NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

December 10, 1999

SYSTEMS GROUP CHAIRMAN FACTUAL REPORT ADDENDUM FOR AGING AIRCRAFT WIRE TESTING BY RAYTHEON SYSTEMS COMPANY

A. ACCIDENT: DCA96MA070

Location : East Moriches, New York

Date : July 17, 1996

Time : 2031 Eastern Daylight Time

Airplane : Boeing 747-131, N93119
Operated as Trans World Airlines (TWA) Flight 800

B. SYSTEMS GROUP

Chairman : Robert L. Swaim
National Transportation Safety Board
Washington, D.C.

C. SUMMARY

On July 17, 1996, at 2031 EDT, a Boeing 747-131, N93119, crashed into the Atlantic Ocean, about 8 miles south of East Moriches, New York, after taking off from John F. Kennedy International Airport (JFK). All 230 people aboard were killed. The airplane was being operated as a 14 Code of Federal Regulations (CFR) Part 121 flight to Charles De Gaulle International Airport (CDG) at Paris, France, as Trans World Airlines (TWA) flight 800.

The wreckage of TWA flight 800 was recovered from the ocean after weeks of submersion. The condition of the electrical wiring was documented in the Systems Group Chairman Factual Report Addendum for Aircraft Wire Inspections and Historical Reports, dated July 28, 1999.

To examine the material properties of wire that was of similar type[1] and age,[2] but which had not been exposed to ocean water, the Safety Board obtained wire samples from two Boeing 747 airplanes that had been manufactured in 1970 and 1973, and a DC-10 manufactured in 1973. The samples from the 747s were marked with the codes for BMS13-42A and -42B, and the samples from the DC-10 were marked with the military specification for similar materials and construction, MIL-W-81044/16. The samples were obtained randomly from pressurized fuselage locations that were protected from traffic, light, or other potential stresses.

The Safety Board contracted the Wiring Qualification Group of Raytheon Systems Company (Raytheon) to perform testing of these wire samples in accordance with the specifications for newly manufactured wire. The Raytheon report notes that the inspected wire samples exhibited contamination, including dirt, lint, paint and lubricant residues, smoke residue, and metal filings. Sporadic areas were found with cracked or damaged insulation, including areas with deep hot-stamp markings that directly led to localized crack formation. In almost all cases, the outer insulation cracked under performance testing and the electrical integrity was dependant on the condition of the inner layer. Attempts were made to understand the aging phenomenon involved with this type of insulated wire.

While some of the wire samples were found to have mechanically damaged insulation, the sections used for electrical testing were selected from those with intact insulation. (Separate tests of damaged insulation samples revealed that "roughly 20%" of the electrical property test points failed, according to Raytheon.) Raytheon's five "Overall Conclusions" about the material properties of the undamaged wire were:

- The wire submitted has definitely aged as indicated by the jacket failures in accelerated aging and lifecycle.
- The inner insulation continued to provide electrical integrity, as it was designed to do, although the outer jacket is losing its ability to mechanically protect the wire.
- The wire submitted for testing would be expected to perform adequately in the short term, provided there is no added stress beyond what it has experienced.
- The weak point in this wire type appears to be the lack of ability to maintain physical and electrical integrity during extended elevated thermal exposure with mechanical stress. As the wire ages, there is an increassed risk of dielectric problems, mechanical damage and loss of electrical integrity.
- No wire was submitted that was exposed to high levels of environmental exposure. Wire from these areas, wheel wells, leading edges, etc., would be expected to perform worse than the wire submitted.

[1] Wiring found in the wreckage of TWA flight 800 was marked with the manufacturing code for Boeing Material Specification BMS13-42A.

[2] The TWA 800 accident airplane, N93119, had been delivired in 1971.

The complete report submitted by Raytheon (Aging Aircraft Wire Testing, Project Number 50-01-142, 29 October 1999) is attached.

Robert L. Swaim
TWA 800 Systems Group Chairman

12/10/99

Raytheon

Raytheon Systems Company
6125 East 21St Street
Indianapolis, IN 46219-2058

29 October 1999

Refer to: 99/CNE560/JK60/075

National Transportation Safety Board
490 L'Enfant Plaza, E., SW
Washington, DC 20594
Attn: Mr. Bob Swaim

Subject: SUBMITTAL OF TECHNICAL REPORT UNDER PURCHASE ORDER NUMBER NTSB12-99-SP-0156

Raytheon is pleased to submit the subject technical report on Aging Wire Testing. We appreciate the opportunity to assist you in this study and hope that we can be of further assistance in the future.

This data is submitted for NTSB information. Please refer inquiries regarding this report to the author, Mr. Joe Kurek, at (317) 306-7029 or the Project Manager, Mr. Rex A. Beach, at (317) 306-7410. For information on contractual matters, please contact Ms. Kate Russell at (317) 306-7650.

Sincerely,

Rex A. Beach

Rex A. Beach
RSC, Indianapolis Project Manager, Aircraft Wiring

Enclosure

Raytheon

Aging Aircraft Wire Testing

Project Number 50-01-142

Technical Report Prepared for

National Transportation Safety Board (NTSB)

29 October 1999

Raytheon Systems Company
Training and Services Division
Indianapolis

Wiring and Qualification Group, CNE560

Prepared By: Joe Kurek, Staff Engineer

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Reviewed By: Jim Meiner, Senior Engineer

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ABSTRACT

Wiring from three different retired commercial passenger aircraft was examined and tested to evaluate the integrity of the insulated wire. The wire tested was insulated with crosslinked extruded alkane-imide polymer with a modified -imide polymer topcoat, also commonly referred to as Poly-X insulated wire. The wire was taken from generally benign areas of the aircraft, where the effects of environmental exposure would be minimized. The inspected wire samples exhibited contamination with a variety of materials, including dirt, lint, paint and lubricant residues, smoke residue, and metal filings. The degree of contamination of the wire samples varied by aircraft and by location on the aircraft. Sporadic areas were found with cracked or damaged insulation, including areas with deep hot stamp markings that directly led to localized crack formation. Visually, much of the wire appeared to be in good condition, although some areas were worse than other areas.

The wire from the three aircraft performed similarly during testing. Test results showed the wire continued to be able to pass many of the performance requirements that new wire must pass, including mechanical, thermal, and aging tests; however, the wire failed other tests, including lifecycle which evaluates the ability to withstand long-term thermal aging under mechanical stress. Wire from benign areas of the aircraft performed better than wire from areas with slightly elevated environmental exposure. In almost all cases, the outer layer of insulation cracked under performance testing, and electrical integrity was dependent upon the condition of the inner layer. Attempts were then made to understand the aging phenomenon involved with this type of insulated wire. The aging failure of Poly-X insulated wire is affected by exposure to various environmental factors, including heat, moisture, radiation, electrical, and mechanical stresses. Wire located in areas of the aircraft with higher levels of environmental stress would be expected to degrade more than those tested in this program.

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1. BACKGROUND

To evaluate the condition of wiring in current commercial passenger aircraft, the National Transportation Safety Board (NTSB) has established a program to investigate the electrical interconnection system and to characterize the condition of wiring in aircraft after long periods of service. The investigation has been prompted by a need to better understand the condition of wiring in aging commercial aircraft. The NTSB contracted Raytheon Systems Company (RSC), Indianapolis to evaluate aircraft wire removed from several recently retired aircraft. Three wire types, BMS 13-42 Rev A and B and MIL-W-81044/16 were selected for the investigation as they are the same type and age as the wiring used on TWA Flight 800, a Boeing 747 model, that is undergoing an accident investigation by the NTSB. The wire samples were subjected to performance tests that new wire was required to pass at the time of purchase. Based on the experience of this laboratory, performance test results are discussed, but it was beyond the scope of this project to perform failure analysis or in-depth study of wire failures.

2. DETAILS

2.1 SOURCE AIRCRAFT

Wire was removed from three different aircraft for testing. The wire samples were taken within two months of the retirement of each aircraft. Two of the aircraft were Boeing model 747 airplanes, and the third was a Douglas Corporation model DC-10. All three aircraft were reported to have been retired for economic reasons, and the operators of each asked not to be identified. None are known to have been involved in any major accidents. The aircraft were arbitrarily identified and will be referred to here as the White 747, DC-10, and European 747.

2.2 WIRE SAMPLE SOURCE LOCATIONS

The wire samples were prepared and shipped under the supervision of Safety Board Investigator Debbie Childress. The wire samples were removed from the aircraft, bagged and labeled to signify the originating location. The wire, along with cables, connectors, cable ties, overbraid, and other hardware was removed from wire bundles that had been routed through the different aircraft. The general areas of the aircraft are shown in Figures 1 – 3. No wire was received protected by overbraid, although some of the wire may have originated in protected bundles. Most of the wire originated from very benign areas of the aircraft, although some of the wire was located in areas of the aircraft that may have been exposed to slightly elevated environmental conditions. No wire was submitted that would have been expected to see high levels of environmental exposure. Table 1 describes the locations in the aircraft from which the samples originated. The environmental conditions of each location are noted for the propensity of the wiring in that area to see elevated environmental conditions.

2.3 WIRE SAMPLE BACKGROUND

The component wire removed from the aircraft represented several different types of wire, but the only wire tested was wire manufactured to BMS 13-42A, BMS 13-42B, or to MIL-W-81044/16, all Poly-X type wire insulation. Depending on the system installations and any rework that may have occurred on a specific aircraft, other wire types were present, such as MIL-W-81044/9 (crosslinked Polyalkene insulated wire) and BMS 13-48 (crosslinked ethylene tetrafluoroethylene, XLETFE, insulated wire.) The latter two wire types are significantly different than the Poly-X insulated wire type tested for this report.

