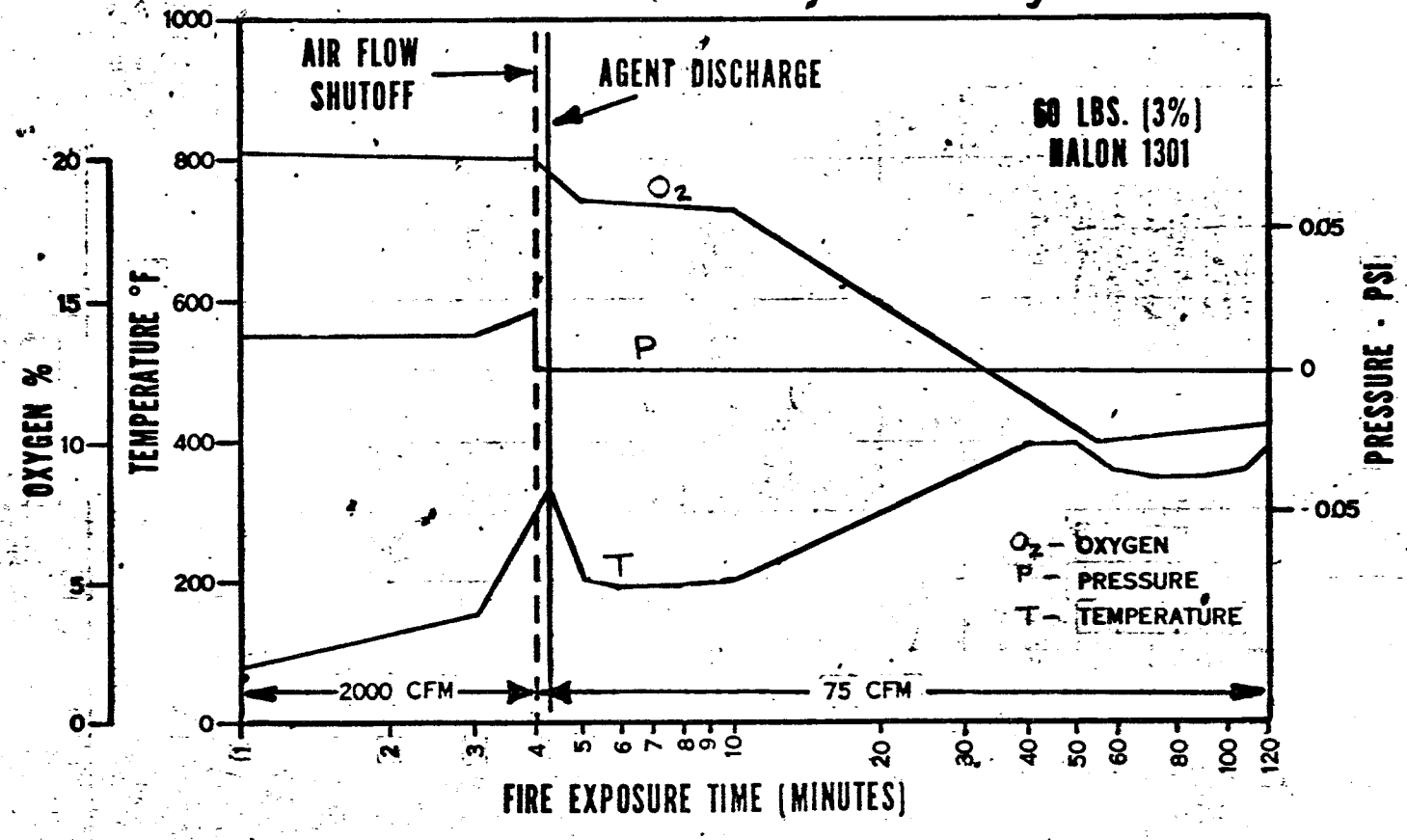
~~FIG. 4~~ URETHANE FOAM FIRE EXTINGUISHMENT PARAMETERS (HIGH RATE AGENT DISCHARGE)

SLIDE # 3

Temperature, Pressure, and Oxygen Recordings of an Airflow-Shutoff Fire-Extinguishing Test in the 10 Percent Load Configuration



