

AN ADVANCED ARC TRACK RESISTANT AIRFRAME WIRE

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St. Augustine, Florida

5/3-33
C834
P-13

HISTORICAL ANALYSIS:

*TENSOLITE COMPANY
TUFFLITE* 2000*

TUFFLITE 2000

DETAILED PRODUCT ANALYSIS

INDEPENDENT TEST DATA:

*BOEING BMS 13-60
US AIR FORCE/McAIR C.R.A.D. STUDY*

BENEFITS OFFERED BY TUFFLITE 2000

- Tensolite is a custom cable manufacturer
- Specializing in high temperature materials as the dielectric medium.
- Expertise lies in:
 - Aerospace/Airframe
 - Specialty Electronics
 - Expanded PTFE
 - Foamed Thermoplastics
 - Mil-spec
 - Engineered Solutions

*Tufflite 2000 is a tradename of a product manufactured by the Tensolite Company. Trade names or manufacturers' names are used in this report for identification only. This usage does not constitute an official endorsement, either expressed or implied, by the National Aeronautics and Space Administration.

- In-house technical services that facilitate application specific cable designs for the following markets:

- **Automated Test Equipment**
- **Telecommunications/Communications**
- **Surgical/Medical Instruments**
 - **Ultrasound Scanners**
 - **Minimally Invasive Surgical**
 - **High Resolution Video Camera**
 - **Patient Monitoring**
 - **Endoscopic (Powered Devices)**
- **Control/Instrumentation**
- **Oscilloscope**
- **Logic Analyzers**
- **Computer**
 - **Large System**
 - **Peripheral**
 - **Workstation**
 - **3D Graphics**
- **Aerospace**
 - **Airframe**
 - **GPI/TCAS**
 - **Satellite**
 - **Missiles**
 - **Military Avionics**

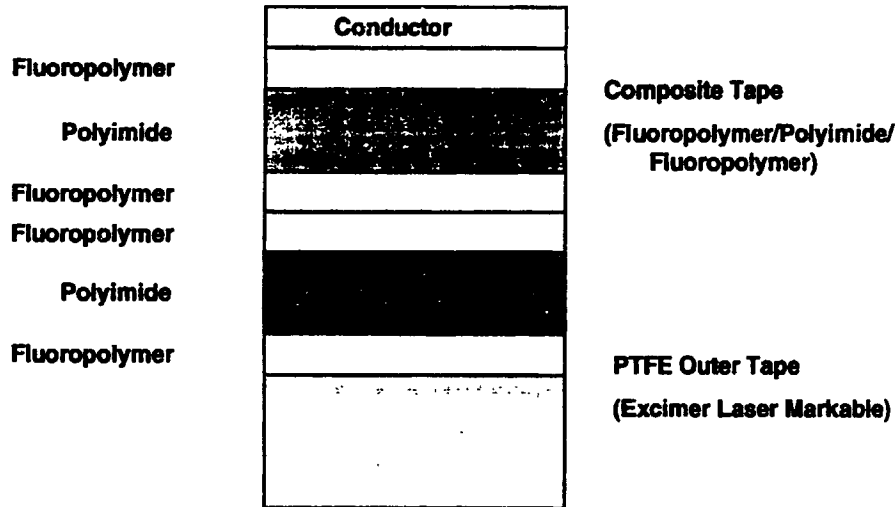
HISTORY OF THE TENSOLITE COMPANY

- 1941** Started Operations in Tarrytown, NY
- 1951** First to Use Teflon as Insulation
- 1960** Became a Subsidiary of Carlisle Corporation
- 1962** First to use Kapton as Insulation Material
- 1978** Moved to Buchanan, NY
- 1979** First to Introduce TPC Conductor with Kapton Insulation
- 1985** Patented the Process for Extruded, Expanded PTFE (Insulation used for high speed data transmission)
- 1988** Developed Tufflite 2000 Insulation System
- 1989** Moved to St. Augustine, FL
- 1993** Received Patent for Tufflite 2000