Figure 1: White 747 Sample Origination as Described by NTSB

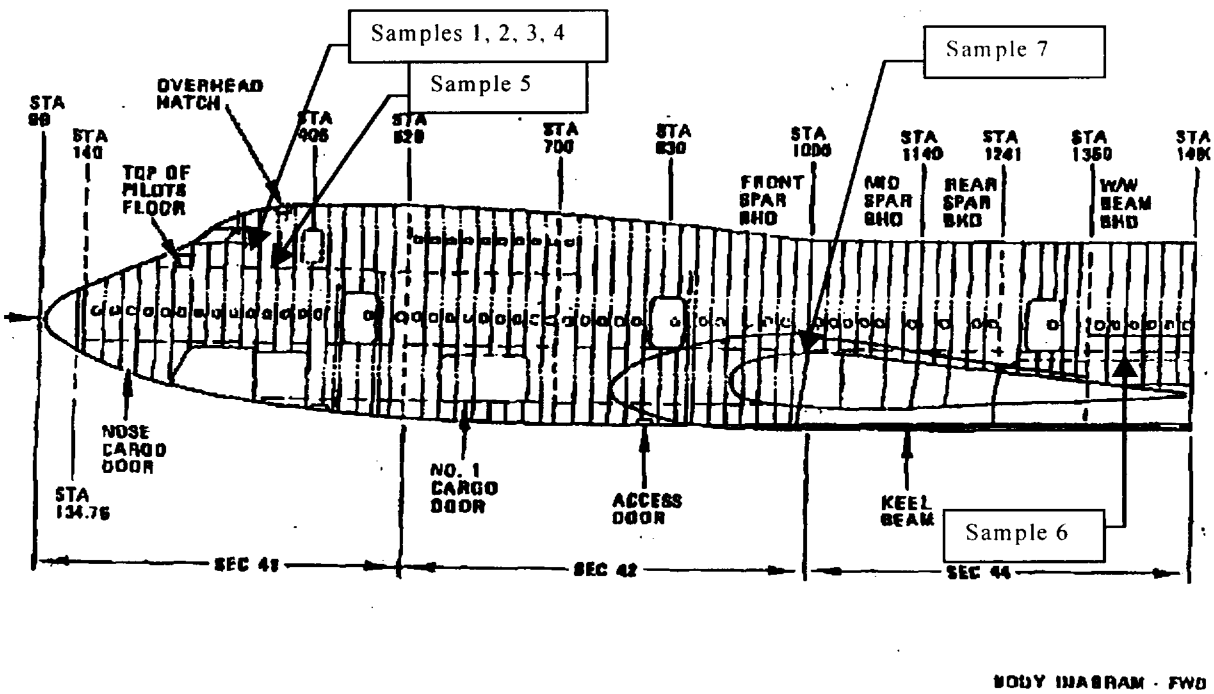

Figure 2: DC-10 Sample Origination as Described by NTSB

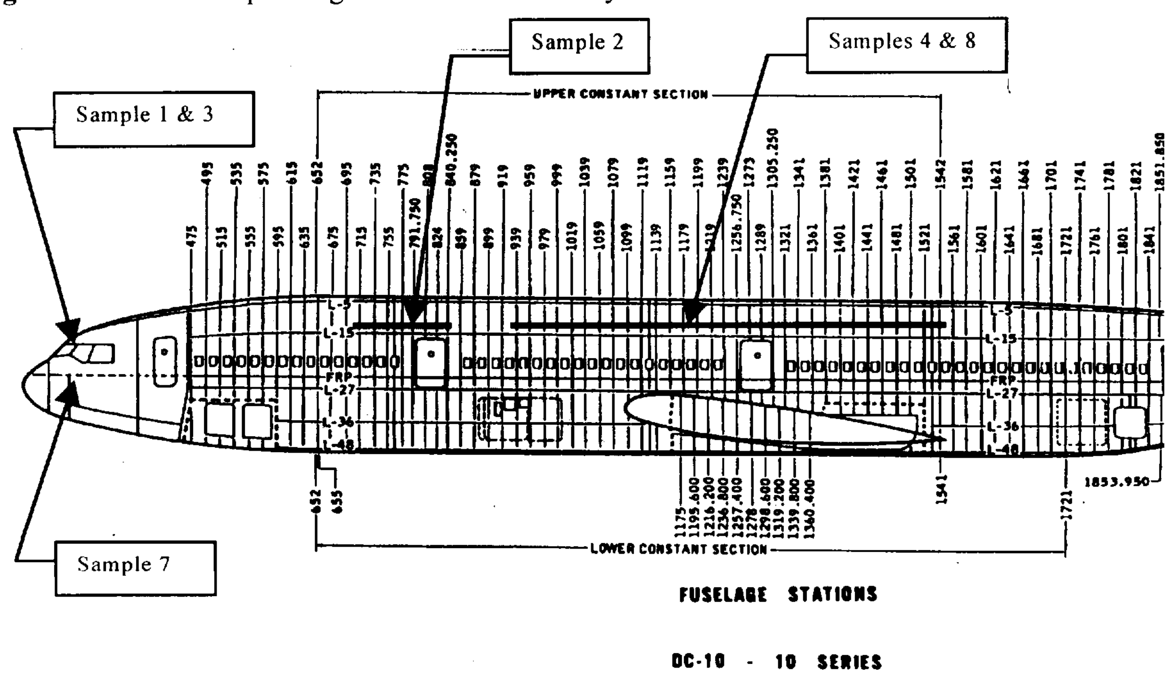

Figure 3: European 747 Sample Origination as Described by NTSB

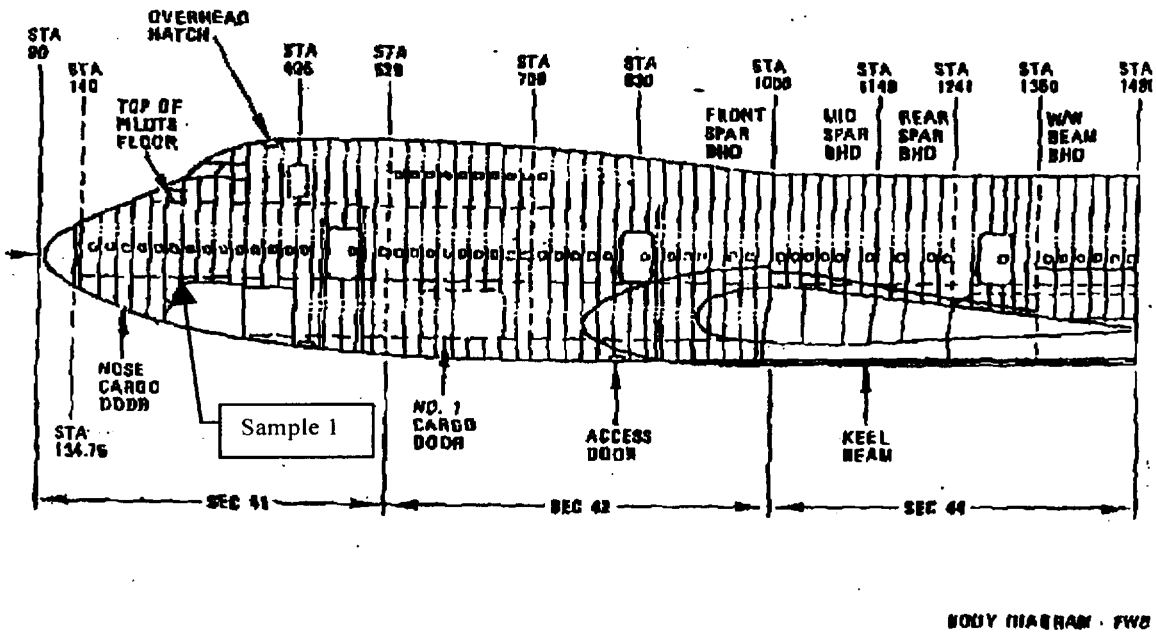

Table 1: Origin of Wire Samples Selected

Aircraft	Sample	Origin of Wire	Potential Environmental Exposure
White 747	S1, S2, S3, S4	Flight Engineer's panel in cockpit	Possible UV (Ultraviolet) exposure
SN: 199**	S5	Station 380, right hand Side of flight crew exit door	
	S6	Station 1438, directly below floor panel of Seats 37 A, B, and C	Benign
Delivery: 1973	S7	Just forward of center fuel tank on the right hand side	
DC-10	S1, S3	Cockpit overhead center panel	Hot, dry, no UV exposure
SN: 465**	S2	Station 770, a 12 foot section taken from above R2 door	Benign
	S4	Station 919 to Station 1239 (not tested)	
Delivery: 1973	S5	Not marked (not tested)	Not Known
	S6	Not marked	
	S7	Underneath flooring, pilot's side yoke area	Benign
	S8	Station 919 to Station 1570, overhead right hand side from R2 door towards rear of aircraft	Elevated temperature
European 747 SN: 197** Delivery: 1970	S1 (All)	Forward cargo hold	Benign

2.4 COMPONENT WIRE DESCRIPTIONS

The component wire specifications are included in Appendices I and II. The wire samples are tin coated copper conductors with a dual layer of crosslinked extruded alkane-imide polymer insulation and a coating of modified -imide polymer. Wire manufactured to the military (MIL-W-81044/16) and Boeing (BMS 13-42A and 13-42B) wire specifications is essentially identical. Only one manufacturer was qualified to this wire type for either of the noted specifications during the wire usage period. The qualified wire manufacturer indicated that the same wire would have been qualified to both specifications. The military specification for the subject wire type was canceled in 1977 due to the manufacturer ceasing production of the wire type. The insulation thickness requirement differed between the specifications. Insulation wall thickness requirements of the wire constructions are as follows:

Specification	Wire Size	Total Insulation Thickness
BMS 13-42/8, 42A/8,	30-10 gauge	.009 inch minimum
and 42B/8	8-0000 gauge	.015 inch minimum
M81044/16	24-00 gauge	.008 inch minimum

2.5 TEST PROGRAM PARAMETERS

Since the wires had been installed for a number of years on the subject aircraft, the wire samples were first examined for general condition and the presence of anything abnormal. A testing regimen was designed that would best indicate the condition of the insulated wire. Certain tests contained in the wire specifications were not performed if the aging of the wire would have no bearing on the outcome of the test, or if the test was not expected to reveal additional information. When possible, samples that may have been exposed to differing environmental conditions were analyzed separately. Testing on the component wire was performed per Boeing specification BMS 13-42A. In most cases the military and Boeing test procedures were very similar, although the Boeing specification contained the additional requirements of deformation, notch sensitivity, scrape abrasion, tape abrasion, and wicking.

