WIRE INSULATION DEGRADATION AND FLAMMABILITY IN LOW GRAVITY

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WIRE INSULATION DEGRADATION AND FLAMMABILITY IN LOW GRAVITY

ORGANIZATION OF PRESENTATION

- INTRODUCTION TO SPACECRAFT FIRE SAFETY
- CONCERNS IN FIRE PREVENTION IN LOW GRAVITY
- SHUTTLE WIRE INSULATION FLAMMABILITY EXPERIMENT
- DROP TOWER RISK-BASED FIRE SAFETY EXPERIMENT
- EXPERIMENT RESULTS, CONCLUSIONS AND PROPOSED STUDIES

SPACECRAFT FIRE-SAFETY CHALLENGES

FIRE SAFETY ALWAYS RECEIVES PRIORITY ATTENTION IN NASA MISSION DESIGNS AND OPERATIONS—THE PRIMARY APPROACH IS THROUGH FIRE PREVENTION.

CONVENTIONAL FIRE-SAFETY TECHNIQUES ARE DIFFICULT TO APPLY TO SPACECRAFT, HOWEVER.

- THE SPACECRAFT INTERIOR IS A CONFINED ENVIRONMENT, WITH LIMITED RESOURCES AND ALMOST NO ESCAPE POTENTIAL.
- THERE IS LITTLE PAST EXPERIENCE TO FURNISH ACCURATE RISK PREDICTIONS FOR DESIGN OF SAFETY SYSTEMS.
- THE EXTREME HIGH VALUE OF SPACECRAFT AND MISSION OPERATIONS OFFERS NO OPTIONS OR SACRIFICES.
- THE LACK OF NATURAL CONVECTIVE STRONGLY INFLUENCES FIRE CHARACTERISTICS.

INFLUENCE OF LOW GRAVITY ON FIRES

BUOYANCY (UP) AND SEDIMENTATION (DOWN) FLOWS ARE GREATLY DIMINISHED, AFFECTING

MASS TRANSFER OF FUEL AND OXYGEN

HEAT TRANSFER TO AND FROM FLAME ZONE

FLAME CHARACTERISTICS OF TEMPERATURE, COMBUSTION PRODUCTS, AND SO ON

FIRES IN SPACE ARE NOT NECESSARILY "BETTER" OR "WORSE"
BUT THEY ARE CERTAINLY "DIFFERENT"

WIRE-INSULATION BREAKDOWNS AND FIRE SAFETY

- BECAUSE OF THE LACK OF CONVECTIVE COOLING IN MICROGRAVITY, SURFACE TEMPERATURES RESULTING FROM BREAKDOWNS (OVERLOADS, ARC TRACKING) CAN EXCEED THOSE IN NORMAL GRAVITY.
- CONSEQUENTLY, IF NO REMEDIAL ACTION IS TAKEN, BREAKDOWNS MAY LEAD TO IGNITIONS AND FIRE SPREAD IN THE PRESSURIZED SPACECRAFT ATMOSPHERE.
- SHUTTLE MISSIONS HAVE EXPERIENCED A BREAKDOWN ON THE AVERAGE OF ONCE EACH 1600 HOURS OF OPERATION.
- NO IGNITION HAS RESULTED FROM THE SHUTTLE BREAKDOWNS, DUE TO THE MATERIAL CONTROLS AND THE IMMEDIATE RESPONSE OF THE CREW.
- THE SPACE STATION MAY HAVE A MORE SEVERE SAFETY PROBLEM IF BREAKDOWNS OCCUR DURING UNTENDED PERIODS.

SHUTTLE "BREAKDOWN" EXPERIENCE

FIVE REPORTED ELECTRICAL EVENTS

APRIL 1983	WIRES OVERHEATED AND FUSED AT MATERIAL PROCESSING UNIT
AUG. 1989	SHORT CIRCUIT FROM CABLE STRAIN AND INSULATION SPLIT AT TELEPRINTER
DEC. 1990	RESISTOR OVERHEATED FROM COOLING FAN FAILURE IN ELAPSED-TIME CIRCUIT OF DIGITAL DISPLAY UNIT
JUNE 1991	REFRIGERATOR-FREEZER FAN MOTOR FAILURE DUE TO COOLING FLOW LOSS
JULY 1992	BLOWN ELECTRICAL CAPACITOR IN MEDICAL APPARATUS

SIX REPORTED INTERMITTENT OR CONTINUOUS FALSE ALARMS

FIVE REPORTED FAILURES OF SMOKE DETECTOR SELF-TEST CONFIRMATIONS

NASA LEWIS
MICROGRAVITY WIRE-INSULATION FLAMMABILITY EXPERIMENTS

WIRE INSULATION FLAMMABILITY (NASA LEWIS, NIST):
SHUTTLE STS-50 GLOVEBOX, JUNE 1992

- LONG-TERM OBSERVATIONS OF MICROGRAVITY FLAMMABILITY AND FLAME SPREAD OVER HEATED WIRES WITH PROMOTED IGNITION AND AIR FLOW OPPOSED TO AND CONCURRENT WITH THE FLAME SPREAD

RISK-BASED FIRE SAFETY EXPERIMENT (UCLA):
NASA LEWIS 2-SEC DROP TOWER, SEPT. TO DEC. 1992

- VERY SHORT-TERM OBSERVATIONS OF MICROGRAVITY DEGRADATION AND IGNITION OF SELF-HEATED WIRES UNDER QUIESCENT CONDITIONS

WIRE-INSULATION BREAKDOWN EXPERIMENT (NASA)
NASA LEWIS AIRPLANE, PROPOSED

- 20-SEC OBSERVATIONS OF LOW-GRAVITY ARC-TRACKING AND IGNITIONS OF SELF-HEATED AND SHORTED WIRES WITH AIR FLOW AND ATMOSPHERIC OXYGEN AND PRESSURE VARIATIONS

