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PROBLEMS WITH AGING WIRING IN NAVAL AIRCRAFT**F. J. CAMPBELL****NAVAL RESEARCH LABORATORY****WASHINGTON, DC****ABSTRACT**

The Navy is experiencing a severe aircraft electrical wiring maintenance problem as a result of the extensive use of an aromatic polyimide insulation that is deteriorating at a rate that was unexpected when this wire was initially selected. This problem has significantly affected readiness, reliability, and safety and has greatly increased the cost of ownership of Naval aircraft.

Failures in wire harnesses have exhibited arcing and burning that will propagate drastically, to the interruption of many electrical circuits from a fault initiated by the failure of deteriorating wires. There is an urgent need for a capability to schedule aircraft rewiring in an orderly manner with a logically derived determination of which aircraft have aged to the point of absolute necessity.

Excessive maintenance was demonstrated to result from the accelerated aging due to the parameters of moisture, temperature, and strain that exist in the Naval Aircraft environment. Laboratory studies have demonstrated that MIL-W-81381 wire insulation when aged at high humidities followed the classical Arrhenius thermal aging relationship. In an extension of the project a multifactor formula was developed that is now capable of predicting life under varying conditions of these service parameters. An automated test system has also been developed to analyze the degree of deterioration that has occurred in wires taken from an aircraft in order to obtain an assessment of remaining life. Since it is both physically and financially impossible to replace the wiring in all the Navy's aircraft at once, this system will permit expedient scheduling so that those aircraft that are most probable to have wiring failure problems can be overhauled first.

AIRCRAFT WIRE SERVICE LIFE

PROBLEM

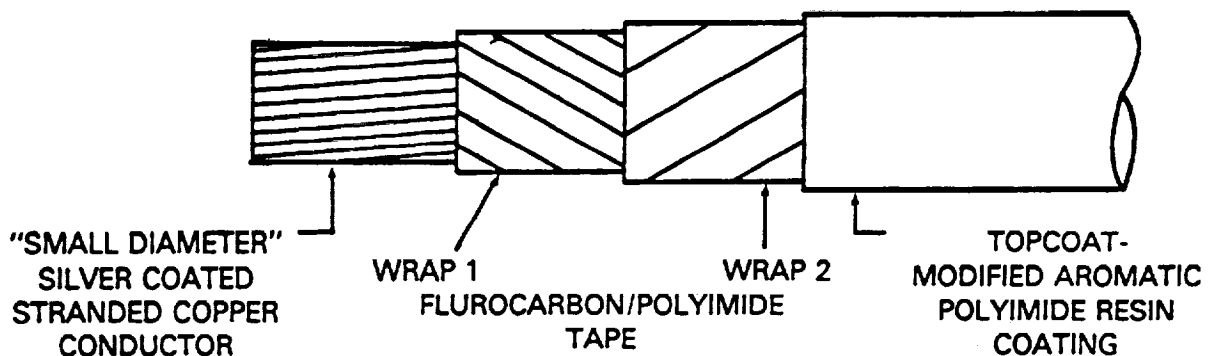
- **KAPTON WIRE INSULATION DETERIORATING PREMATURELY.**
 - **ACCELERATED BY MOISTURE, MECHANICAL AND ELECTRICAL STRESSES.**
 - **SERVICE LIFE SHORTER THAN DESIGN LIFE.**
- **CONSEQUENCES OF INITIAL PREMATURE FAILURES LEAD TO SHORT-CIRCUIT ARCING.**
 - **COMPLETE WIRING BUNDLE SEVERED WITH A SINGLE WIRE FAULT.**
- **NAVY NEEDS TO PLAN ITS MAINTENANCE BUDGET.**

OBJECTIVE

DEVELOP A METHODOLOGY FOR DETERMINING AN OVERHAUL SCHEDULE FOR KAPTON WIRED NAVAL AIRCRAFT.