Temperature, Pressure, and Oxygen Recordings of a Halon 1301 Fire-Extinguishing Test in the 10 Percent Load Configuration



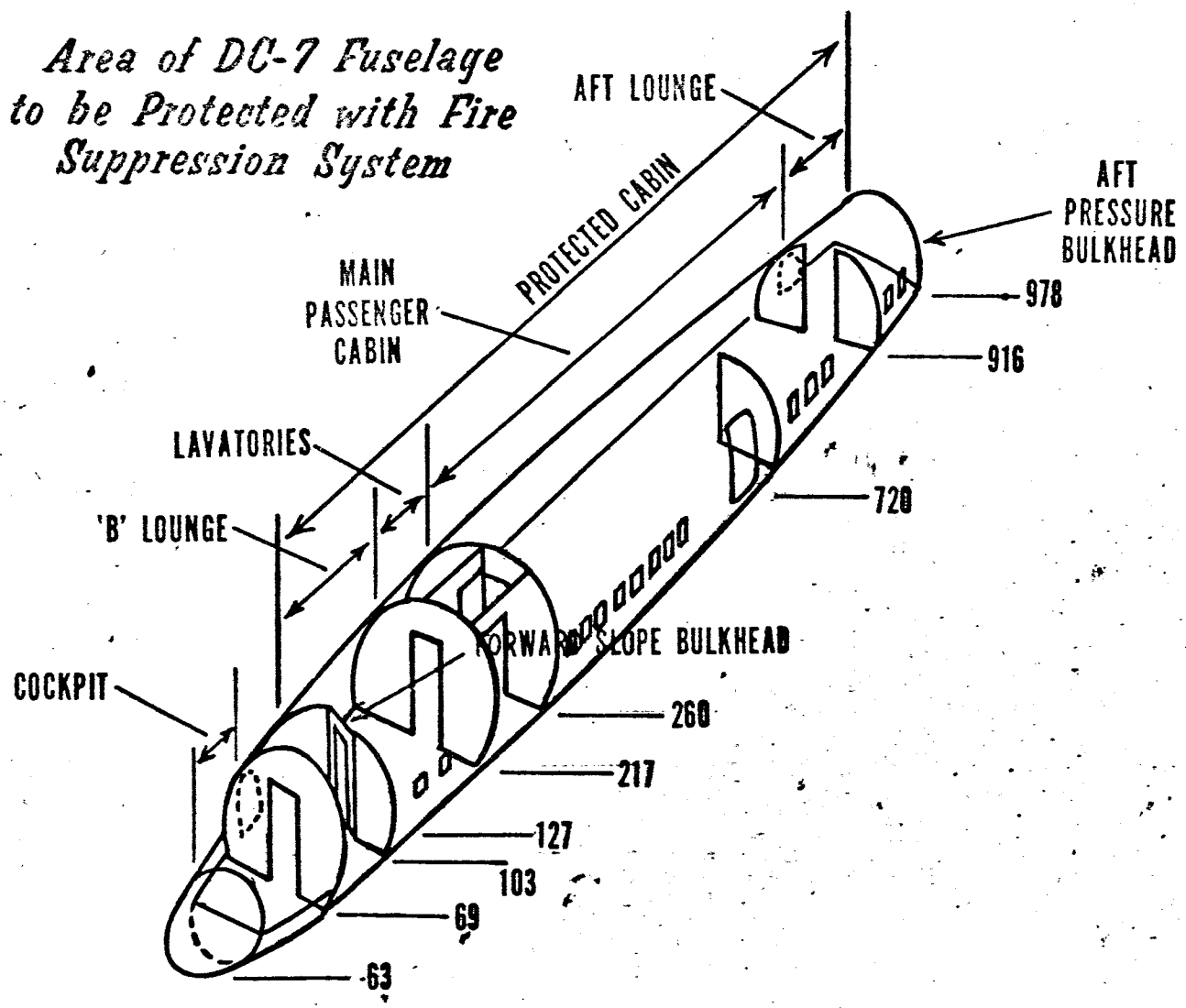
SLIDE # 5

PHOTO OF DC-7 PASSENGER CABIN

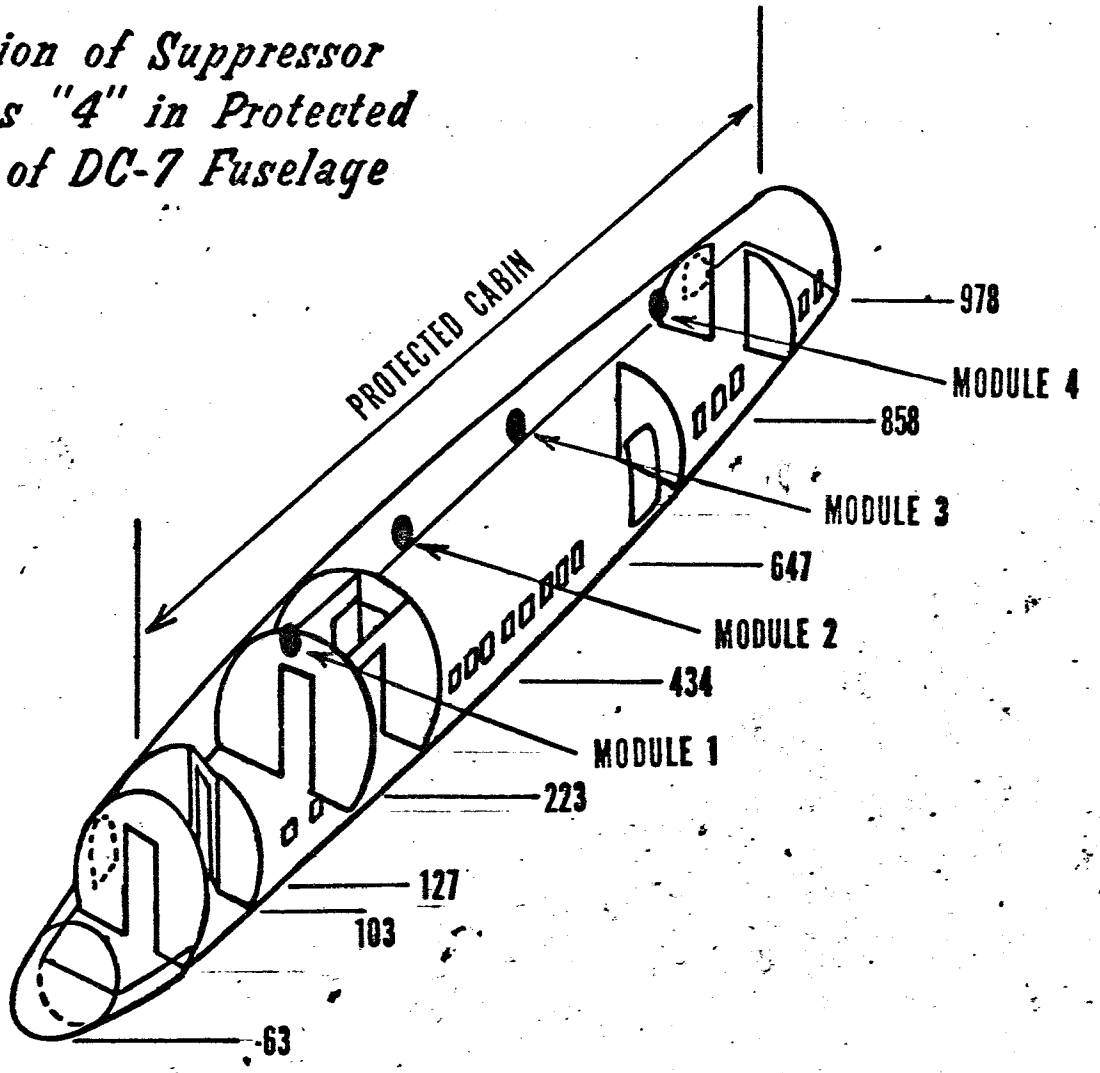
(NOT AVAILABLE)