WIRE INSULATION FLAMMABILITY EXPERIMENT

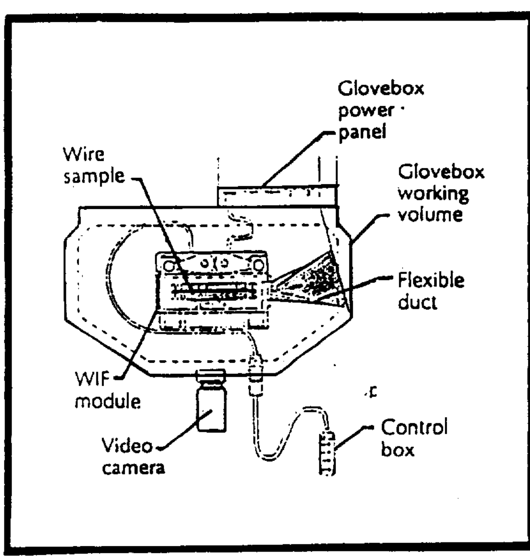
USML-1 GLOVEBOX ON SHUTTLE STS-50, JUNE 1992

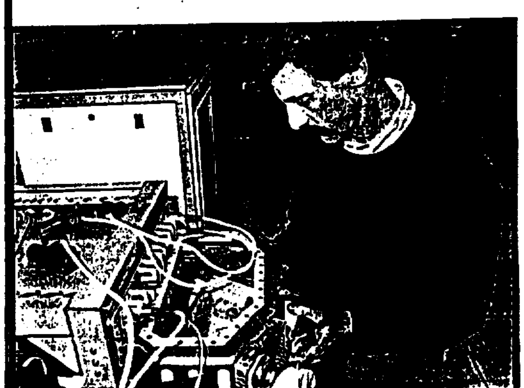
OBJECTIVES:
- FLAMMABILITY AND FLAME-SPREAD RATES OF WIRE INSULATION IN QUIESCENT MICROGRAVITY ENVIRONMENT
- EFFECTS OF CONTROLLED AIR FLOW ON ABOVE
- TRANSIENT HEATING AND OFFGASSING BEHAVIOR IN MICROGRAVITY

APPARATUS:
- FOUR SEPARATE TEST MODULES WITH ONE SAMPLE EACH FOR TESTS AT FOUR CONDITIONS OF HEAT LEVELS AND AIR FLOWS OPPOSED AND CONCURRENT TO FLAME SPREAD

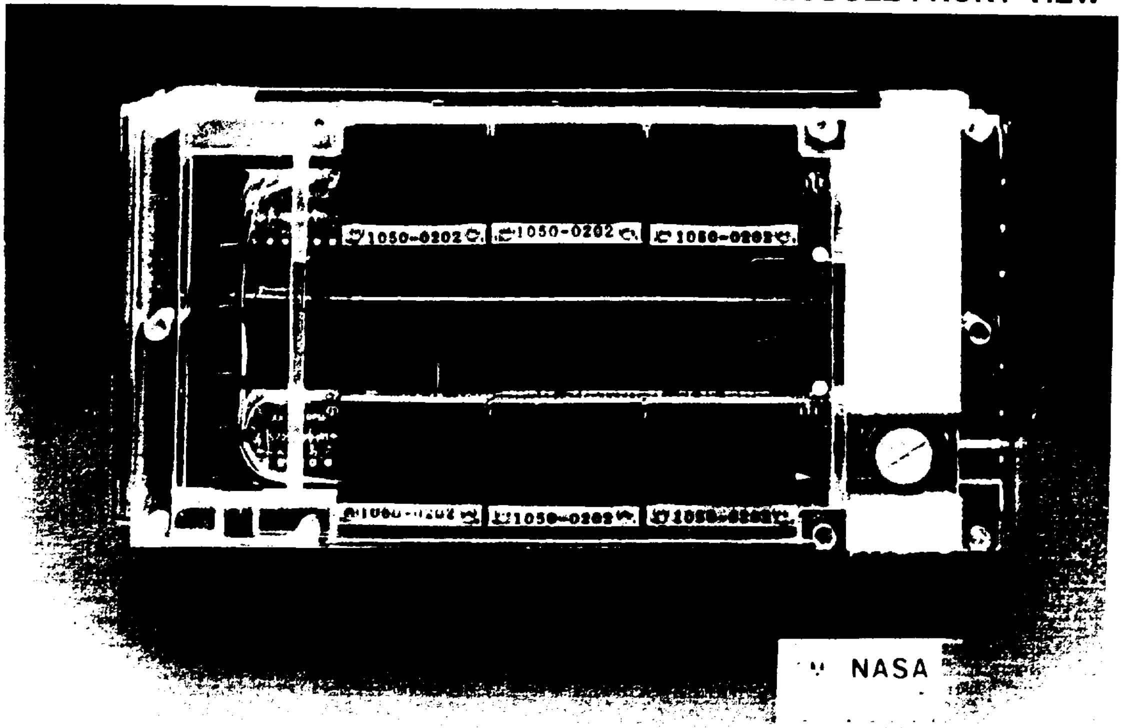
APPROACH:
- POLYETHYLENE-INSULATED NICHROME WIRE IS HEATED BY ELECTRIC CURRENT, THEN IGNITED BY EXTERNAL HOT WIRE IGNITER AT ONE END OF WIRE