MIL-W-81381/11
KAPTON

WIRE, ELECTRIC, FLUROCARBON/POLYIMIDE INSULATED,
MEDIUM WEIGHT, SILVER COATED COPPER CONDUCTOR, 600 VOLT,
NOMINAL 8.4 MIL WALL, 200°C

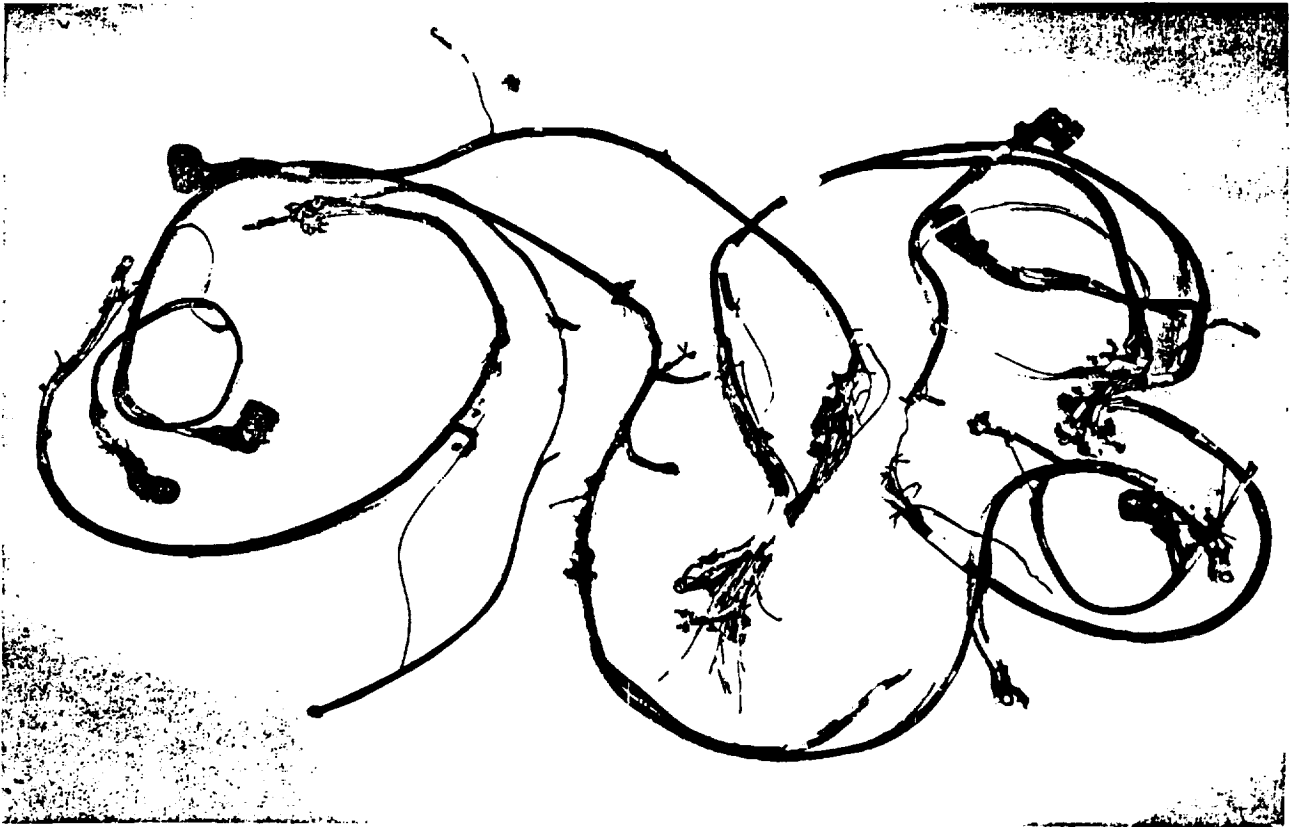


NAVAL AIRCRAFT CONCERNS

- DRY WIRE FLASHOVER AND BURNING
- WET WIRE TRACKING AND FLASHOVER

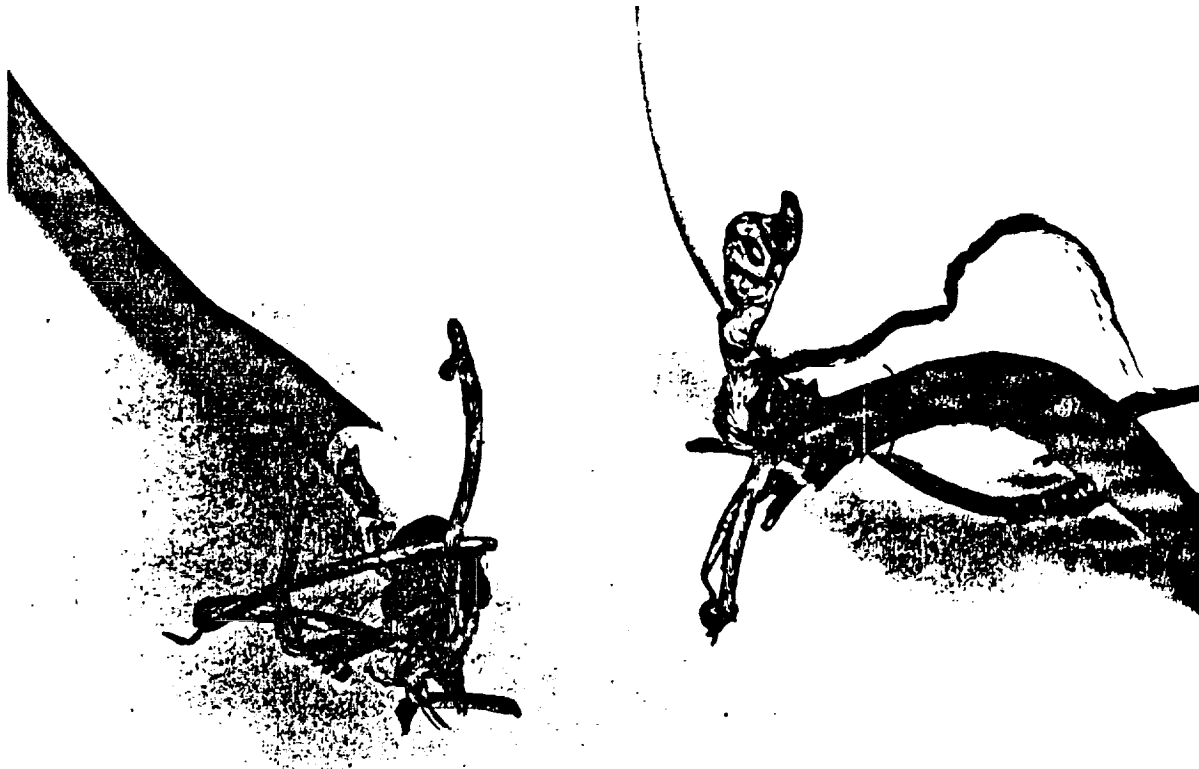
MAINTENANCE AND DESIGN
FOR FAULT PREVENTION
INITIAL WIRE SELECTION

- SYSTEMS AND FAILURE MECHANISMS



F/A-18 FORWARD FUSELAGE CABLE ASSEMBLY
INFLIGHT WIRE HARNESS CHAFING ARCING/FIRE
SEVERED LEFT AND RIGHT GENERATOR CIRCUITS

STRIKE FIGHTER SQUADRON 136
MAYPORT NAVAL AIR STATION, FLORIDA
8 APRIL 1987



AIRCRAFT WIRE SERVICE LIFE

PAYOFF

- o NAVY HAS APPROXIMATELY 4,000 A/C WITH KAPTON WIRING
- o NAVY NEEDS TO PLAN ITS WIRING REPLACEMENT BUDGET
\$1M TO \$4M FOR EACH A/C
- o SPECIFIC REPLACEMENT OF PROBLEM WIRING HARNESSSES AS ALTERNATIVE
- o NAVY IS SCHEDULING OVERHAULS
 - F-14 A TO D CONVERSION
 - S-3 A TO B
 - A-6 E TO F
 - EA-6B AVIONICS UPDATE