3. TEST PROCEDURES AND RESULTS

3.1 Visual Examination

Appendix III contains photographs of each of the wire samples submitted to RSC for testing. Bundles contained wires ranging from 10 to 24 gauges, although the majority of the wire was 18, 20, and 22 gauge. When possible, the same wire size was used throughout any given test.

Each submitted wire sample was examined and photographed. The wire samples were examined for various elements, including general condition, mechanical damage, electrical damage, thermal damage, contamination, and foreign debris. Degradation of the wire to some degree would not necessarily be considered unusual for aircraft wire, especially wire which had been in service for many years. Observations of each sample were noted and are listed in Table 2. Photographs were taken when appropriate, and are included in Appendix IV. Few of the submitted wire samples exceeded 8 feet in length for the White 747 or 26 feet in length for the European 747 or DC-10. Many of the specimens did not appear to be damaged over these limited lengths.

A brief summary of the observations noted from the physical examination of the wire samples included:

- the presence of debris, such as lint and small metal chips, paint residue, and possibly foam or adhesive residue
- contamination by what appeared to be oil or grease and a dark brown film
- mechanical damage, such as insulation cracking, indentations caused by tight clamps or nylon tie wraps, abrasion of the insulation, and various nicks and cuts
- deep hot stamp marking resulted in cracking of the insulation
- extremely brittle insulation resulted in cracking of the outer layers with gentle handling in the laboratory
- roughly one-fifth of the insulation cracks resulted in dielectric failures

Several of these observations are considered to be potentially detrimental to the performance of the wire. During the testing phase, the performance of the wire was evaluated. Dielectric tests were performed on many wire samples, including a number of the areas in which problems were observed. Many of these areas passed dielectric tests, although some did fail.

Mechanical damage was found throughout many of the samples. Wire in certain aircraft areas appeared to be in worse physical shape than other areas. This may be due to greater exposure to environmental conditions, such as vibration or abrasion, or may be due to increased handling, such as during maintenance. The areas with heavier hot stamp marking contained direct examples of insulation cracking at the mark (Photo D1, D2). Tight tie wraps appeared to permanently deform insulation directly below the tie wrap, at times cutting into the insulation. Each of these examples of mechanical damage creates stress points that may degrade the electrical performance and possibly accelerate the aging of the wire.

The wire bundles were heavily coated in areas with a brownish film and released an odor of cigarette smoke. This may have been due to the smoke residue of passengers' cigarettes during the 1970s and early 1980s. The film could be wiped off with a dry cloth or scratched off with a fingernail. The film did not appear to have caused any visible damage to the wire insulation. Physical damage to the insulation is undetermined, but the brown film, if it is smoke residues, is not expected to be chemically reactive with the organic insulation.

White residue on the European 747 wire was analyzed by Fourier Transform Infrared (FTIR) Spectroscopy. The spectrum obtained, Figure 4, indicated the white residue was polyurethane based.

The clear yellow residue on the White 747 Sample 1 (referred to as S1) wire insulation was not identified, although the spectrum, Figure 5, indicates that the residue is an organic that exhibits nitrile peaks and may be similar to a polyurethane material. The residue was fairly thin and extremely brittle. A brown residue was present on the White 747 Sample 2 wire insulation. This residue was hard and brittle, and appeared to be similar to a foam or adhesive residue.

Figure 4: White Residue FTIR Spectrum (European 747, Sample 1)

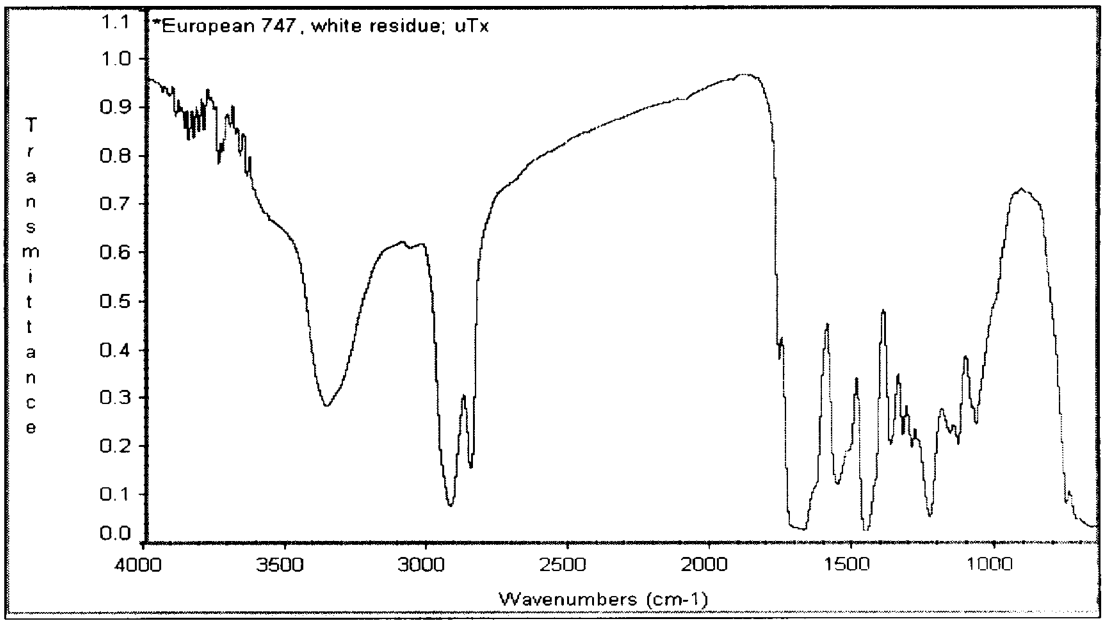

Figure 5: Yellow Residue FTIR spectrum (White 747, Sample 1)

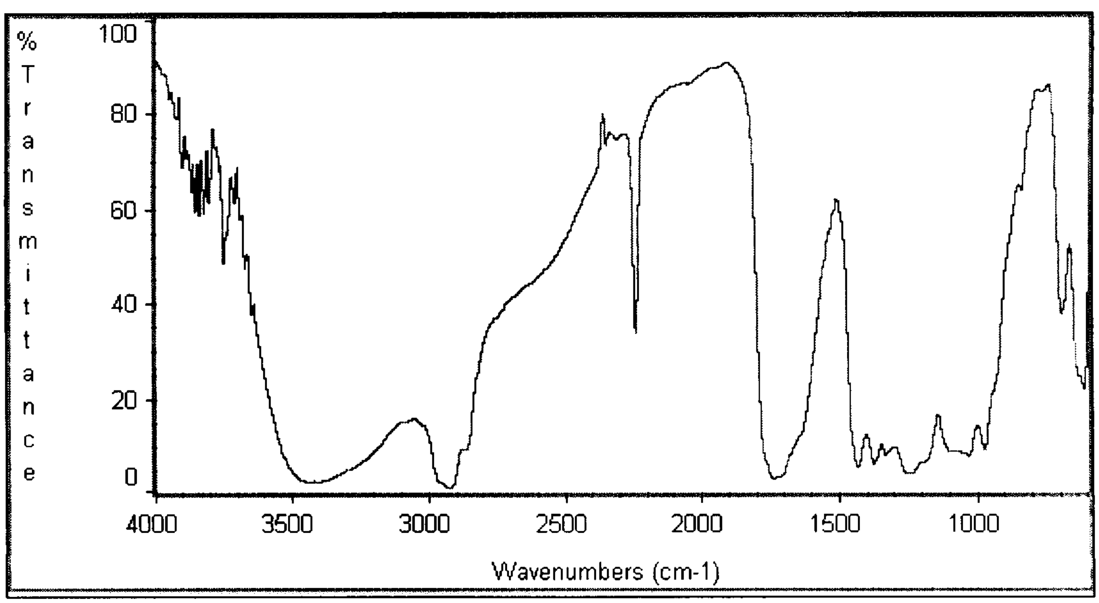

Table 2: Visual Examination Results

Sample	Area	Observations
White 747	S1	Wire relatively dirty. Clear yellowish residue on wire insulation. A few abrasions on the wire. Deep hot stamp markings (Photo D1, D2). Several radial cracks (Photo D3) and damaged wire insulation (Photo D4) with dielectric failures.
White 747	S2	Wire relatively dirty. Brown film on wire with an odor of cigarette smoke, along with brown residue in certain areas (Photo D5). Some nicks in wire insulation (one dielectric failure). Deep hot stamp markings. Deformation possibly due to tight clamps or tie wraps (Photo D6).
White 747	S3	Gouge in insulation (passed dielectric test) and scrape abrasion (Photo D7). Tie wraps very tight. Possible dielectric failures. Dark yellowish sticky material on areas of insulation. Deep hot stamp markings.
White 747	S4	No Poly-X type wire in sample
White 747	S5	Larger gauge wire (12 gauge) exhibited scrapes, abrasions (Photo D8), and gouges (Photo D9) in insulation. Small gauge wire did not exhibit damage.
White 747	S6	Gouges in insulation (Photo D10). Small metal filings present on surface of insulation (Photo D11).
White 747	S7	A few small cracks in insulation. Chafing (Photo D12) and gouges (Photo D13, D14).
DC-10	S1	Clean short samples with connectors.
DC-10	S2	Wire dirty with brown film and strong odor. M81044/9 type wire, no Poly-X type wire.
DC-10	S3	Dirty or heavy brown film on the ends of the wire. Some Poly-X wire that was not labeled as either BMS or Mil-spec wire.
DC-10	S4	Heavy brown film covering wire with a strong odor. M81044/9 type wire, no Poly-X type wire.
DC-10	S5	Some cuts into insulation. One wire insulation (20 gauge) cracked when straightened (Photo D15), passed dielectric. Some Poly-X type wire that was not labeled to a specification.
DC-10	S6	One wire (22 gauge) cracked and failed dielectric test.
DC-10	S7	Wire dirty, dusty, and slightly oily. Isolated cases of chaffing and gouging of the insulation on twisted pairs.
DC-10	S8	Brown film covered much of wire, along with a strong odor of cigarette smoke. Some areas were covered with more dirt or a heavier brown film than other areas. Fifty-foot harness held together by about 40 very tight nylon tie wraps. Dielectric failure in wire sample with mangled area (Photo D16). Connector strain relief very tight on wire. A section of wire was protected by overbraid. This wire was bright white and much less brittle.
European 747	S1	Wire was dirty. Approximately one-third of the wire was covered with an oil or grease residue, some of which was sticky or tacky while other areas were dried. Several areas were covered with a white residue (Photo D17). Some fine metal filings on wire, especially between the twisted pairs. Wire insulation with abrasions on twisted triples.