GLOVEBOX WIRE INSULATION FLAMMABILITY EXPERIMENT (WIF) MODULE

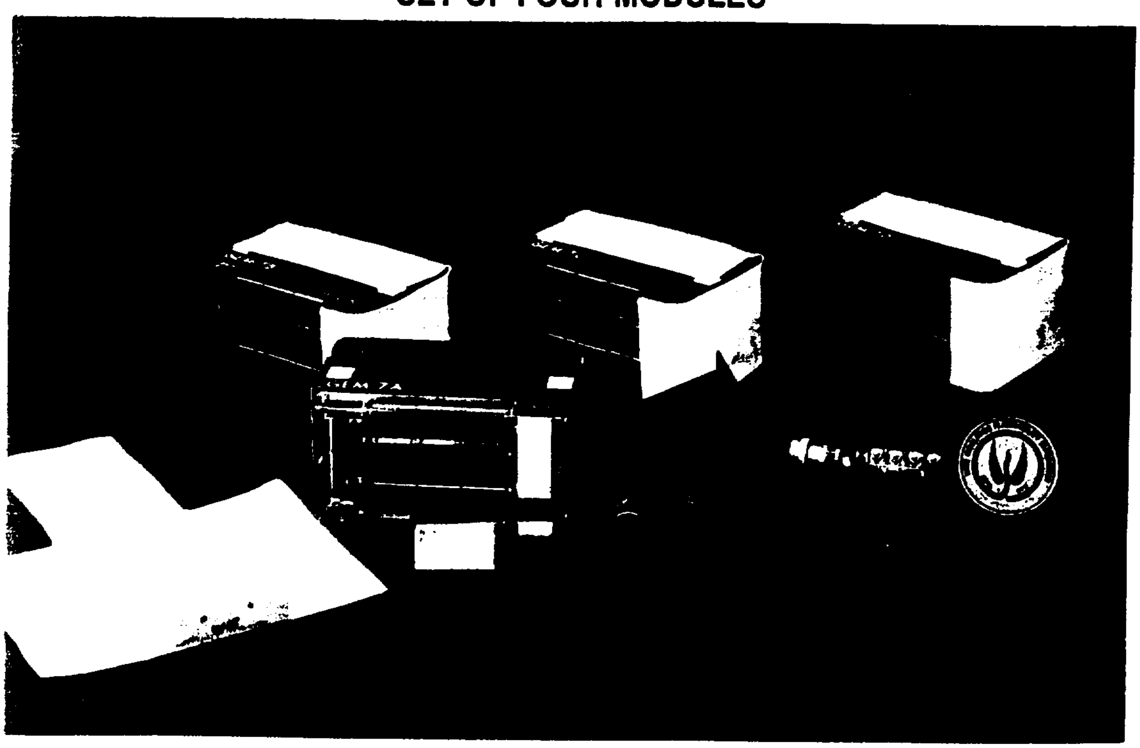




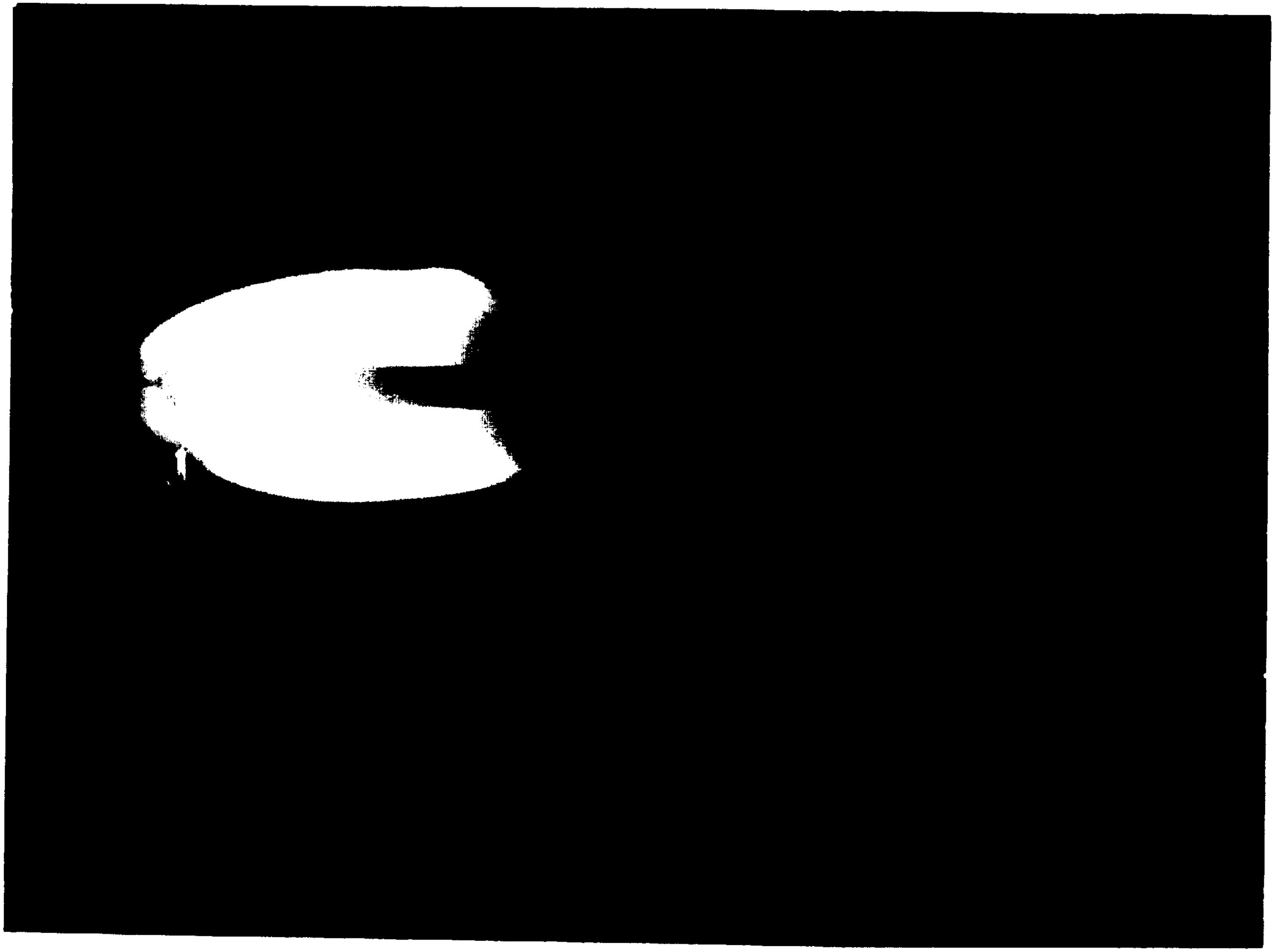