PLANNED F-14 A TO D CONVERSION SCHEDULE - 450 AIRCRAFT

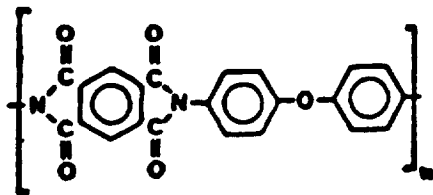
<u>YEAR</u>	<u>NUMBER OF A/C</u>
1990	6
1991	12
1992-2010	24 PER YEAR

APPROACH

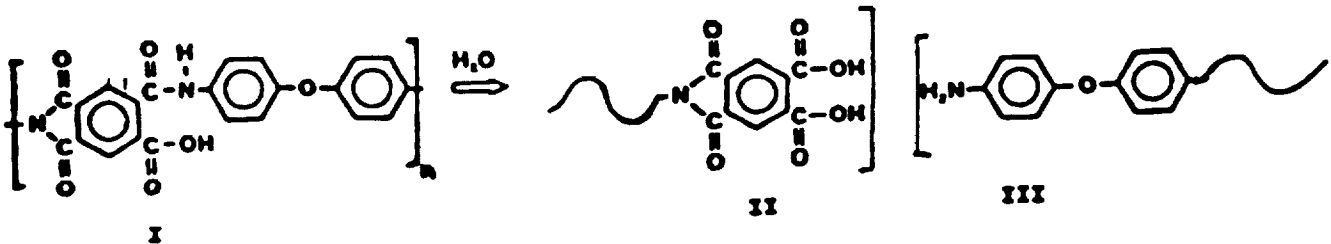
- DEVELOP ARRHENIUS PLOTS OF RELATIVE HUMIDITY SUPERIMPOSED ON TEMPERATURE-LIFE CURVES
- DEVELOP DATA BASE OF STRESS INFLUENCES ON THE HYDROLYSIS DEGRADATION RATE
 - MECHANICAL STRESS
- DEVELOP FORMULAS FOR EXPRESSING EFFECTS OF INTERACTIVE FACTORS
- DEVELOP MODEL FOR INTEGRATING CUMULATIVE DEGRADATION AS A FUNCTION OF TIME AT VARIOUS ENVIRONMENTAL AND STRESS FACTORS FROM A TYPICAL SERVICE DEPLOYMENT HISTORY.