3.2 Mechanical and Electrical Tests

3.2.1 Concentricity

The concentricity test measures manufacturing accuracy and is quite important for an extruded insulation type wire. The proper dielectric properties of a wire are dependent on the ability of the insulation system to protect the conductor. Manufacturing problems may be encountered that reduce the thickness of the insulation at any one point, and will directly affect the voltage level that can breakdown the remaining insulation. In older wire, this test also becomes a check on the integrity of the insulation and any presence of cold flow or wire wear that may also decrease the effectiveness of the insulating properties.

Test specimens are carefully cross-sectioned from the wire sample with a sharp razor blade. The specimen is then held at a right angle to an optical measuring device, and the thickness of the insulation layers in relation to the conductor and overall sample geometry are evaluated. Concentricity of insulation is measured as a ratio of the thickest to the thinnest wall thickness in a specimen. New wire manufactured to these specifications required 70% minimum concentricity.

On several of the submitted wire test specimens, there appeared to be some layer separation between the outer layer and the inner layers, and between the inner layers (Photo D18, D19). Repeated thermal or mechanical cycling may promote separation of layers. Results are provided in Table 3.

Table 3: Concentricity Results

Samples	Area	Specimens	Concentricity (%)	Results
White 747	S2	W42B/8/1 - # gauge	82%	Passed
		W42B/8/1 - # gauge	Separation of layers	Failed
White 747	S6	W42B/8/1 - # gauge	76%	Passed
		W42B/8/1 - # gauge	47%	Failed
DC-10	S1	M81044/16 - 22 gauge	93.5%	Passed
		M81044/16 - 22 gauge	85%	Passed
DC-10	S6	M81044/16 - 22 gauge	88%	Passed
		M81044/16 - 22 gauge	57%	Failed

Gauge size not recorded

3.2.2 Dielectric Test

The dielectric test employed was an electrical test commonly used to determine the integrity of wire insulation. It is often called a Dielectric Withstand Voltage (DWV) test, or Wet Dielectric test. An electrical potential across the insulation will short if any area of the insulation is too weak to contain the electrical potential. This test measures the leakage current sensed by the ammeter.

The wire is submerged in a 5% salt water solution, and a potential is applied across the insulation by connecting the positive lead to the conductor and the negative lead to a copper rod in the salt solution. A potential of 2500 volts at 60 hertz alternating current was applied for 5 minutes to test the wire specimens for insulation electrical integrity. Insulation failures are determined by a leakage current exceeding 10 milliamps. The leakage current was not specified in either the military or Boeing specifications.

This test was used in conjunction with other tests as a proof test for insulation integrity. The results are listed with the applicable test.

3.2.3 Insulation Resistance

The insulation resistance is a measure of the electrical resistance that an insulation imparts between a conductor and ground. Greater electrical resistance provides better insulating properties. The presence of shorts, weak areas, or poor material quality of the insulation can lead to low values.

Wire specimens, as long as possible, were taken from the sample bundles and tested for the insulation resistance by immersion in a water bath with 0.5% anionic surfactant per the Boeing test method. After a four hour soak, 500 volts potential is applied across the wire and surfactant solution. Twenty-six feet is required per the test specification, but this length was only available from one of the samples. The test results can be variable, and long specimen lengths are necessary to extrapolate values out to 1000 feet. Test values from shorter specimens may not be as accurate as from longer specimens. Samples from the elevated environmental exposure areas did not have enough length to perform this test. Values are usually given in ohms per thousand feet of wire. The requirement for the insulation on new wire per the Boeing specification is

10000 megohms (M^{Ω})/1000 ft (30 - 22 gauge)
5000 M^{Ω}/1000 ft. (20 - 10 gauge)
500 M^{Ω}/1000 ft. (8 - 0000 gauge).

The requirement for the military specification wire is

5000 M^{Ω}/1000 ft. (24 - 10 gauge)
2000 M^{Ω}/1000 ft. (8 - 00 gauge).

The results in Table 4 indicate that the wire specimens far surpass the original requirements of the Boeing and military specifications.

Table 4: Insulation Resistance Results

Samples	Area	Specimen	Specimen Length	Resistance (MΩ/1000 ft.)	Results
White 747	S7	W42B/8/1 - 20 gauge	8 feet	30,100	Pass
DC-10	S8	M81044/16 - 16 gauge	26 feet	23,750	Pass
European 747	S1	W42A/8/1 - 20 gauge	26 feet	37,500	Pass

3.2.4 Insulation Tensile and Elongation

As a material ages, the elasticity or strength may change dramatically. The molecular bonds of a material may weaken due to various mechanisms, such as hydrolysis, thermal breakdown, ultraviolet degradation, etc. This material degradation can often lead to a decrease in the ability to withstand physical stress. Tensile strength and elongation are two properties that are often used to characterize a material. For example, aging may cause a material to harden and the tensile strength to increase and elongation to decrease. Materials that harden will tend to crack and fall apart when moved or disturbed. The materials used for the wire insulation must continue to keep their properties over the service life of the wire in order to meet the performance required of it. Disintegration of wire insulation is unacceptable in an aerospace environment.

Three inch slugs of insulation were removed from the wire. The specimens were tested to determine the tensile and elongation using a compression/tension machine with a 2 inch/minute jaw separation. Insulation composed of several layers, such as the subject wire, was tested to multiple endpoints: tensile of the first layer, final break strength, and the ultimate elongation. Requirements on the original wire for the Boeing and military specifications were 50% minimum elongation to break and 7500 pounds per square inch (psi) minimum to break (10 gauge and smaller) or 5000 psi minimum to break (8 gauge and larger wire) for the total insulation.

The results in Table 5 show that one wire insulation sample had degraded to the point where it has begun to fail the tensile strength requirement, and another wire sample had degraded to fail the elongation requirement. Many wire samples were close to the requirements, while a few maintained good characteristics. The range of values in this test was fairly significant within each sample. Statistical deviation was up to ±50% of the value for elongation, but only up to ±4% of tensile strength of the outer layer. Depending on the sample, statistical deviation was sometimes much less. The failed elongation specimen passed the tensile requirement. Values are given for the total insulation, for the combined inner and outer layers, for the peak tensile strength at break, and for the final overall elongation. The tensile strength of the outer layer of insulation was always higher, while the elongation of the inner layer was higher. On all specimens, the outer insulation layer broke first, with less elongation than the inner layer. Dual wall insulated wire may have an advantage since the outer layer protects the inner material so that does not degrade as quickly in service. This is represented by the fact that the inner layer continues to maintain a suppleness that allows for the elongation to continue to meet the original requirements of the wire specifications. During the physical evaluation of the wire, several instances of cracked wire which maintained electrical integrity were found due to the continued physical capacity of the inner layer.

Table 5: Insulation Tensile Strength and Elongation Results

Samples	**Area**	**Specimens***	**Elongation (%) avg. 50% Requirement**	**Tensile Strength (psi), avg. peak 7500 psi Requirement**	**Results**	
					Elongation	**Tensile**
White 747	S2	W42B/8/1-18 total insulation	211%	7452	Passed	Borderline
White 747	S2	W42B/8/1-20 total insulation	37% (14% outer)	11653	Failed	Passed
White 747	S5	W42B/8/1-18 total insulation	218%	8487	Passed	Passed
White 747	S7	W42B/8/1-20 total insulation	203% (15% outer)	10502	Passed	Passed
DC-10	S1	M81044/16-18 total insulation	197% (128% outer)	7962	Passed	Passed
DC-10	S7	M81044/16-16 total insulation	262% (29% outer)	10740	Passed	Passed
DC-10	S8	M81044/16-20 total insulation	88% (17% outer)	11693	Passed	Passed
European 747	S1	W42A/8/1-20 total insulation	49% (22% outer)	11200	Borderline	Passed

* Note – Five specimens were tested for each sample. Because it was impossible to separate the inner insulation from the outer insulation, the total insulation was pulled together; however, the outer insulation would break before the inner insulation.

3.2.5 Notch Sensitivity

This test measures the ability of a wire insulation to resist the propagation of a nick or cut through the insulation layers to the conductor. One of the major drawbacks of some of the more rigid insulation systems is the tendency for the materials to crack, and for the cracking to continue all the way through to the conductor to create potential dielectric failure sites. There are several ways in which wire manufacturers have addressed this problem. One is to use materials that do not exhibit the tendency to propagate cracks. Another is to use more than one layer of material so that if one layer develops a crack or is nicked, another layer will retain its integrity.

A blade that protrudes a certain dimension out of the fixture is used. The insulation of the wire specimen is then scored to that depth using the fixture blade, then physically stressed by wrapping 360° around a 1.0 inch mandrel with the notch on the outside of the bend to induce propagation of the notch. A 2500 volt dielectric test in a 5% salt water solution is performed to verify the integrity of the insulation. The Boeing specification requires a .004 inch notch depth. This test is not a requirement in the military specification.

As shown in Table 6, all samples tested passed the requirements by maintaining electrical integrity during the dielectric voltage test. The inner insulation material refrained from propagating the notch through to the conductor. The test also was performed on thermally aged specimens to determine if the embrittled insulation would propagate cracking. The accelerated aging specimens also passed the dielectric voltage test following the notch of the insulation, Table 7. Again, the inner insulation protected the conductor.