WIRE INSULATION FLAMMABILITY EXPERIMENT - MODULE FRONT VIEW



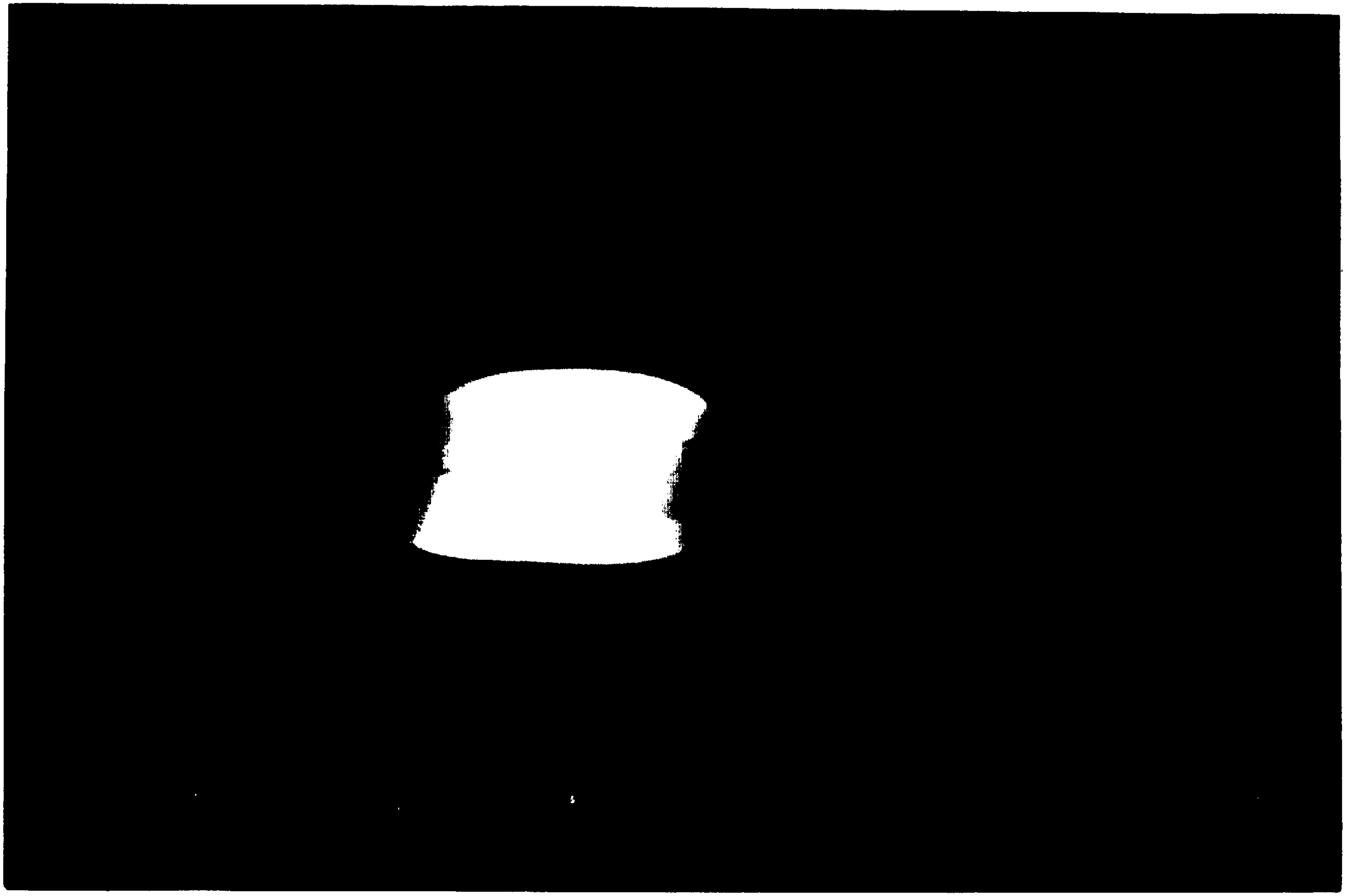
WIRE INSULATION FLAMMABILITY EXPERIMENT
SET OF FOUR MODULES