SLIDE #6

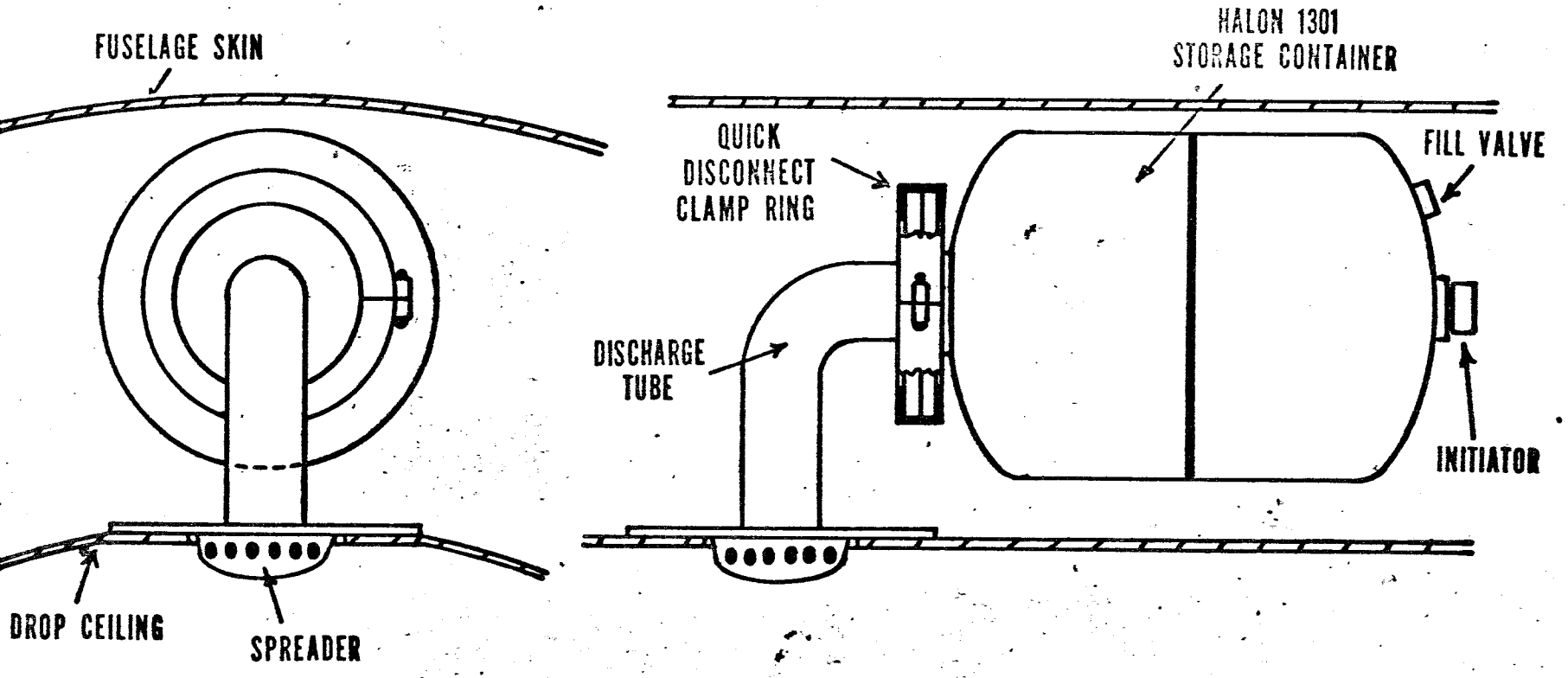
Area of DC-7 Fuselage to be Protected with Fire Suppression System