Table 6: Notch Sensitivity Results

Samples	Area	Specimen	Results, Dielectric
White 747	S1	W42B/8/1 - 22 gauge	Passed
White 747	S6	W42B/8/1 - 20 gauge	Passed
White 747	S7	W42B/8/1 - 22 gauge	Passed
DC-10	S1	M81044/16 - 22 gauge	Passed
DC-10	S7	W42B/8/1 - 22 gauge	Passed
European 747	S1	W42A/8/1 - 20 gauge	Passed

Table 7: Notch Sensitivity Results Following Aging

Samples	Area	Specimens	Results, Dielectric
White 747	S5	W42B/8/1- 16 gauge	Passed
White 747	S7	W42B/8/1- 18 gauge	Passed
DC-10	S3	M81044/16- 16 gauge	Passed
DC-10	S7	M81044/16- 16 gauge	Passed

3.3 Thermal Tests

3.3.1 Blocking

Wire is expected to have insulation that does not adhere to itself after heating. Potential problems may result if wire insulation melts together (blocks) and forms a large mass. Vibration, flexing, and other thermal or mechanical stress causing movement of the wire may rip or otherwise damage the insulation from one of the wires, creating sites that may lead to dielectric failures. In addition, this test can evaluate the potential for materials to revert, which may result in electrical failure.

Wire specimens were wrapped tightly around a 1 inch diameter mandrel (1.5 inch for 16 gauge wire), with the turns up against each other. A three pound weight (five pound weight for 16 gauge wire) was hung from the conductors to keep the turns taught around the mandrel, and the specimens were heated to 200°C for 6 hours. The wire specimens were cooled and inspected for any sign of adhesion between the turns of insulation. The requirement for new wires is no adhesion following heat exposure.

All samples passed this requirement with no adhesion of the insulation, Table 8.

Table 8: Blocking Results

Samples	Area	Specimen	Adhesion	Results
White 747	S5	W42B/8/1- 22 gauge	None	Pass
White 747	S7	W42B/8/1- 22 gauge	None	Pass
DC-10	S3	M81044/16- 16 gauge	None	Pass
DC-10	S7	M81044/16 - 22 gauge	None	Pass

3.3.2 Low Temperature (Cold Bend)

In an aerospace environment, the temperatures experienced by the aircraft quickly reach –65°C at altitude. Wire must be able to retain some physical performance abilities due to the physical stress that occurs in flight at low temperatures. Within the passenger cabin and cockpit, temperatures are regulated, but outside of these areas, where much of the wire in a commercial aircraft is located, the temperatures reach extremes. Many polymeric materials undergo thermomechanical transition at subambient temperatures, and become hard and brittle. Aerospace wire is expected to retain physical and electrical integrity through mechanical and electrical stress at the temperature extremes

With 5 pound weights attached, wire specimens were cooled to –65°C and tested by being wrapped around a 1.5 inch mandrel at the cold temperature, and then visually checked for insulation cracking. In addition to this, the military specification MIL-W-81044 continues with a wet dielectric test in a 5% salt water solution to prove the insulation integrity.

As shown in Table 9, 16 gauge samples were tested and all specimens passed the final wet dielectric withstand voltage test, and the specimens did not exhibit cracking in the outer insulation at the low temperatures. This test does not address long duration service stress such as vibration at cold temperatures.

Table 9: Low Temperature Cold Bend Results

Samples	Area	Specimen	Number of Specimens	Results, Visual	Results, Dielectric
White 747	S3	W42B/8/1 - 16 gauge	2	No Cracks	Passed
White 747	S6	W42B/8/1 - 16 gauge	1	No Cracks	Passed
DC-10	S3	M81044/16 - 16 gauge	1	No Cracks	Passed
DC-10	S7	M81044/16 - 16 gauge	1	No Cracks	Passed

3.3.3 Shrinkage

This test indicates whether the wire insulation is physically and dimensionally stable when exposed to short term elevated temperature. Polymeric materials may often expand or contract if not completely cured, or if the material contains inherent stresses from manufacturing.

Twelve inch long specimens are cut so that the ends of each side are flush. The specimens are then heated to 200°C for 6 hours to allow the wire specimens to relax and the insulation to move, losing any physical stresses and reaching its lowest energy state. The specimens are allowed to cool, and the difference between the end of the conductor and insulation are measured on each specimen. Any change in the position of the conductor relative to the insulation is noted to the nearest 0.001 inch for each end of the specimen. The wire specifications allow a maximum of 0.06 inch (0.125 inch for the military specification) shrinkage for a 12 inch specimens of new wires.

All wire specimens exhibited no deviation between the conductor and insulation on both ends, Table 10. Since these wires have been in service for so many years, and have been exposed to many thermal fluctuation cycles, they would not be expected to change appreciably.

Table 10: Shrinkage Results

Samples	Area	Specimens	Deviation (inch)	Results
White 747	S1	W42B/8/1- 22 gauge	0.0	Passed
White 747	S6	W42B/8/1- 22 gauge	0.0	Passed
DC-10	S1	M81044/16- 24 gauge	0.0	Passed
DC-10	S7	M81044/16- 22 gauge	0.0	Passed

3.3.4 Thermal Shock

Thermal shock is similar to the shrinkage test, but with several changes in the test procedure. The test measures an insulation's ability to resist shrinkage and expansion following several thermal cycles to temperature extremes. Inherent mechanical stresses may cause deviation of the insulation in relation to the conductor.

Five foot specimens were coiled in one foot loops. The ends were stripped of insulation, and the exposed conductor measured accurately. The specimens were cycled from hot (150°C), to cold (-55°C), to room temperature (25°C) four times, with measurements being taken on the dimensional change of length between the conductor and insulation after each cycle. Both wire specifications allow a maximum of .060 inch shrinkage on each end for new wire.

The maximum deviation on each end is provided in Table 11. All specimens passed the requirement, although the deviation resulting from shrinkage of the insulation was more apparent in this test than in the shrinkage test. Wire exposed to numerous thermal cycles would be expected to be quite stable and not exhibit large deviations.

Table 11: Thermal Shock Results

Samples	Area	Specimens	Deviation on each end (inch)	Results
White 747	S5	W42B/8/1 - 22 gauge	0.052, 0.038	Passed
White 747	S7	W42B/8/1 - # gauge	0.017, 0.049	Passed
DC-10	S8	M81044/16- 22 gauge	0.014, 0.047	Passed
European 747	S1	W42A/8/1 - 20 gauge	0.008, 0.017	Passed

Gauge size not recorded

3.3.5 Wrapback

The wrap test evaluates the ability of wire to withstand thermal stress while under mechanical stress. The test is short term, but the high mechanical stress during the thermal exposure can reveal weaknesses in the insulation and susceptibility of the insulation to cracking. The wrapback variant of the wrap test uses the wire itself as the mandrel, so that the bend is extremely small and tight.

Twelve inch specimens were wrapped tightly around themselves for a minimum of four close turns. The specimens were hung in an oven at 200°C for 6 hours. After oven exposure, the specimens were inspected for cracking of the insulation. Requirements of the specifications require no cracking following oven exposure.

One specimen failed during the thermal exposure as shown in Table 12. This may indicate that the insulation has weakened due to aging, and may be somewhat brittle.

Table 12: Wrapback Results

Samples	Area	Specimen	Number of Specimens	Results, Visual	Results, Dielectric
White 747	S2	W42B/8/1- 20 gauge	3	Spiral Cracks (1)	Failed
				No Cracks (2)	Not Performed
White 747	S7	W42B/8/1- 20 gauge	3	No Cracks	Not Performed
DC-10	S1	M81044/16- 18 gauge	2	No Cracks	Not Performed
DC-10	S7	M81044/16- 22 gauge	2	No Cracks	Not Performed

3.4 Thermal Aging Tests

3.4.1 Accelerated Aging

The accelerated aging test is used to evaluate a wire's ability to withstand a higher temperature under mechanical stress for a short period of time. Wire insulation is expected to survive short-term tests to temperatures above the temperature rating of the insulation. This assumes that the test temperatures are below the melt temperatures of the insulating materials for thermoplastic insulations. This test, sometimes called crosslink proof, is also used to determine if the insulation of a wire has been converted to a thermoset material by polymer crosslinking. For crosslink proof, a temperature above the melt point of the non-crosslinked material is selected. In this case, the insulation is a crosslinked material.

Specimens are hung over a 1.0 inch mandrel with 4.0 pound weights attached to impart physical stress on the insulation, then placed in an air circulating oven at 250°C for 7 hours. Following the heat exposure, the specimens are bent and proof tested with a dielectric withstand voltage in a 5% salt water solution. New wire is expected to pass the dielectric test following high temperature exposure. Insulation and conductor degradation is allowed provided the electrical integrity is maintained.

As shown in Table 13, all specimens cracked during the thermal exposure or bend test, but passed the dielectric withstand test, indicating that the inner insulation layer remained intact even though the outer layer cracked. Notch Sensitivity was performed on these specimens following aging. All specimens passed as noted in Table 7.

Table 13: Accelerated Aging Results

Samples	Area	Specimens	Results, Visual	Results, Dielectric
White 747	S5	W42B/8/1 - 16 gauge	Insulation cracked during bend	Passed
White 747	S7	W42B/8/1 - 18 gauge	Insulation cracked during bend	Passed
DC-10	S3	M81044/16 - 16 gauge	Insulation cracked during thermal exposure	Passed
DC-10	S7	M81044/16 - 16 gauge	Insulation cracked during bend	Passed

3.4.2 Life Cycle

The life cycle test is similar and complementary to the accelerated aging test. Samples are exposed to elevated temperatures under mechanical stress, with temperatures lower than for accelerated aging, but for a longer exposure time. This test is used to determine the ability of a wire to withstand temperatures above the temperature rating of the insulation for an extended period of time.

Twenty-four inch specimens were hung over an appropriate mandrel with corresponding weights on each end (determined by the wire size) and suspended in an air-circulating oven at 200°C for 168 hours. After thermal exposure, the specimens are bent and proofed by a dielectric withstand test in a 5% salt water solution. New wire would be expected to pass this test with no failures, legible marking, intact insulation, and without pitting of the conductor.