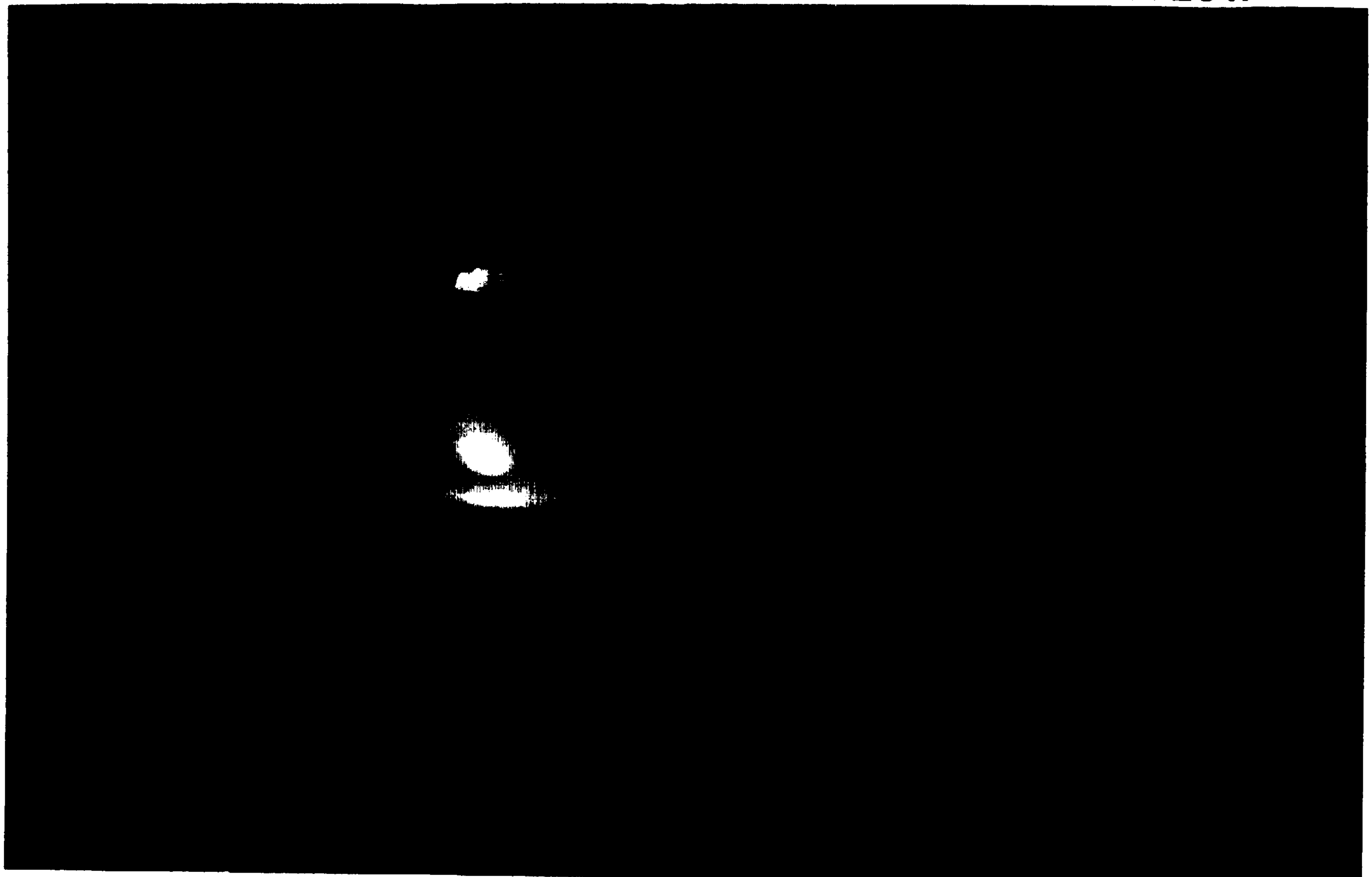
WIRE INSULATION FLAMMABILITY EXPERIMENT
FLAME PROGRESSING FROM LEFT TO RIGHT - CONCURRENT AIR FLOW