AIRFRAME WIRE DEVELOPMENT

- 1962** Kapton insulation system introduced to airframe manufacturers.
TENSOLITE: One of first to be approved for these constructions.
- 1979** Irradiated Tefzel insulation system introduced to airframe manufacturers.
- 1980** US Navy begins to report ARC TRACKING problems with Kapton Insulation.
- 1982** **TENSOLITE:** Begins design of multi-layered insulation system to reduce arc tracking.
- 1986** US Navy bans Kapton insulation from their aircraft. (US Air Force is undecided)
- 1987** US Air Force commissions McAir to determine: "New Insulation Systems for Aerospace Wiring Applications." C.R.A.D. Study (Customer Research . And Development)
- 1988** **TENSOLITE:** Improves multi-layered constructions; making an insulation system to answer all issues with minimal compromise:
TUFFLITE 2000
- 1989** Testing begins on US Air Force/McAir C.R.A.D. Studies.
Boeing begins testing for New General Purpose, ARC RESISTANT, Airframe wire.
TENSOLITE: Submits TUFFLITE 2000 samples to Boeing and Air Force tests.
- 1991** BMS 13-60 Document released concerning all purpose arc resistant wire.
TENSOLITE: First approved source for BMS 13-60 Document. US Air Force C.R.A.D. Study completed.
TENSOLITE: TUFFLITE 2000 found superior to all available airframe wires.

TUFLITE DESIGN



US AIR FORCE/McAIR C.R.A.D. RESULTS

1.	FILOTEX*	8.22
2.	TENSOLITE	8.23
3.	MIL-W-81391 (KAPTON)	9.21
4.	TELEDYNE THERMATICS	9.39
5.	NEMA	10.48
6.	MIL-W-22759 (XL ETFE)	11.38

* This submission is not manufacturable on an industrial scale. It was processed in laboratory conditions, and Filotex does not have plans to develop it into a production construction."

As quoted from US Air Force/McAIR C.R.A.D. Document, section 12.0; Observations.

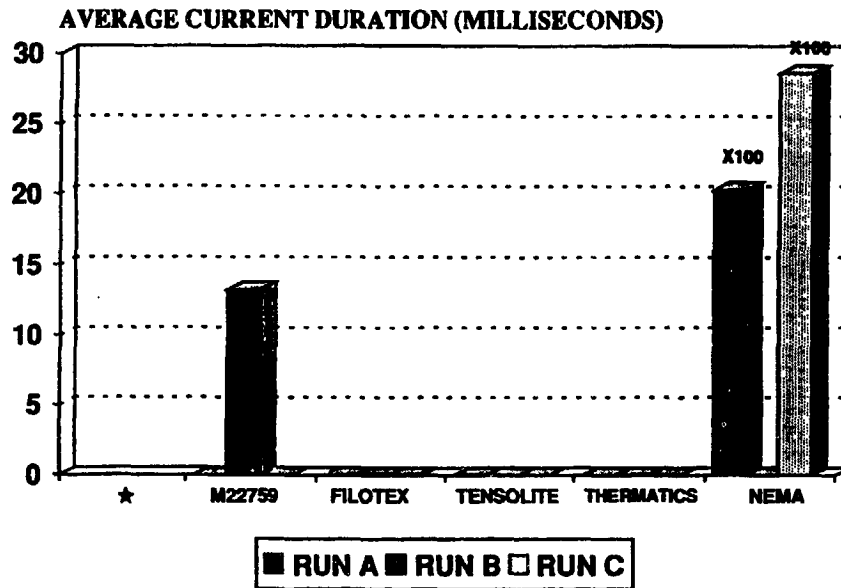
Screening Tests

Test	Document	Weight
• Finished Diameter	S-901	4.2
• Finished Weight	S-902	4.2
• Workmanship	S/M - 4.1.4	3.0
• Stiffness and Springback	S-708	4.2
• Dry Arc Resistance	S-301	5.5
• Flammability	S-801	4.3
• Toxicity	B0482	5.0
• Fluid Immersion	S-601	4.5
• Verification of Retained Properties:		
- Heat Aging (1,000 hr @ 200°C)		
- Abrasion	A-D09.16	5.5
- Dynamic Cut Through	S-703	4.5
- Flex Life	S/M - 3.9.6	5.5
- Notch Propagation	S-707	5.0
- Voltage Withstand	S-510	5.5
- Insulation Resistance	S-504	4.5
- Examine Product	S/M - 4.1.4	3.0
		Avg = 4.6