As shown in Table 14, all but three samples failed the bend test, although the elevated environmental exposure samples fared much worse than did the samples with low environmental exposure. Exposure to environmental conditions may degrade the wire insulation at a much faster rate than wire insulation that sees benign conditions. Various aircraft conditions, including shock, constant vibration, abrasion, ultraviolet radiation, thermal cycling, moisture, and fluid exposure, all affect the life of a wire. This test combines the high heat, to accelerate the thermal exposure based on the Arrhenius principle, as well as static stress on the insulation while hanging with weights and dynamic stress during the bend test. Results of this test indicate the type of thermal life that the wire may continue to exhibit.

Table 14: Lifecycle Results

Samples	Area	Specimen	Mandrel	Weights Each end	Number of Specimens	Results	Results, Dielectric
White 747	S2	W42B/8/1 - 20 gauge	¾ inch	4 lb.	6	6 failed bend	6 failed
White 747	S7	W42B/8/1 - 22 gauge	¾ inch	2.5 lb.	3	1 failed bend	1 failed
DC-10	S3	M81044/16 - 16 gauge	1 inch	4 lb.	3	3 failed bend	3 failed
DC-10	S8	M81044/16 - 22 gauge	¾ inch	2.5 lb.	3	2 failed bend	2 failed

3.4.3 Additional Life Testing

The wire insulation underwent a test program that is designed to evaluate new wires. New wires are expected to provide a certain service life once installed on aircraft, but over time the wire ages and may exhibit decreased performance properties and a lowered threshold for future service life. To provide an indication of the remaining service life that may be exhibited, the wire was evaluated to determine whether the performance properties could be maintained for any significant length of time. Several parameters were examined: accelerated aging and lifecycle, shown above, along with forced hydrolysis, and mechanical and electrical integrity following extended thermal aging. Most of these test methods have been described in earlier sections.

3.4.3.1 Electrical Integrity During Forced Hydrolysis

The polyimide insulation is affected by continued exposure to various environmental factors. Each of these factors place a different mode of stress on the insulation. Combinations of these factors will affect the wire to a greater degree. Samples were subjected to forced hydrolysis testing since it is known that polyimide material is hydrolyzed by moisture. The current state of the wire samples with regards to hydrolysis is unknown, and previous exposure to moisture may have initiated some damage already.

Forced hydrolysis was performed according to the SAE AS 4373 method 601 test procedure with the exception that several different temperature exposures were utilized. Five insulated wire specimens per sample were wrapped tightly around an appropriate sized mandrel and subjected to a heated salt water bath without submerging the ends of the specimens. Exposure to heat speeds up the process of hydrolysis. Periodically the specimens were removed and a dielectric withstand voltage of 1.5 kilovolts was applied for 1 minute to determine the electrical integrity of the specimens. Once specimens failed the dielectric test, they were removed from further exposure.

Results of the forced hydrolysis testing are shown in Table 15. Increased temperature exposure decreases the time required to reach dielectric failure. Specimens degraded much more rapidly than with temperature exposure alone and no moisture. The insulation under stress on the mandrels cracked during the exposure, first damaging the outer layer, then eventually the inner layer until dielectric failure was reached (Photo D20).

Table 15: Average Time to Dielectric Failure with Forced Hydrolysis

Samples	Area	Specimens	Time to Dielectric Failure, Hrs. (avg.)		
			60°C	70°C	90°C
White 747	S3	W42B/8/1 - 20 gauge	990	850	469
White 747	S7	W42B/8/1 - 20 gauge	1070	930	469
DC-10	S8	M81044/16 - 20 gauge	690	610	447
European 747	S1	W42A/8/1 - 20 gauge	890	930	537

3.4.3.2 Mechanical Properties and Electrical Integrity During Heat Aging

Insulating materials degrade over time with exposure to thermal stress. The tensile strength and ultimate elongation of the insulation were used to monitor the mechanical degradation during heat exposure, while the bend and dielectric tests were used to determine the electrical integrity of the wire. Periodic testing during thermal exposure allowed for the monitoring of the physical and electrical properties of the insulation as the material aged.

Thermal aging of the wire specimens was performed similar to the ASTM D3032 test method for thermal index testing. Wire specimens were hung in an air-circulating oven with just enough weight to keep the wire specimens straight. Periodically, a portion of insulation from each specimen was removed to perform tensile strength and elongation tests, and the remaining specimen was subjected to the bend and dielectric test to determine whether the insulation was maintaining electrical integrity. Specimens were placed back into the oven for continued thermal aging. This cycle repeated until the specimen failed electrical integrity. At minimum, 5 specimens per sample were used for each temperature of exposure.

The heat aging caused the specimens to become extremely brittle. The bend test would often crack the outer insulation with little thermal aging (Photo D21, D22). The following tables present the electrical (Table 16) and mechanical (Tables 17-22) test results with respect to the thermal aging of the specimens. The time to failure of wire specimens decreased with higher temperatures, and samples from all three aircraft behaved similarly. The tensile strength was not affected much over time, although the deteriorating condition of the specimens created problems with stripping portions of wire in order to perform the test. The ultimate elongation of the insulation provided a better view of the deterioration over time. This ultimate elongation of the insulation was dependent on the inner insulation, which also controlled the electrical integrity. The results clearly show the decline in the properties of the wire insulation with respect to time and to temperature.

Table 16: Average Time to Dielectric Failure with Thermal Aging

Samples	Area	Specimens	Time to Dielectric Failure, Hrs. (avg.)		
			180°C	200°C	220°C
White 747	S2	W42B/8/1 - 20 gauge	358	100	36
White 747	S7	W42B/8/1 - 20 gauge	178	98	36
DC-10	S8	M81044/16 - 20 gauge	338	83	36
European 747	S1	W42A/8/1 - 20 gauge	298	98	36

Table 17: Insulation Tensile Strength after Thermal Aging at 180°C

Samples	Area	Specimens	Tensile Strength, psi (avg.)					
			0 hrs	48 hrs	148 hrs	248 hrs	348 hrs	448 hrs
White 747	S2	W42B/8/1 - 20 gauge	11655	10555	10880	10735	9805	8335
White 747	S7	W42B/8/1 - 20 gauge	10500	8755	10225	10305	10975	5075
DC-10	S8	M81044/16 - 20 gauge	11695	10980	10840	11065	9555	10505
European 747	S1	W42A/8/1 - 20 gauge	11200	10320	10780	10780	9810	5990

Table 18: Insulation Tensile Strength after Thermal Aging at 200°C

Samples	Area	Specimens	Tensile Strength, psi (avg.)			
			0 hrs	48 hrs	148 hrs	172 hrs*
White 747	S2	W42B/8/1 - 20 gauge	11655	10905	9340	10640
White 747	S7	W42B/8/1 - 20 gauge	10500	10625	8230	
DC-10	S8	M81044/16 - 20 gauge	11695	10265	8025	
European 747	S1	W42A/8/1 - 20 gauge	11200	11080	9150	

* Note: Most specimens failed before last time exposure.

Table 19: Insulation Tensile Strength after Thermal Aging at 220°C

Samples	Area	Specimens	Tensile Strength, psi (avg.)		
			0 hrs	24 hrs	48 hrs
White 747	S2	W42B/8/1 - 20 gauge	11655	10500	10015
White 747	S7	W42B/8/1 - 20 gauge	10500	10415	9495
DC-10	S8	M81044/16 - 20 gauge	11695	10390	10625
European 747	S1	W42A/8/1 - 20 gauge	11200	10840	10295

Table 20: Insulation Ultimate Elongation after Thermal Aging at 180°C

Samples	Area	Specimens	Ultimate Elongation, % (avg.)					
			0 hrs	48 hrs*	148 hrs	248 hrs	348 hrs	448 hrs
White 747	S2	W42B/8/1 - 20 gauge	36.8	15.3*	129	20.2	16.1	11.3
White 747	S7	W42B/8/1 - 20 gauge	203	10.9*	51.5	15	15.3	5.6
DC-10	S8	M81044/16 - 20 gauge	88.2	16.8*	59.2	16.9	16.6	16.6
European 747	S1	W42A/8/1 - 20 gauge	49.3	15.7*	166	14.4	12.1	7.0

* **Note:** Specimens at 48 hours recorded elongation of outer layer only, not the total elongation.

Table 21: Insulation Ultimate Elongation after Thermal Aging at 200°C

Samples	Area	Specimens	Ultimate Elongation, % (avg.)			
			0 hrs	48 hrs	148 hrs	172 hrs*
White 747	S2	W42B/8/1 - 20 gauge	36.8	33.2	11.2	13.9
White 747	S7	W42B/8/1 - 20 gauge	203	17.9	9.7	
DC-10	S8	M81044/16 - 20 gauge	88.2	16.4	8.4	
European 747	S1	W42A/8/1 - 20 gauge	49.3	17.6	8.9	

* Note: Most specimens failed before last time exposure.

Table 22: Insulation Ultimate Elongation after Thermal Aging at 220°C

Samples	Area	Specimens	Ultimate Elongation, % (avg.)		
			0 hrs	24 hrs	48 hrs
White 747	S2	W42B/8/1 - 20 gauge	36.8	16.2	11.1
White 747	S7	W42B/8/1 - 20 gauge	203	13.6	9.4
DC-10	S8	M81044/16 - 20 gauge	88.2	14	18.2
European 747	S1	W42A/8/1 - 20 gauge	49.3	14	14.8

The tested samples, which had previously been aged in service, passed most of the tests, except for the lifecycle test. Samples passed accelerated aging and in addition, passed the notch sensitivity test following thermal aging. The polyimide insulation broke down upon exposure to forced hydrolysis, and failed dielectric testing more rapidly than without exposure to moisture. Following thermal aging, the wire insulations exhibited lower tensile strength and elongation, and increased mechanical and electrical failures. Over time, the outer insulation of the specimens cracked first, then the inner insulation layers cracked and led to electrical failure. In addition, the conductors discolored during thermal aging, showing oxidation of the tin coated copper conductor. These parameters indicate that the wire insulations have degraded during the thermal aging testing program.

The ability of this aged wire to perform to most of the original requirements, and the continued integrity of the insulation during a portion of the thermal cycling indicate that the wire should continue to perform as intended for a period of time before general failure begins to occur. The fact that the wire still has the capacity to degrade indicates the final life has not been reached.