WIRE INSULATION FLAMMABILITY EXPERIMENT
FLAME PROGRESSING FROM LEFT TO RIGHT - OPPOSED AIR FLOW

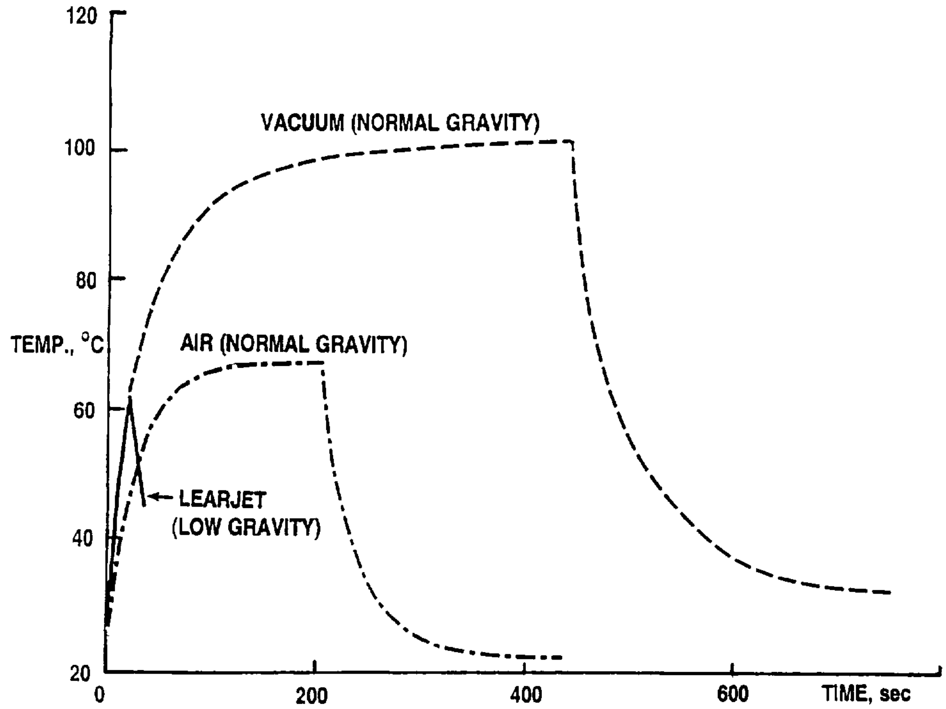


WIRE INSULATION FLAMM. EXPER. - CONCURRENT AIR FLOW



NOTE →ASYMMETRIC INSULATION DROPLET →GLOBULE EXPULSION

WIRE INSULATION FLAMMABILITY EXPERIMENT
SELECTED WIRE TEMPERATURE HISTORIES



WIRE INSULATION FLAMMABILITY EXPERIMENT
RESULTS AND CONCLUSIONS

BEHAVIOR IN MICROGRAVITY COMPARED TO NORMAL GRAVITY

- TRANSIENT HEATING RATES AND MAXIMUM WIRE TEMPERATURES ARE HIGHER THAN IN (NORMAL-GRAVITY) AIR BUT COMPARABLE TO THOSE UNDER VACUUM.
- FLAME-SPREAD RATE IS STRONGLY AFFECTED BY THE FORCED AIR FLOW. RATES ARE HIGHER FOR CONCURRENT FLOW THAN FOR OPPOSED FLOW. IN FACT, STEADY STATE WAS NEVER ACHIEVED IN CONCURRENT FLOW.
- MOLTEN FUEL FORMS SPHERICAL DROPS ADHERING TO WIRE.
- FUEL VAPORS FROM OVERHEATED WIRE CAN ACCUMULATE AND IGNITE.
- MEAN SOOT PARTICLE SIZE IS GREATER BY FACTOR OF 2 FOR CONCURRENT FLOW, BY 3 FOR OPPOSED FLOW; SIZE RANGE IS ALSO GREATER.

UCLA RISK-BASED FIRE-SAFETY EXPERIMENT

NASA LEWIS 2-sec DROP TOWER, SEPT.-DEC. 1992

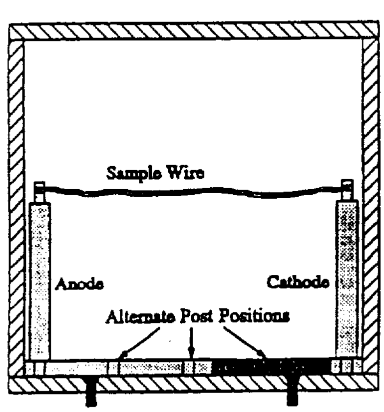
OBJECTIVES:
- QUANTITATIVE RISK ASSESSMENTS OF FIRE PROBABILITIES AND CONSEQUENCES IN ADVANCED SPACECRAFT
- SMALL-SCALE FIRE EXPERIMENTS TO FURNISH CHARACTERISTICS AND TIME CONSTANTS FOR ANALYSES
- EVENTUAL SPACE EXPERIMENT IN GASCAN

APPARATUS:
- CHAMBER WITH WIRE SAMPLE MOUNTED IN FRAME FOR DROP TESTING IN FREE-FALL MICROGRAVITY

APPROACH:
- TEFLON, TEFZEL (FLUORINATED ETHYLENE-PROPYLENE), AND KAPTON (POLYIMIDE)-INSULATED COPPER WIRES ARE OVERHEATED TO DEGRADATION OR IGNITION, TO REPRESENT A PROBABLE SPACECRAFT BREAKDOWN INCIDENT