Full Performance Tests

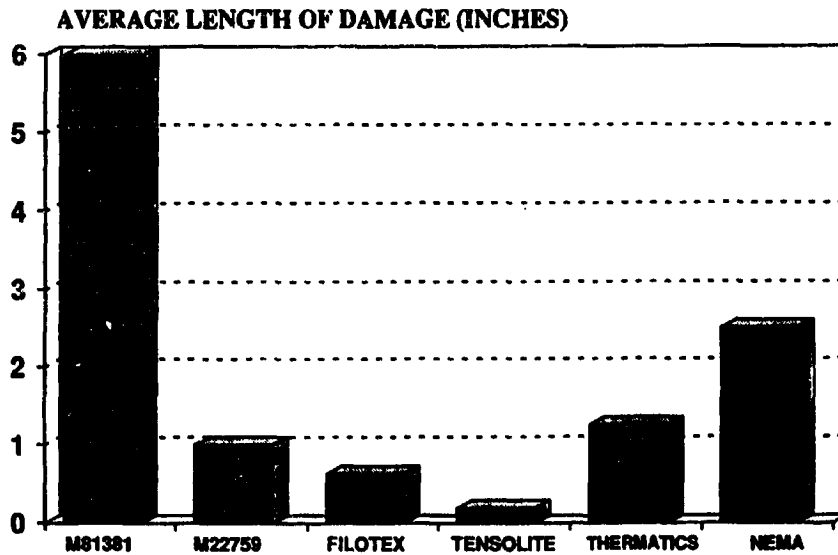
Test	Document	Weight
Dielectric Constant	S-501	2.0
Corona Inception and Extinction	S-502	3.3
Surface Resistance	S-506	2.2
Time/Current to Smoke	S-507	3.3
Wet Arc Tracking	S-509	3.2
Wire Fusing Time	S-511	3.2
Forced Hydrolysis	S-602	3.5
Humidity Resistance	S-603	4.5
Weight Loss (Outgassing)	S-604	2.2
Weathering Resistance	S-606	3.5
Wicking	S-607	3.5
Abrasion	A-D09.16	5.2
Cold Bend	S-702	3.3
Dynamic Cut Through	S-703	4.8
Flex Life	S/M - 3.9.6	4.7
Insulation Impact Resistance	S-705	3.1
Insulation Tensile Strength	S-706	3.2
Notch Propagation	S-707	5.0
Smoke Quantity	S-803	4.3
Thermal Index	S-804	4.0
Thermal Shock	S-805	4.0
Wire Surface Markability	DMS 2325	3.8
Crush Resistance	A-D3032	3.0
Aging Stability - SJ Cable	M-4.5.10	3.0
Jacket Wall Thickness - SJ Cable	F-1018	3.3
Wire-to-Wire Rub	DAC Procedure	TBD
Dry Arc Prop.-Large Gauge, Thermal Age	BSI No. 43	TBD
270VDC Dry Arc Prop.-No Protection	S-301	TBD
270VDC Dry Arc Prop.-With Protection	CuDust	TBD
270VDC Dry Arc Prop.-Large Gauge, Inorganic	CuDust	TBD

BSI DRY ARC PROPAGATION TEST RESTRIKE POWER APPLICATION TEST RESULTS



★ M81381 was not tested due to its propensity for Arc Tracking.