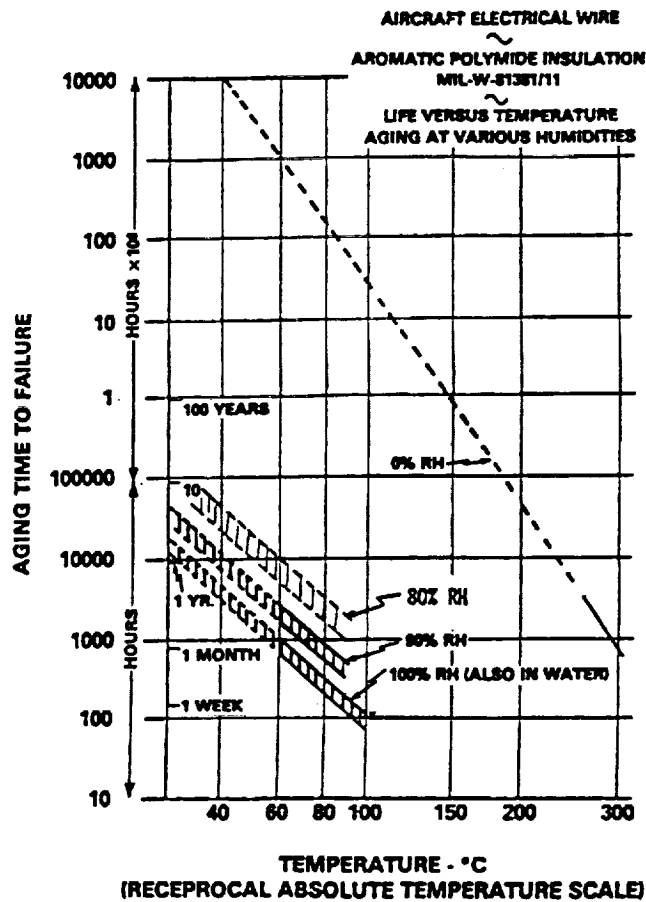
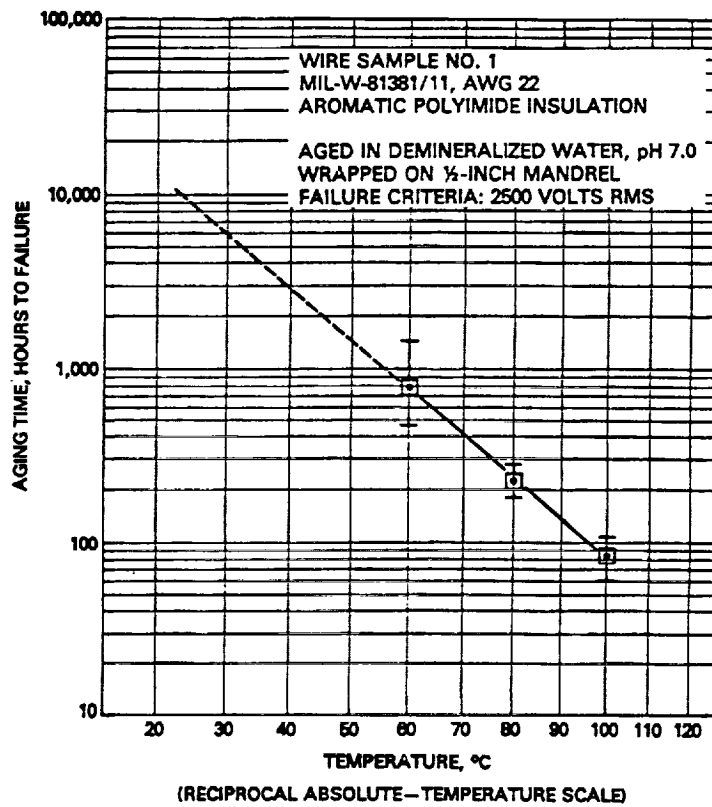
CHEMICAL MECHANISM OF KAPTON HYDROLYSIS

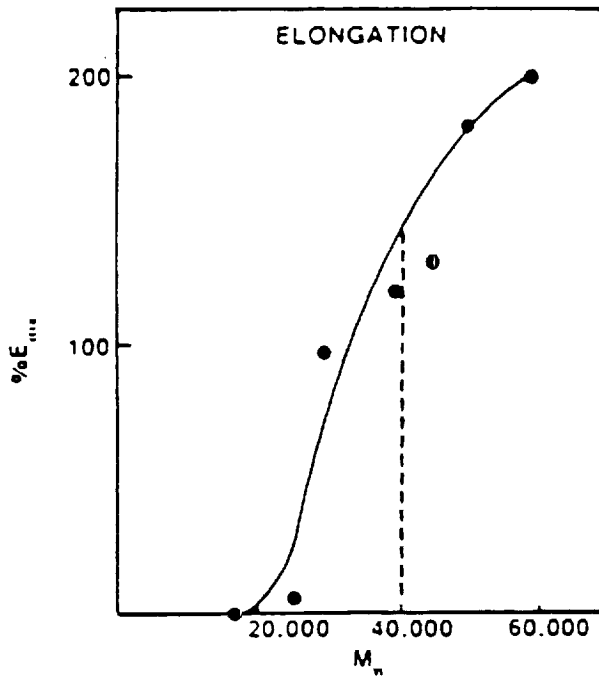
Polymer Chain Repeating Unit



Chain Splitting Reaction







$\% E_{mx}$ is the percent elongation (mechanical strain) at which the polyimide insulation fractures.