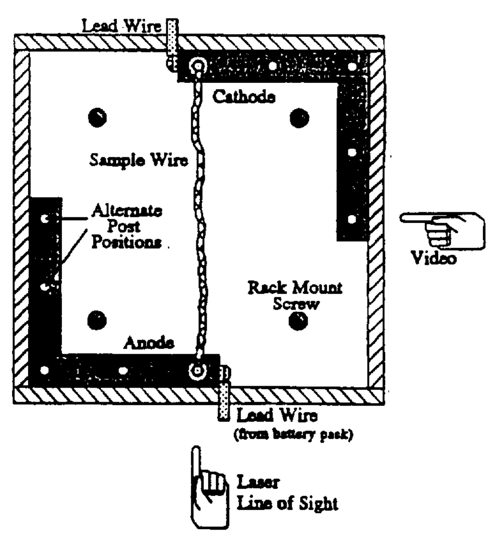
APPARATUS FOR HEATED-WIRE SCENARIO VALIDATION

MICROGRAVITY TEST SERIES AT LeRC



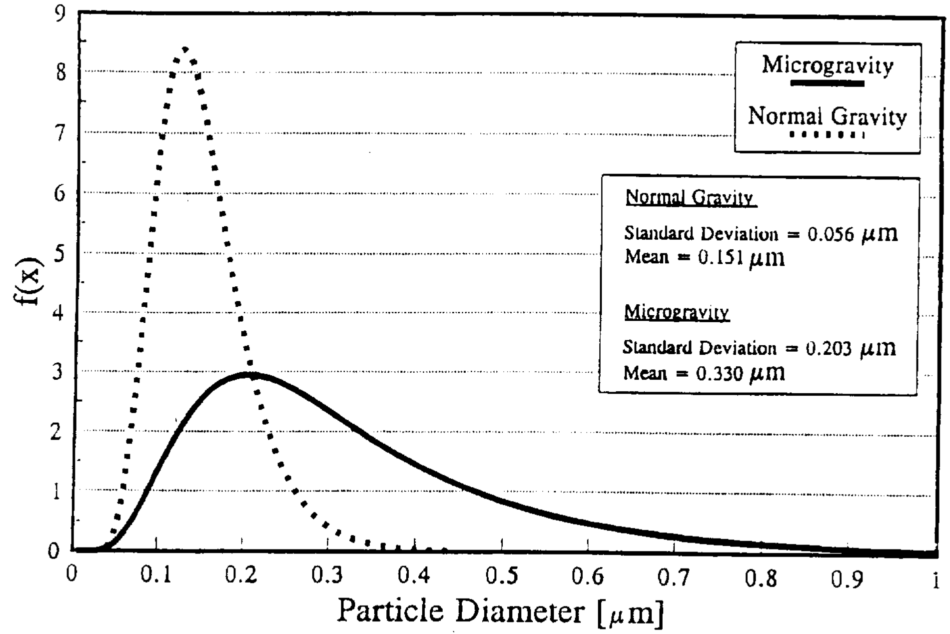
Front View

Plexiglass
Aluminum

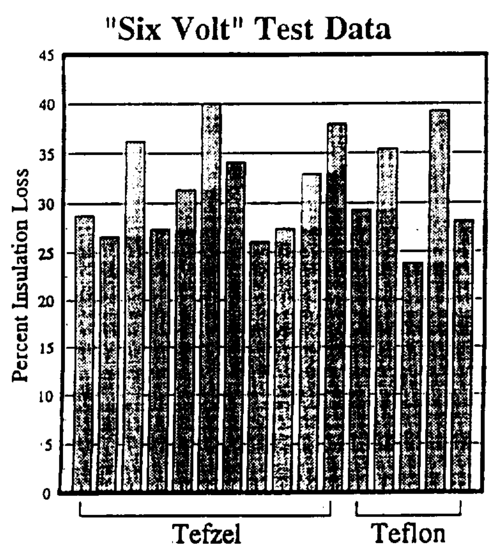


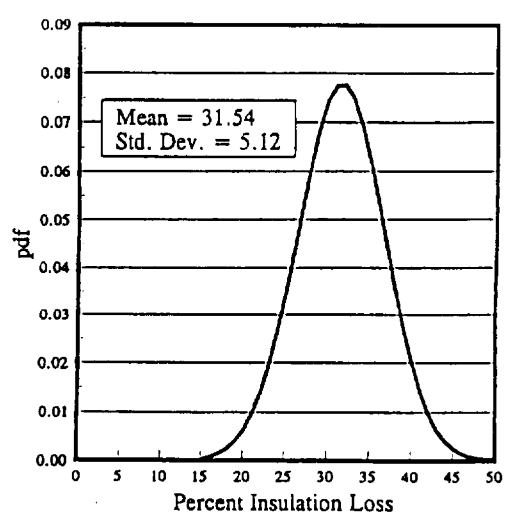
Plan View

LOG-NORMAL CURVE FIT FOR PARTICLE DIAMETERS

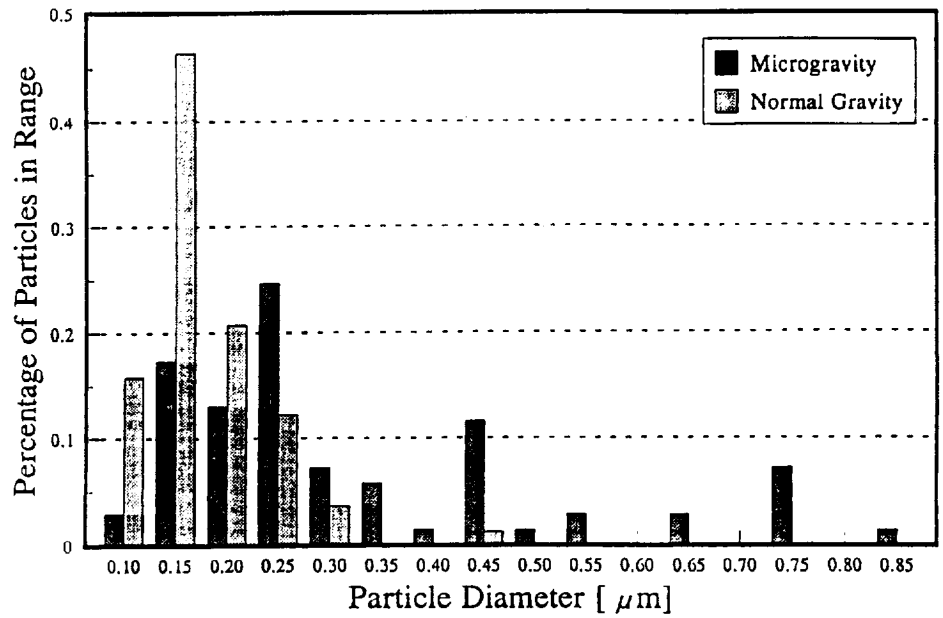


GROUND-BASED TEST RESULTS ON INSULATION MASS LOSS





PARTICLE DIAMETER HISTOGRAM



UCLA RISK-BASED FIRE-SAFETY EXPERIMENT

RESULTS AND CONCLUSIONS

BEHAVIOR IN MICROGRAVITY COMPARED TO NORMAL GRAVITY

- **KAPTON AND TEFZEL INSULATION (CONSIDERED NON-FLAMMABLE IN NORMAL GRAVITY) FLAMED IN SOME INSTANCES.**
- **DAMAGE TO WIRE INSULATION IS MORE SEVERE.**
- **MASS CONSUMPTION RATE OF BURNING INSULATION IS GREATER; HENCE, MORE SMOKE AND GASES ARE PRODUCED.**
- **MEAN SMOKE PARTICLE SIZE IS GREATER BY FACTOR OF 2.**
- **SMOKE-PARTICLE SIZE DISTRIBUTION IS WIDER (GREATER STANDARD DEVIATION).**