WET ARC TRACKING HARNESS TEST RESULTS 22 AWG, 5.8 MIL WALL, HOOK UP WIRE



DYNAMIC CUT THROUGH TEST RESULTS

22 AWG, 8.6 MIL WALL, AIRFRAME WIRE

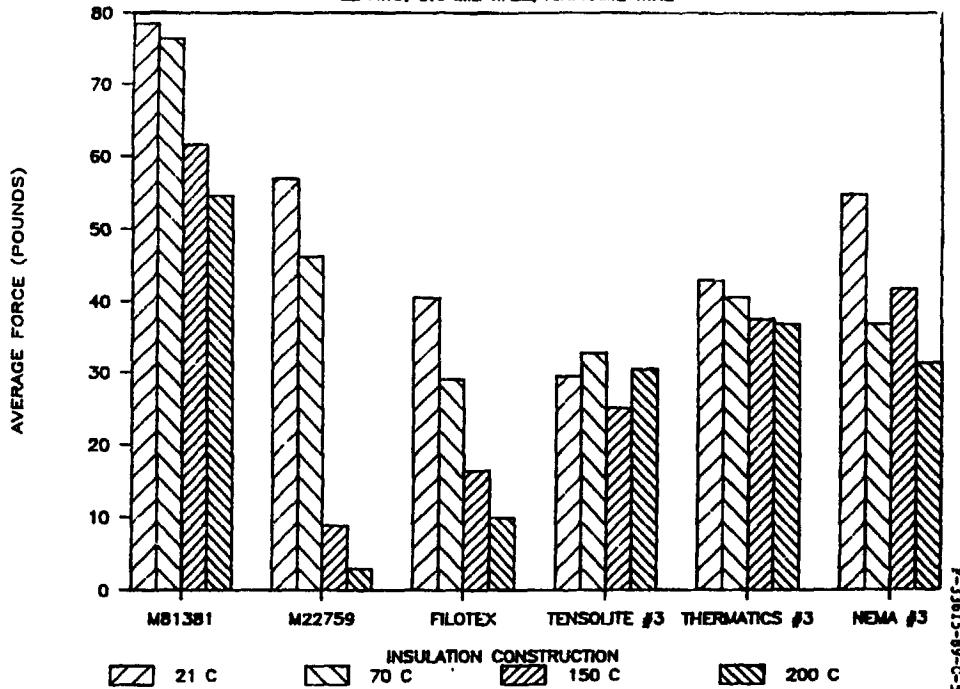
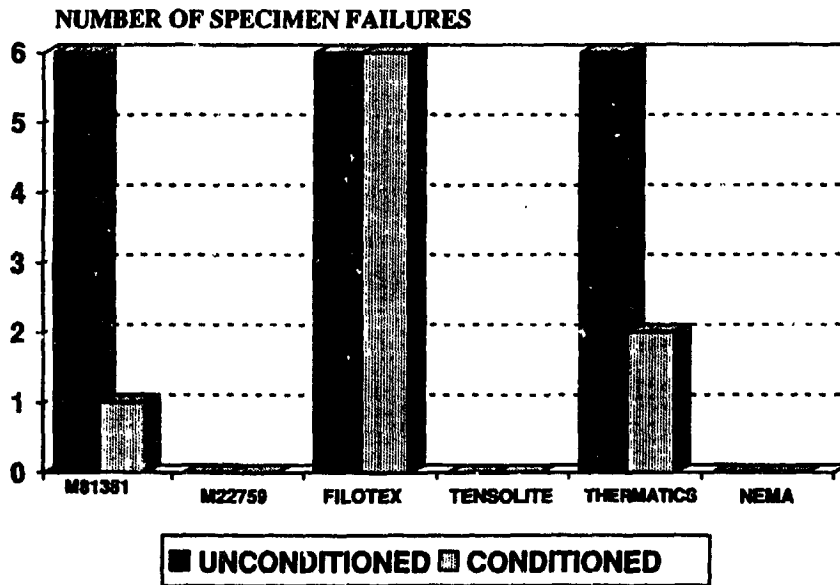


FIGURE 5.64 - DYNAMIC CUT THROUGH TEST RESULTS,
22AWG, 8.6 MIL WALL, AIRFRAME WIRE

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FORCED HYDROLYSIS TEST RESULTS

22 AWG, 5.8 MIL WALL, HOOK UP WIRE



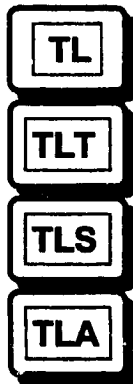
TUFFLITE 2000 PASSES ALL BMS 13-60 TESTS!

- ACCELERATED AGING**
- ARC RESISTANCE (Wet and Dry)**
- DYNAMIC CUT THROUGH**
- HUMIDITY RESISTANCE**
- WIRE-TO-WIRE ABRASION**
- FLAMMABILITY**
- SMOKE**
- WEIGHT**
- NOTCH SENSITIVITY**
- FLEXIBILITY**
- MARKABILITY**

ONE WIRE CONCEPT

ONE INSULATION SYSTEM

(Tufflite 2000 can be used in both PRESSURIZED and UNPRESSURIZED zones)



Standard Construction

Replacement for Mil Std 81381/11

Thin Wall Construction

Replacement for Mil Std 81381/7

Increased Wall Construction

Replacement for Mil Std 22759/6

TLS with Aluminum Conductor

Power Feeder Cable

AVAILABLE IN THREE TEMPERATURE RATINGS: (150 C, 200 C, 260 C)

TENSOLITE TLS Weight Savings Analysis:

Boeing -Everett (Wide Body) and Renton (Narrow Body) Switched to TLS for Unpressurized applications.