Location of Suppressor Modules "4" in Protected Cabin of DC-7 Fuselage

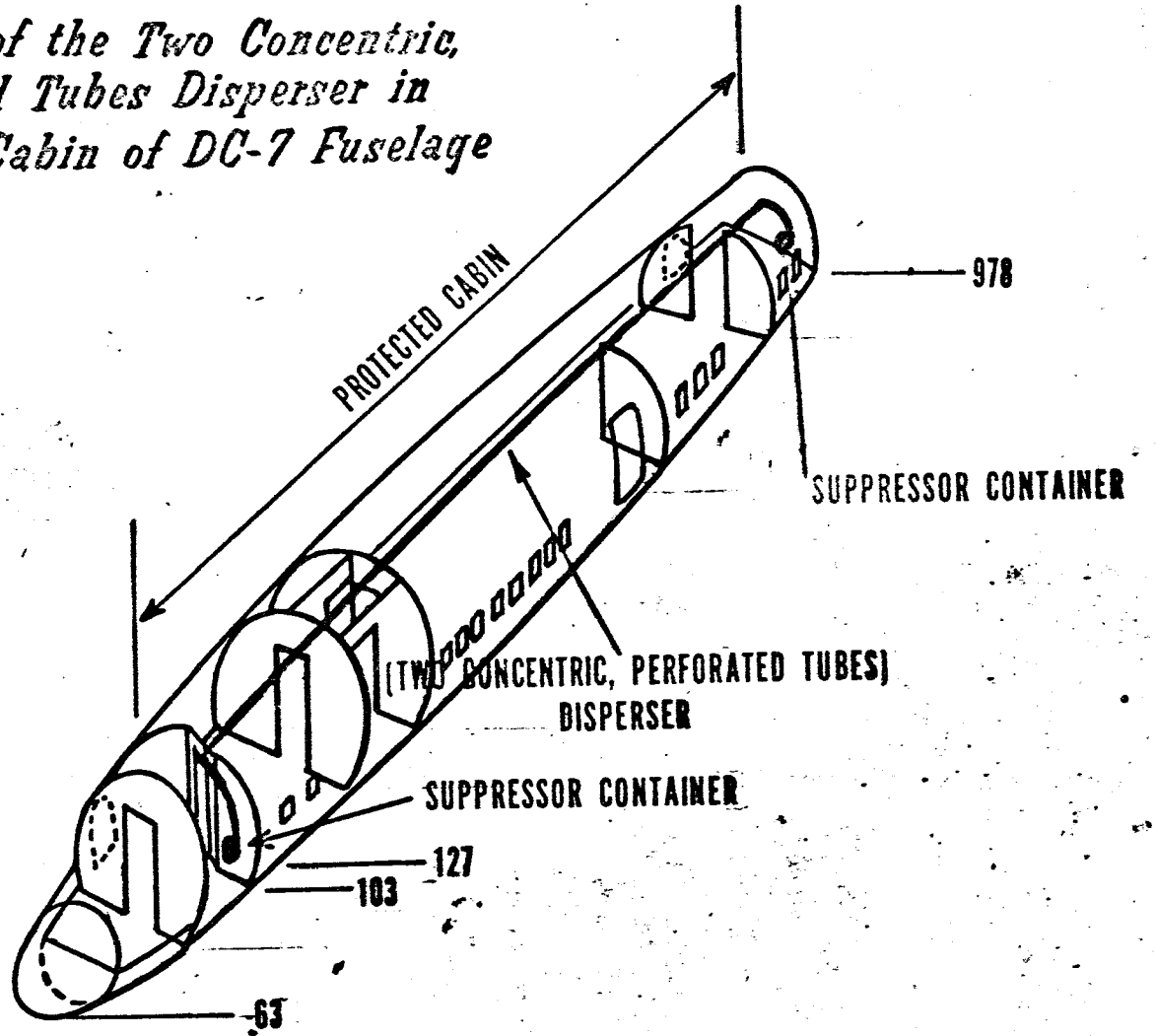


Halon 1301 Suppressor Module
Designed for Aircraft Installations

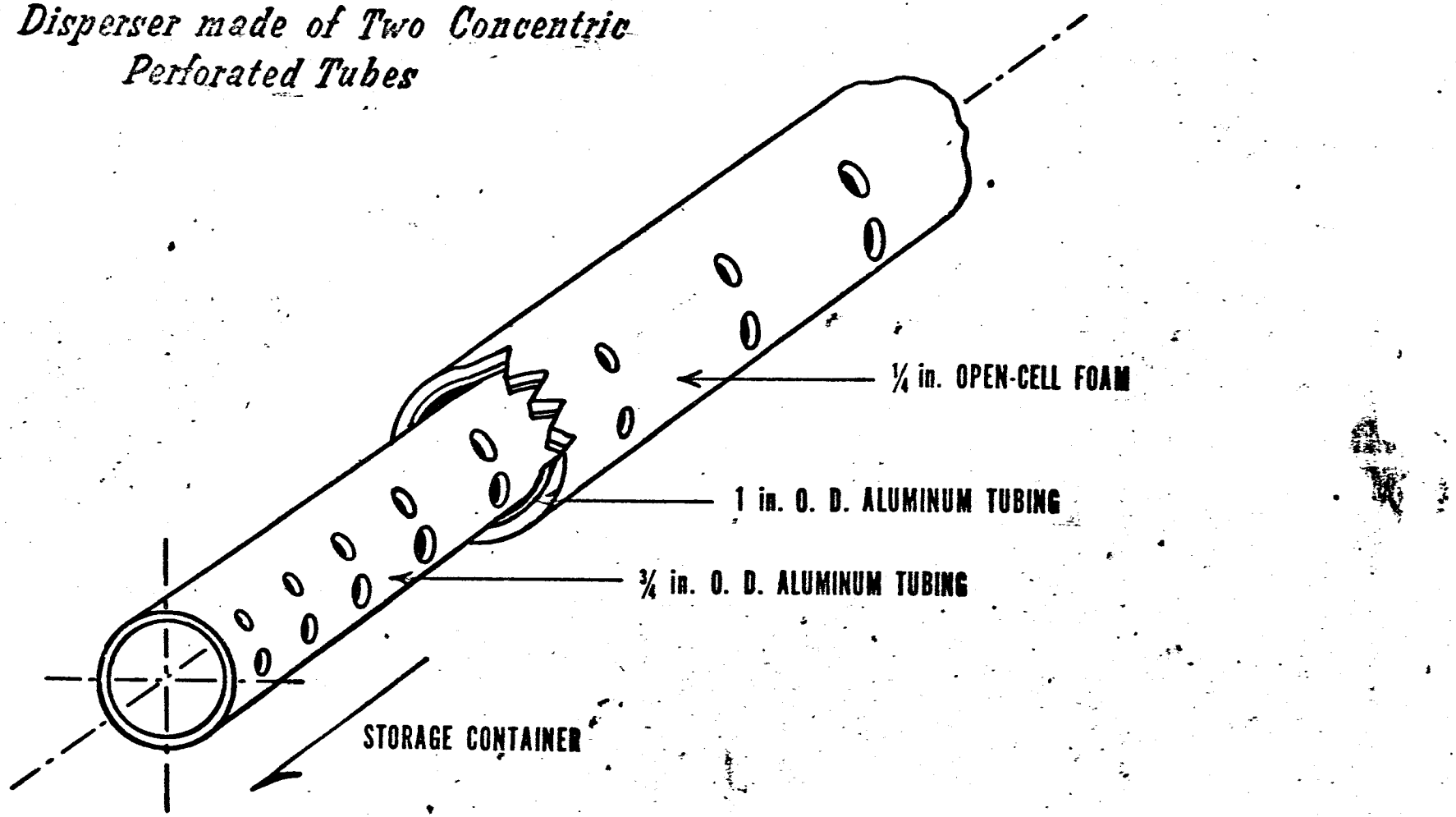


SLIDE # 9

Location of the Two Concentric, Perforated Tubes Disperser in Protected Cabin of DC-7 Fuselage



Disperser made of Two Concentric Perforated Tubes



SLIDE # 11

EVALUATION OF FIRE SUPPRESSION SYSTEM

1 AGENT DISTRIBUTION

- A - MIXTURE HOMOGENEITY
- B - SYSTEM REPEATABILITY
- C - AGENT CONCENTRATION AT REMOTE LOCATIONS
- D - EFFECT OF OPEN EXITS
- E - AGENT CONCENTRATION NEAR PASSENGERS