M_n is the number average molecular weight of the polyimide molecules in the insulation.

- Relationship between the elongation at break and the molecular weight of the polyimide. (Reference: M.L. Wallach, Journal of Polymer Science, A-2, 6, 953 (1968)).

WIRE INSULATION DETERIORATION MECHANISM

IS A MULTIFACTOR STRESS EFFECT

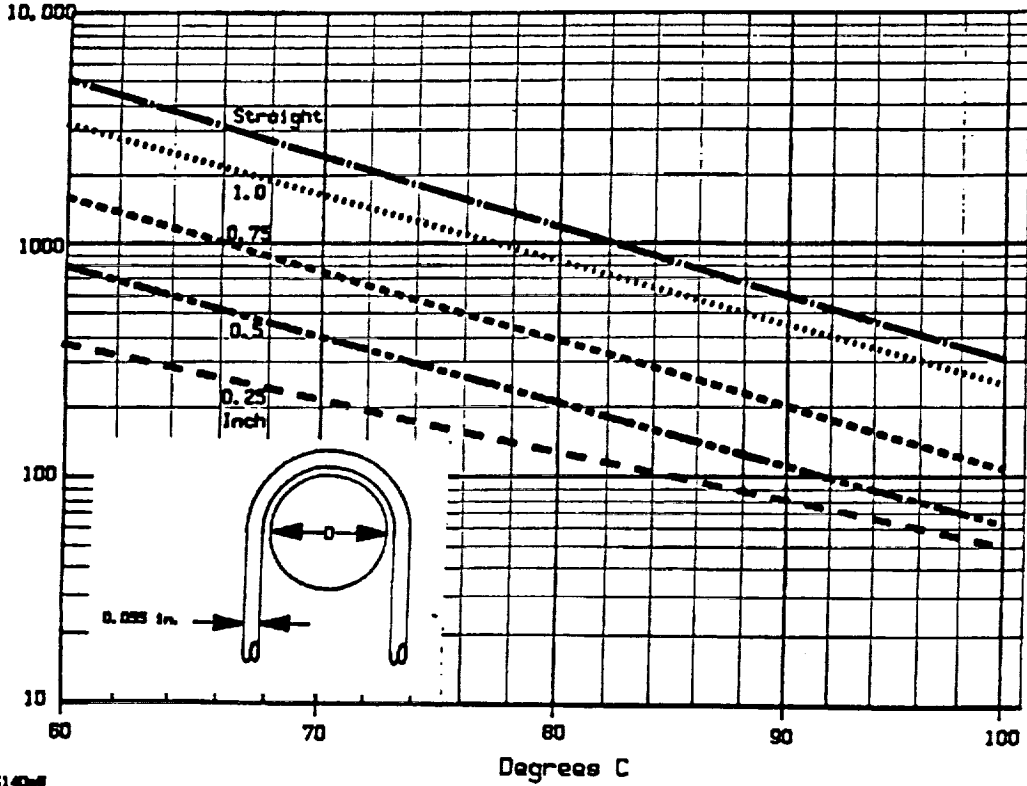
DETERIORATION RATE AS A FUNCTION OF BEND DIAMETER



$$\text{STRAIN (\%)} = \frac{100}{1 + D/d}$$

Hours
Life

Wire Insulation Life
81381 AWG # 20 @ Various Bending Dia., 100% RH



File A-61408

MULTI-FACTOR STRESS FORMULA

$$\text{LOG (Life)} = \text{INTERCEPT (R.H.)} - \text{SLOPE (D/d)/(T}^\circ\text{C} + 273)$$