3.5 DISCUSSION SUMMARY

Wire samples pulled from the three subject aircraft appeared to be in similar condition. Although the wire samples were in generally decent condition for having 25 years service life, there were problems evident during the inspection and performance testing. Within a given aircraft, the condition and performance of the samples varied. Various sites were noted which could lead to electrical failure given the opportunity for the conductor to ground at that location. Most of the sites were able to pass a dielectric test, indicating that the electrical integrity of the wire remained. Much of the damage appeared isolated within a given sample, but certain samples exhibited more damage than other samples. Wire damage may have occurred by human or environmental means, such as through manufacturing and assembly, maintenance, vibration, chafing, or many other possibilities.

The wire samples passed the majority of the performance tests: insulation resistance, notch sensitivity, blocking, cold bend shrinkage, thermal shock, and accelerated aging, to the requirements that new wire must pass. Specimens following accelerated aging also passed the notch sensitivity test.

The wire did not pass several other tests. A number of specimens failed concentricity, indicating that the insulation was degrading with layer separation. Several specimens on different aircraft failed this requirement. As evidence the wire became more brittle with age, the elongation of the outer insulation was extremely low. Although the layers together often met the requirement, the outer layer failed with very little elongation. This would be a problem if the wires were handled or vibrated such that the insulation is stressed. The inner layer may protect the wire from potential electrical failure, but damage to the outer layer would create sites for further degradation since the outer insulation protects the softer inner insulation. Wrapback tests the susceptibility of the wire to failure with thermal and mechanical stress on the insulation. One specimen from one sample failed, while other samples passed. This failure indicates that some of the samples may be in worse condition than other samples, or that the samples are reaching a point where the wire has less resistance to stresses. None of the samples tested passed the lifecycle test, indicating that the long-term life of all samples may be limited. Additional thermal life testing put some of the results into perspective and showed that the samples had some limited life remaining before beginning to fail physically and electrically.

The inspection and performance test results show that some of the wire samples were in worse condition than other samples. The better performing samples appear to have originated from more benign areas of the aircraft. Other factors may have been involved with the outcome of the performance tests, including localized damage or weaknesses in the insulation that were not caught by inspection or damage to the insulating materials caused by fluid exposure. Although these factors may have impacted the results of specific specimens, the impact on the overall performance of the wire samples in this test program should be minimal.

With the exception of specific mechanical damage already incurred by the wire samples, the wire of all three aircraft would be expected to retain mechanical and electrical integrity in the short-term. The long-term performance of the wire will be very poor as the wire continues to degrade from exposure to additional mechanical, thermal, electrical, moisture, radiation, chemical, and human induced stress.

4. CONCLUSIONS

4.1 General Condition

- Much of the wire from the aircraft was in fairly good condition
- Sporadic areas of damage were found in the wire samples
- Much of the wire damage appeared in common areas
- A variety of problems were found during the wire inspection
  - Contamination
    - brown film (possibly due to cigarette smoke residue)
    - paint and lubricant residue
    - foreign debris, such as lint and metal filings
  - Mechanical damage
    - gouges, cuts, scrapes, and abrasion
    - cracked wire insulation due to brittle wire
    - deep hot stamp markings
  - Electrical failure points
    - dielectric failures in mechanically damaged areas
    - a failure rate of roughly 20% in areas with damaged insulation

4.2 Performance Tests

- Many of the performance requirements were passed successfully by the aged wires.
- The wire in the three aircraft appeared and performed similarly.
- Wire from areas which may have had slightly elevated environmental conditions performed worse than wire from more benign areas in several tests.

- Mechanical Tests
  - Some of the wire specimens were very brittle, and the tensile strength and elongation would not meet the original requirements.
  - This insulation construction should continue to resist propagation of minor nicks and cuts without imminent dielectric failures, as seen from the notch sensitivity results.
  - Areas with deep hot stamp markings or other surface damage showed a greater propensity to crack than undamaged wire.

- Thermal Tests
  - The thermal properties of the wire insulation have most likely stabilized during the 25 plus years of service; therefore, assuming the wire was manufactured properly, the ability to withstand blocking and resist shrinkage and thermal shock should not decrease.
  - The wire insulation exhibits sufficient cold temperature performance to allow for the physical and electrical stress that may be experienced during flight.
  - Failures were noted in specific tests that exposed wire to high thermal stress.

- Thermal Aging Tests
  - All specimens passed accelerated aging test.
  - No specimens tested passed the lifecycle test.
  - The physical and electrical properties of the wire samples from the three aircraft continued to degrade following additional thermal aging.

- The presence of moisture with mechanical stress increased the rate of failure.
- Degradation of the wire increased with respect to time and temperature.
- Ultimate elongation was a better physical property than tensile strength to track insulation degradation. Tensile strength was a function of the outer insulation, which tended to fail before overall wire failure, while ultimate elongation was a function of the inner layer, which continued to maintain electrical integrity.

4.3 Overall Conclusions

- The wire submitted has definitely aged as indicated by the jacket failures in accelerated aging and lifecycle.
- The inner insulation continued to provide electrical integrity, as it was designed to do, although the outer jacket is losing its ability to mechanically protect the wire.
- The wire submitted for testing would be expected to perform adequately in the short term, provided there is no added stress beyond what it had experienced.
- The weak point in this wire type appears to be the lack of ability to maintain physical and electrical integrity during extended elevated thermal exposure with mechanical stress. As the wire ages, there is an increased risk of dielectric problems, mechanical damage and loss of electrical integrity.
- No wire was submitted that was exposed to high levels of environmental exposure. Wire from these areas, wheel wells, leading edges, etc., would be expected to perform worse than the wire submitted.

APPENDIX I

Boeing BMS 13-42/8
BMS 13-42A
BMS 13-42B

Wire Specifications

Ronald J. Hinderberger
Director
Airplane Safety
Commercial Airplanes Group

The Boeing Company
P.O. Box 3707 MC 67-XK
Seattle, WA 98124-2207

05 October 1999
B-H200-16785-ASI

Mr. Rex Beach or Mr. Joseph Kurek, M/S 60
Raytheon Systems
6125 E. 21st Street
Indianapolis, IN 46219-2058:

BOEING

Subject: BMS 13-42B -TWA 747-100, N93119 Accident Off Long Island, NY – 17 July 1996

Dear Sirs:

Mr. Bob Swaim, from the NTSB, requested that a copy of Boeing Material Specification (BMS) 13-42B be sent to you to support current testing. He had also asked that the proprietary nature of this document be waived so that it can be referenced in your test report.

Please find enclosed a copy of this specification. This information is not proprietary to The Boeing Company, however, we request that only information that is necessary to explain a condition or the original requirement with your test result be used in your report.

If you have any questions, please do not hesitate to call.

Very truly yours,

R. T. Howes for

Ronald J. Hinderberger
Director, Airplane Safety
Org. B-H200, MC 67-PR
Telex 32-9430, STA DIR AS
Phone (425) 237-8525
Fax (425) 237-8188

Encl: *BMS 13-42B,* dated 08 October 1970 (55 pages), and *Qualified Products List* (1 page)

cc: Mr. Bob Swaim, NTSB, AS-40

1. **SCOPE**

a. This specification covers crosslinked alkane-imide polymer insulated copper and copper alloy wire and cable. This specification requires qualification of products.

b. RATING

The wire of this specification is rated for the following conditions.

(1) When operating potentials do not exceed 600 volts (RMS).

(2) Where any combinations of ambient temperature and conductor current, for either intermittent or continuous service, does not produce a stabilized conductor temperature in excess of 302 F (150 C).

2. **REFERENCES**

Except where a specific issue is indicated, the noted issue of the following references shall be considered a part of this specification to the extent specified herein.

2.1 SPECIFICATIONS

2.1.1 FEDERAL

a.	TT-S-735, Type III	Standard Test Fluids; Hydrocarbon March 1964
b.	UU-T-450B	Tissue, Facial 24 Sept. 1963
c.	CCC-T-191b	Textile Test Methods 15 May 1951
d.	C-F-206C	Felt, Sheet, Wool Pressed 30 July 1968

2.1.2 MILITARY

a.	MIL-C-7078B	Cable Electric Aerospace Vehicle General Specification for 17 March, 1964
b.	MIL-T-5438	Tester; Abrasion, Electrical Cable 19 Dec. 1949
c.	MIL-H-5606B	Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordnance 26 June 1963
d.	MIL-J-5624F	Jet Fuel, Grades JP3, JP4 and JP5 14 May 1964
e.	MIL-L-7808E	Lubricating Oil, AircraftTurbine Engine, Synthetic Base 13 March 1963
f.	MIL-L-23699	Lubricating Oil, Aircraft Turbine Engine, Synthetic Base 1 March 1965

2.2 STANDARDS

2.2.1 FEDERAL

a. FED-STD-228 — Cable and Wire, Insulated; Methods of Testing, 14 April 1967

2.2.2 MILITARY

a. MIL-STD-104A — Limits for Electrical Insulation Color, 12 July 1963

b. MIL-STD-105D — Sampling Procedures and Tables for Inspection by Attributes, 29 April 1963

c. MIL-STD-109A — Quality Assurance Terms and Definitions, 30 Oct. 1961

2.3 OTHER PUBLICATIONS

2.3.1 COMMERCIAL

a. Munsell Book of Color — Munsell Color Co., Baltimore, Maryland

2.3.2 BOEING

a. BMS 3-11B — Hydraulic Fluid, Fire Resistant

2.4 AMERICAN SOCIETY OF TESTING AND MATERIALS (ASTM)

a. B 33-63 — Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes

b. B 298-64 — Standard Specification for Silver-Coated Soft or Annealed Copper Wire

c. D 1371-68 — Recommended Practice for Cleaning Plastic Specimens for Insulation Resistance, Surface Resistance, and Volume Resistivity Testing.

d. E 104-51 — Recommended Practice for Maintaining Constant Relative Humidity by means of Aqueous Solutions

(Copies of ASTM publications may be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103).