2 OTHER FACTORS AFFECTING PASSENGER COMPOSITION

- A - OVERPRESSURE
- B - NOISE
- C - SCATTERING OF LIGHTWEIGHT OBJECTS
- D - TEMPERATURE

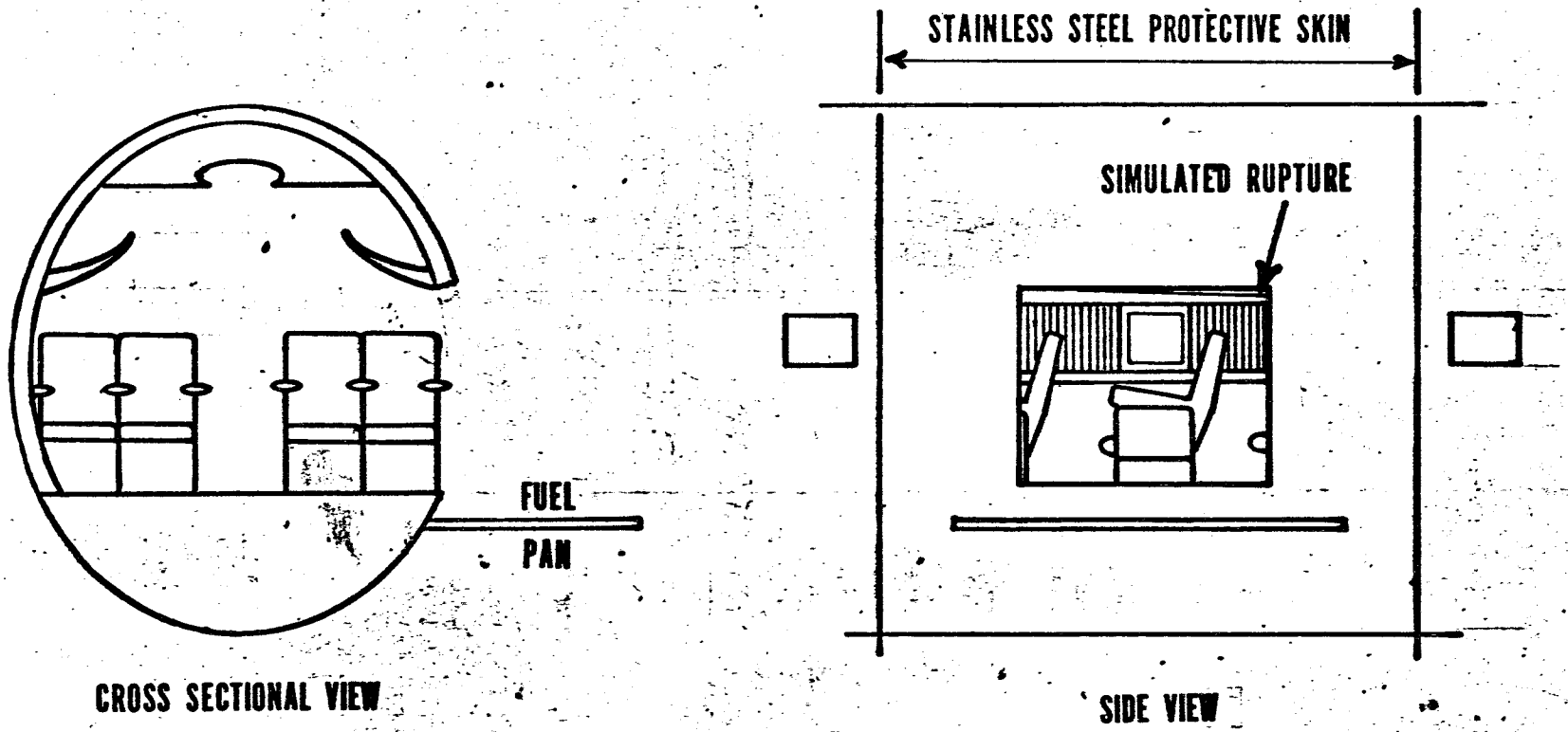
AUTOMATIC EXTINGUISHMENT OF CABIN FIRES

1 OBJECTIVE : EXTINGUISH FIRES WITH MINIMAL FORMATION OF TOXIC GASES AND SMOKE

2 EVALUATE OPTIMUM FIRE SUPPRESSION SYSTEM

3 THERMAL DETECTORS
- A - UNIT
- B - CONTINUOUS COMPARATOR

4 INSTRUMENTATION
- A - OXYGEN
- B : CARBON MONOXIDE
- C - SMOKE
- D - HALON 1301
- E - HYDROGEN FLUORIDE
- F - HYDROGEN BROMIDE
- G - TEMPERATURE
- H - 16 MM COLOR FILM



Test Setup Simulating Survivable Crash with Fuselage Rupture and External Fuel Fire