WIRE-INSULATION BREAKDOWN EXPERIMENT

PROPOSED FOR NASA LEWIS LOW-GRAVITY AIRPLANE FACILITY

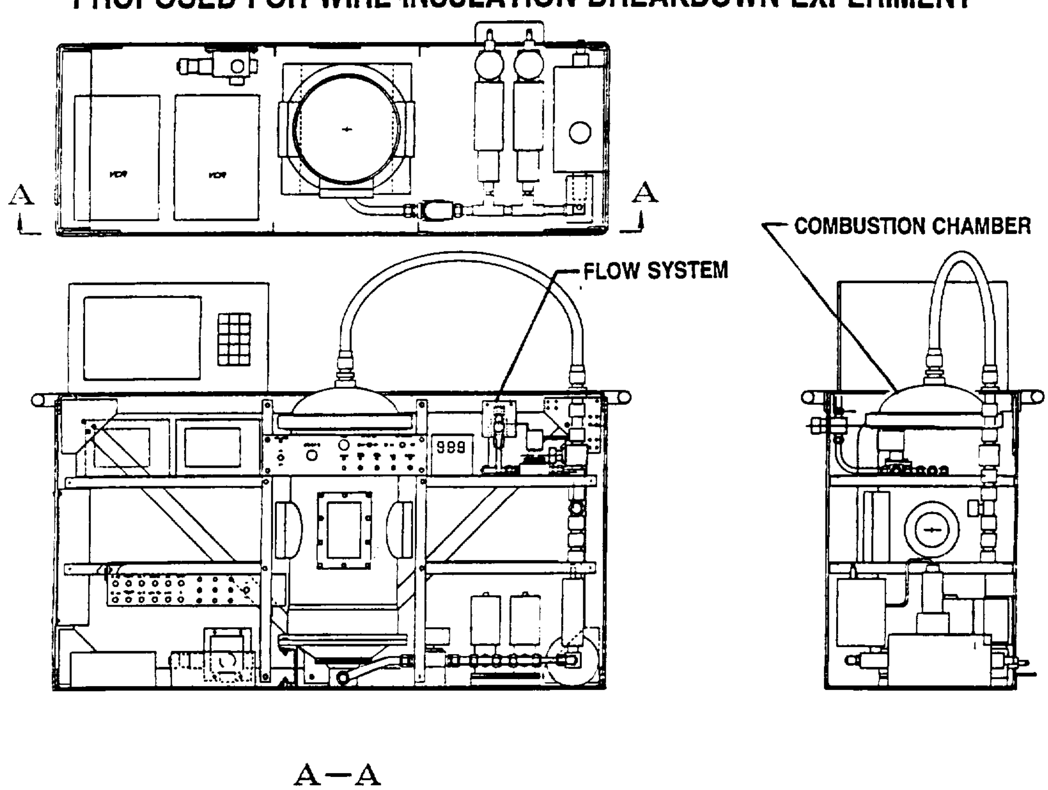
OBJECTIVES:
- ARC-TRACKING, DEGRADATION, AND IGNITION SUSCEPTIBILITY OF CURRENT AND ADVANCED WIRES INSULATIONS IN A LOW-GRAVITY ENVIRONMENT
- EFFECTS OF CONTROLLED AIR FLOW ON ABOVE
- EFFECTS OF ATMOSPHERIC PRESSURE AND OXYGEN

APPARATUS:
- TEST CHAMBER, FLOW SYSTEM, AND DIAGNOSTICS EXISTING; TEST FIXTURE AND EXPERIMENT PLAN TO BE DEVISED

APPROACH:
- STILL UNDER DISCUSSION

IN ADDITION TO THE PROPOSED AIRPLANE ACCOMMODATION, THIS EXPERIMENT IS AN EXCELLENT CANDIDATE FOR A SHUTTLE GLOVEBOX PROJECT.

LOW-GRAVITY AIRPLANE FIRE SAFETY FACILITY PROPOSED FOR WIRE-INSULATION BREAKDOWN EXPERIMENT



CONCLUSIONS

- THERE IS A FINITE PROBABILITY OF A BREAKDOWN (ARC TRACKING, FOR EXAMPLE) OCCURRING IN SPACECRAFT (ABOUT ONCE IN 1600 MISSION HOURS).
- THE LACK OF CONVECTIVE COOLING CAN LEAD TO HIGHER SURFACE TEMPERATURES FOLLOWING BREAKDOWNS. IN THE PRESSURIZED SPACECRAFT CABIN, THIS OVERHEATING CAN INCREASE THE PROBABILITY OF IGNITIONS.
- THE RELATIVE RANKING OF MATERIAL RESISTANCE TO DEGRADATION, OFF-GASSING, OR IGNITION MAY BE DIFFERENT IN MICROGRAVITY COMPARED TO NORMAL GRAVITY.
- THE AUTOMATED DETECTION OF SMOLDERING, DEGRADATION, OR OTHER BREAKDOWN "SIGNATURES" IN SPACECRAFT IS VERY DIFFICULT.
- ADDITIONAL EXPERIMENTAL DATA AND ANALYSES ARE CRITICALLY NEEDED TO SUPPORT RISK ASSESSMENTS, MATERIAL ACCEPTANCE STANDARDS, FIRE DETECTION, AND FIRE SUPPRESSION IN SPACECRAFT.