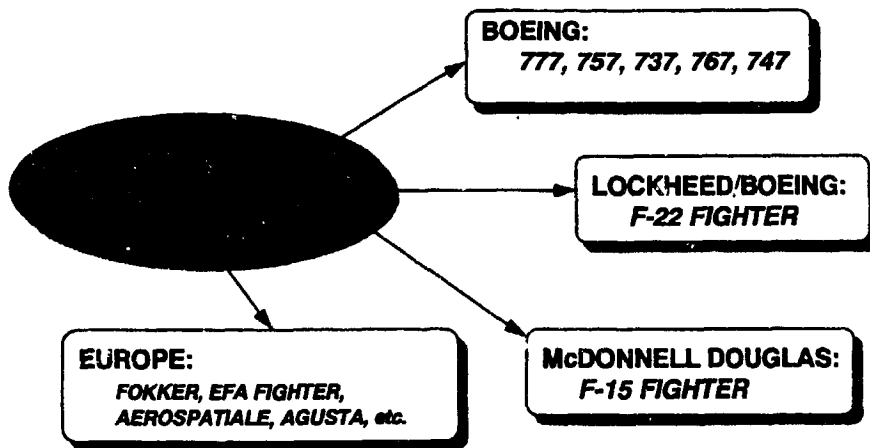
Tensolite TLS (Boeing BMS 13-60 Types 7 through 12) replaced:

- EMS 13-31 - Mineral filled Teflon Cables (triax)
- BMS 13-58 - PTFE/Kapton/Braid

TLS is replacing these wires in the Engine, Wings and Landing Gear areas of the plane

*** This switch to TLS from the older technology wiring saved Boeing 150 lbs. per 747-400! This was the entire weight savings budget for the electrical engineering group for 1994.**

A LOOK AT THE AIRFRAME INDUSTRY



Tufflite 2000 Provides

- Flight proven performance on Boeing 737 and 757 airplanes
- Tufflite is the airframe wire chosen for the McDonnell Douglas F-15 fighter for Saudi Arabia and for the Lockheed F-22 ATF.
- Air Force/McAir C.R.A.D. independent tests show Tufflite superior to Mil-W-81381 Polyimide and Mil-W-22759 irradiated ETFE wire in a battery of forty-three (43) tests.
- Excellent Wet and Dry Arc Track resistance - far superior to Mil-W-81381 or Mil-W-22759 crosslinked ETFE.
- Lighter weight and smaller in diameter than traditional Mil-W-81381 Polyimide or Mil-W-22759 crosslinked ETFE.
- Superior dynamic Cut-Through performance even at elevated temperatures.
- True 260°C performance by utilizing Nickel plated copper conductors.

BSI DRY ARC RESISTANCE TEST

SCOPE:

The Dry Arc Propagation Test patterned after the British Standards Institute procedure endeavors to simulate representative aircraft harness damage resulting from the creation of the arc.

TEST SAMPLE:

Three, seven wire harnesses were fabricated for each of the five thermally aged insulation samples tested, for a total of 15 harness specimens. The length of the harness was 28 in. and consisted of four 12 AWG, 8.6 mil wall airframe wires and three 16 AWG 5.8 mil wall, hook-up wires that had been thermally aged in a forced draft oven at 210 C for 504 hours.

TEST EQUIPMENT:

Generating system: Constant speed drive system rated at 75,000 volt-amperes, 115 V, three phase, 400 Hz, mounted to a 200 horsepower GE motor. DC power was supplied by two transformer rectifier units rated at 28 V DC with a current rating of 150 amps which provided a total rated DC current output of 300 amps.

BSI DRY ARC RESISTANCE TEST (continued)

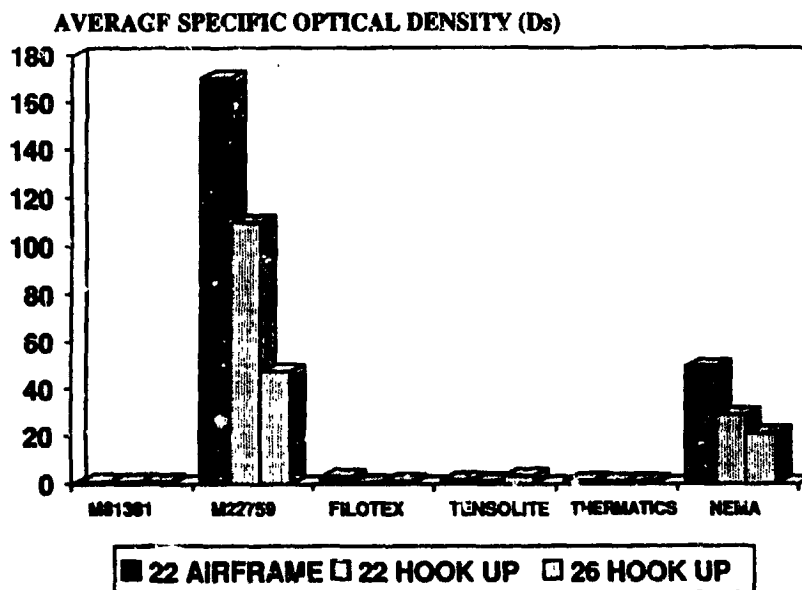
TEST PROCEDURE:

An aluminum blade was set in a guillotine type device attached to a reciprocating arm set to oscillate at 10 Hz. The wire harness was positioned so that the two notched wires were on top of the harness. The aluminum blade was then brought in contact with the exposed conductors with a force of 52 grams. The test was initiated by oscillating the arm to 10 Hz and energizing the AC and DC contactors to apply power simultaneously to the harness and observing arc conditions, a video camera was used for recording visual data. Power was maintained to the harness for 10 seconds after a circuit breaker opened. The blade was removed from the harness, the generator was brought off line, and the DC motor was turned off and data recorded. A restrike attempt was performed on the specimen 15 to 20 minutes after the initial strike. The blade was not included in the restrike attempt.

TEST RESULTS:

Current duration of the arc for the initial power application as well as the restrike were recorded. In addition, the visual harness damage was recorded for physical phenomenon, such as length of disintegration as a result of the arc, length of insulation charring, and the amount of exposed or recessed conductor.

SMOKE QUANTITY TEST RESULTS



BSI WET ARC TRACKING

SCOPE:

The Wet Arc Tracking Test was used to evaluate the performance of an unconditioned insulated wire sample under wet arc tracking conditions. This test became a BSI standard as of March 1989.

TEST SAMPLE:

One seven wire harness was fabricated from each of the following: (1) 22 AWG, 8.6 mil wall airframe samples, (2) 20 AWG 5.8 mil wall, airframe wire samples. Each of the seven wires were cut to a length of 400 mm. Two of the seven wires were notched. The notches were placed at 200 mm and 210 mm from one end. The harness was fabricated with wires positioned in a six around one configuration.

TEST EQUIPMENT:

Generating Equipment: Three phase, 115 V, 400 Hz, 100 amps per phase, laboratory power. A 100 mL pipette capable of delivering a drop sized to 20 mm at a rate of two drops/min was positioned 2 to 4 mm over the harness. The harness was attached to a Teflon plate with the solution positioned to flow over the first notch in the harness, then over the second notch, and out through a hole connected to a drain. The fluid consisted of 1% ammonium chloride and 0.02% iso-octylphenoxypolyethanol, a non-ionic wetting agent, diluted undistilled water.

TEST PROCEDURE:

The test was performed at room (ambient) temperature in a vented chamber. Electrolyte flow was initiated and power was applied to the harness. Care was taken to ensure that the electrolyte solution was flowing over the damaged sections and into the wire harnesses and not rolling off the sides. The test ran continuously on each harness for eight hours unless an active failure occurred. The test was observed for one of the following:

ACTIVE FAILURE: Either (1) Disruptive arc such that an open circuit occurred. (2) Tripping of the circuit breaker. (3) Arc propagation resulted. Following an active failure the electrolyte flow was stopped and power was maintained to the harness for 30 minutes. The circuit breakers were reset and power was reapplied for 15 minutes. There was no additional reset of the circuit breakers.

PASSIVE FAILURE: A passive failure will not trip circuit breakers, but will usually involve the progressive erosion of the conductors until an open circuit occurs on one or both of the damaged wires. A passive failure was detected by monitoring the indicating lights on each powered line.

TEST RESULTS:

The test results recorded the time for circuit interruption (active or passive failure), circuit breakers which tripped initially and after being reset, insulation resistance test, and description of the damage to the insulation including the length of charring.

TENSOLITE DATABUS CABLE:

Fly-By-Wire

BOEING 777

Tensolite developed the new databus cable for the Boeing 777. The proposed designs were subjected to extensive tests by Tensolite and Boeing engineers in order to develop a cable that would meet the stringent requirements.

DESIGN CRITERIA

The databus chosen for the Boeing 777 is ARINC 629 using digital autonomous terminal access control (DATAC). The design criteria for the cable was: lightweight, high speed capability, signal integrity, and signal isolation (very little leakage).

EXPANDED PTFE

The Tensolite design utilizing expanded PTFE insulation was chosen as the one and only design for the DATAC or "stub" cable.