GIVEN VARIABLES: TIME OF EXPOSURE TO RELATIVE HUMIDITY AND TEMPERATURE
BEND DIAMETER OF THE INSTALLED WIRE
WIRE DIAMETER

D/d	4.5	9.1	10.6	11.9	13.6	18.2	36.4	100	inf
-Slope(D/d)	3160	3223	3241	3256	3273	3330	3521	3821	4500

Relative Humidity	0.0 %	70 %	80 %	90 %	100 %
Intercept(R.H.)	0.0	-5.0	-5.9	-6.2	-6.8

A COMPUTER MODEL HAS BEEN DEVELOPED TO INTEGRATE SERVICE AGING PARAMETERS INTO THE FORMULA TO PREDICT LIFE OF THE WIRES, USING A PROGRAM WE HAVE WRITTEN INTO THE SOFTWARE PACKAGE, TRISOLVER.

AIRCRAFT WIRE SERVICE LIFE

OBJECTIVES ACCOMPLISHED

- * DEVELOPED A COMPUTER MODEL FOR INTEGRATING SERVICE CONDITIONS WITH AGING RATES TO CALCULATE REMAINING WIRE LIFE
 - IN ORDER TO SCHEDULE WIRING OVERHAUL PRIORITIES.

- * DEVELOPED A SYSTEM TO DETERMINE THE DEGREE OF WIRE INSULATION DETERIORATION BY LABORATORY ANALSES OF PERIODIC SAMPLES
 - IN ORDER TO TRACK REMAINING LIFE
 - SUPPORT CALCULATIONS MADE BY THE COMPUTER MODEL.

- * DEVELOPED A MULTI-FACTOR STRESS THEORY AND PROCESS FOR DETERMINING SERVICE LIFE OF ORGANIC MATERIALS BY ACCELERATED LABORATORY AGING EXPERIMENTS.

W I D A S

Wire Insulation Deterioration

Analysis System



W I D A S

PURPOSE

- o Determine amount of Kapton wire insulation deterioration BEFORE wire failure and/or destructive arcing occurs.

SYSTEM PROCEDURE

- o Select Aircraft to be Tested
- o Identify Locations
- o Remove Wire Samples
- o Test Samples in LAWIDA
- o Analyze Results
- o Report to Customer
- o Establish History Data Base

ORGANIZATIONS THAT USE KAPTON

U.S. NAVY

U.S. AIR FORCE

U.S. ARMY

N.A.S.A. SPACE SHUTTLE

NATO MILITARY AIRCRAFT

DOMESTIC AND FOREIGN COMMERCIAL AIRLINES

NUCLEAR POWER PLANTS

ACTION

- 0 AS A DIRECT RESULT OF THIS PROGRAM THE U.S. NAVY AND THE U.S. ARMY HAVE ISSUED DIRECTIVES ABOLISHING THE FURTHER USE OF KAPTON WIRE.

ADDITIONAL WIRING PROGRAM ASSIGNMENTS

- 0 AGING ANALYSIS OF KAPTON WIRING IN AGING AIRCRAFT.
- 0 STUDY ALTERNATE INSULATION SYSTEMS AND KAPTON HYBRIDS FOR MOST PROBABLE FAILURE MODES.
- 0 DEVELOP STANDARD TEST METHODS FOR DETERMINING SUSCEPTIBILITY TO HARNESS DESTRUCTION FROM PROJECTILES, CHAFING AND WET-TRACKING.
- 0 STUDY EFFECTS OF 270 VOLT DC ON WIRE LIFE, ARCING AND TRACKING RESISTANCE.
- 0 STUDY NEW TECHNOLOGY CIRCUIT PROTECTION METHODS.
- 0 DEVELOP METHODS TO DETECT INCIPIENT FAULTS.
- 0 STUDY LIGHTNING STRIKE EFFECTS ON COMPOSITE CONNECTORS.
- 0 MAINTAIN LIAISON WITH MILITARY AND INDUSTRIES OF U.S. AND ALLIED NATIONS ABOUT WIRING FAILURE CONCERNS.