2.5 MISCELLANEOUS

a. Alkaline Detergent Solvent (pH 10-10.5)

b. Aerosafe 2300, Type I Stauffer Chemical Co., New York, N. Y.

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LIST OF TABLES

3. CONFIGURATION

3.1 TYPES

a. Type I — Wire or Cable - Lightweight Insulation, Tinned Copper Conductor.

One insulated conductor or two or more insulated conductors laid in a suitable spiral to make a multiconductor cable.

b. Type II — Not Applicable.

c. Type III — Shielded and Jacketed Cable - Lightweight Insulation, Tinned Copper Conductor.

Type I wire or cable over which the following is applied:

First - An overall shield of tinned copper braid.
Second - A jacket of alkane-imide polymer.

d. Type IV — Jacketed Cable - Lightweight Insulation, Tinned Copper Conductor.

Type I cable (Class 2 or greater) over which an alkane-imide polymer jacket is applied.

e. Type V — Wire or Cable - Lightweight Insulation, Silver Coated Copper Alloy Conductor.

One insulated conductor or two or more insulated conductors laid in a suitable spiral to make a multiconductor cable.

f. Type VI — Shielded and Jacketed Cable - Lightweight Insulation, Silver Coated Copper Alloy Conductor.

Type V wire or cable over which the following is applied:

First - An overall shield of tinned copper braid.
Second - A jacket of alkane-imide polymer.

g. Type VII — Jacketed Cable - Lightweight Insulation, Silver Coated Copper Alloy Conductor.

Type V Cable (Class 2 or greater) over which an alkane-imide polymer jacket is applied.

h. Type VIII — Wire or Cable - Normal Weight Insulation, Tinned Copper Conductor.

One insulated conductor or two or more insulated conductors laid in a suitable spiral to make a multiconductor cable.

i. Type IX — Wire or Cable - Normal Weight Insulation, Silver Coated Copper Alloy Conductor.

One insulated conductor or two or more insulated conductors laid in a suitable spiral to make a multiconductor cable.

3.2 CLASSES

The class designation shall be by arabic numerals which will indicate a single insulated wire or a number of insulated wires in a multiconductor cable.

Examples: Class 1 - A single insulated conductor.

Class 2 - Two spirally laid wires.

Class 24- Twenty-four spirally laid wires.

3.3 SIZES

Wire sizes covered in this specification are listed in Table II.

3.4 COLOR CODE

3.4.1 TYPES I, III, V, VI, VIII AND IX, CLASS 1.

Unless otherwise specified on the purchase order the finished wire color shall be white.

3.4.2 TYPES I THROUGH IX, CLASS 2 THROUGH 24

The finished color for wires in a multiconductor cable shall be as shown in Table I. On the eleventh through the twenty-fourth wire a stripe of the color shown in Table I shall be applied to the outer surface of the coating. The stripe shall be not less than .030 inch wide and shall make one complete turn around the wire in every two inches of axial length for wire sizes 30 through 12 and in every two inches of axial length for wire sizes 30 through 12 and in every four inches of axial length for wire sizes 10 through 4/0.

3.4.3 The colors shall be within the light and dark limits specified in MIL-STD-104A Class 1 or Class 2, except as noted. The color, color striping, and identification shall withstand a minimum of 125 cycles (250 strokes) when tested per paragraph 8.9.

3.5 WIRE AND CABLE DESIGNATION

The designation for a wire or cable of this specification shall be as follows:

BMS 13-42	TYPE	CLASS	SIZE
Material Specification No.	Type Designation Para. 3.1	Class Designation Para. 3.2	Size Para. 3.3

4. FORMS

Not applicable.

TABLE I

COLOR CODE FOR WIRES IN MULTICONDUCTOR CABLE

WIRE NUMBER	INSULATION COLOR	STRIPE COLOR
1	Red	----
2	Blue	----
3	Yellow	----
4	Green	----
5	Black	----
6	Purple	----
7	Orange	----
8	Brown	----
9	Pink *	----
10	White	----
11	White	Red
12	White	Blue
13	White	Yellow
14	White	Green
15	White	Black
16	White	Purple
17	White	Orange
18	White	Brown
19	White	Pink *
20	Red	Blue
21	Red	Yellow
22	Red	Green
23	Red	Black
24	Red	Purple

* Pink shall be between Munsell Renotation 2.5R 6.9/7.4 and 10RP 4.3/7.0 with the lighter value preferred.

5. REQUIREMENTS

a. The wire and cable furnished under this specification shall be a product which has been tested and has passed the qualification tests specified herein, prior to acceptance of production orders.

b. Where conflict exists between this specification and any specification referenced herein, this specification shall govern.

5.1 MATERIALS

5.1.1 CONDUCTOR MATERIALS

All strands used in the manufacture of the conductors shall be soft annealed copper conforming to ASTM Standards B33-63 or shall be high-strength copper alloy. Strands shall be free from lumps, kinks, splits, scraped or corroded surfaces and skin impurities. In addition, the strands shall conform to the following requirements as applicable.

5.1.1.1 Tin-Coated Copper Strands

The tin coating shall be as specified in ASTM Standard B33-63.

5.1.1.2 High Strength Copper Alloy

The strands shall conform to the requirements of 5.2.1.1.c for elongation and tensile strength and shall be silver coated in accordance with ASTM Standard B 298-64 with not less than 40 microinches of silver.

5.1.2 SHIELD MATERIALS

Shield strands (as applicable) shall be in accordance with the requirements for conductor materials (5.1.1).

5.1.3 INSULATING MATERIAL

5.1.3.1 Insulation

All polymers used in any type of insulation shall be certified virgin material (5.1.3.1.a) containing no additives except those required as pigmentation for colors, lubricants used in extrusion, stabilizers, and fillers. When tested in accordance with para. 8.14 the insulation material shall have a tensile strength and elongation as indicated in 5.2.1.2.a.

5.1.3.1.a Virgin Material

For purposes of this specification, virgin material shall be 100 percent new material which has been through only the processes essential to its manufacture and its application to the wire and cable which has previously been through these essential processes one time only. Any material which has previously been processed in any other manner is considered non-virgin material. This requirement shall apply to the manufacture of all ingredients and components used.

5.2 CONSTRUCTION

Construction of the wire and cable shall be as specified herein.

5.2.1 FINISHED WIRE CONSTRUCTION

5.2.1.1 Conductor

5.2.1.1.a Stranding

5.2.1.1.a(1) The stranding of conductors for wire sizes 30 through 10 AWG shall be as specified in Table II and shall be concentric in construction with a unidirectional lay or a true concentric lay.

5.2.1.1.a(1) (Continued)

Unidirectional lay shall be interpreted to be a center strand surrounded by one or more layers of helically wound strands. All layers shall have left-hand lay with the length of lay to be increased with each successive layer. The length of lay of the outer layer shall be not less than 8 times nor more than 16 times the maximum conductor diameter.

True concentric lay shall be interpreted to be a center strand surrounded by two or more layers of helically wound strands with direction of lay being reversed in each successive layer and with the length of lay to be increased with each successive layer. For the outer layer of strands the direction of lay shall be left-hand and the length of lay shall be not less than 8 times nor more than 16 times the maximum conductor diameter.

5.2.1.1.a(2) Wire sized 8 through 0000 shall be rope-lay as specified in Table II and in (a) and (b) below.

(a) Rope-lay stranded conductors shall be laid up concentrically with a central core surrounded by one or more layers of helically wound members. It is optional for the direction of lay of successive layers to be alternately reversed (true concentric lay), or to be in the same direction (unidirectional lay). The length of lay of the outer layer of rope-lay stranded members forming the conductor shall be not less than 10 nor more than 14 times the outside diameter of the completed conductor. The direction of lay of the outside layer shall be either left or right hand.

(b) Members of rope-lay stranded conductors: The length of lay of the wires composing the stranded members shall be not greater than 16 times the outside diameter of the member. Stranding or the individual members may be either concentric or bunch.

TABLE II

DETAILS OF CONDUCTORS

Size (AWG)	Nominal Conductor Area (Circular Mils)	Stranding (Number of Strands X AWG Gage of Strands)	Allowable No. of Missing Strands	Nominal Dia. of Individual Strands (Inch)	Diameter of Stranded Conductor		Max. Resistance of Finished Wire (OHMS/1000 ft. at 20 C)	
					Min. (Inch)	Max. (Inch)	Tin Coated Soft or Annealed Copper	Silver Coated High Strength Copper Alloy
30	112	7 x 38	0	0.0040	0.0114	0.013		120.5
28	175	7 x 36	0	0.0050	0.0144	0.016		76.4
26	304	19 x 38	0	0.0040	0.018	0.021		44.4
24	475	19 x 36	0	0.0050	0.023	0.026	25.4	28.1
22	754	19 x 34	0	0.0063	0.029	0.033	15.9	17.6
20	1,216	19 x 32	0	0.0080	0.037	0.041	9.76	10.9
18	1,900	19 x 30	0	0.0100	0.046	0.051	6.22	
16	2,426	19 x 29	0	0.0113	0.052	0.058	4.82	
14	3,831	19 x 27	0	0.0142	0.066	0.073	3.05	
12	5,874	37 x 28	0	0.0126	0.082	0.090	2.00	
10	9,354	37 x 26	0	0.0159	0.103	0.114	1.26	
8	16,983	133 x 29	0	0.0113	0.157	0.173	0.702	
6	26,818	133 x 27	0	0.0142	0.198	0.217	0.444	
4	42,615	133 x 25	0	0.0179	0.250	0.274	0.279	
2	66,500	665 x 30	2	0.0100	0.320	0.340	0.183	
1	81,700	817 x 30	2	0.0100	0.360	0.380	0.149	
0	104,500	1,045 x 30	3	0.0100	0.405	0.425	0.116	
00	133,000	1,330 x 30	3	0.0100	0.455	0.480	0.091	
000	166,500	1,655 x 30	4	0.0100	0.515	0.540	0.071	
0000	210,900	2,109 x 30	5	0.0100	0.580	0.605	0.056	

5.2.1.1.b Splices

Splices in individual strands or member shall be butt-brazed. There shall be not more than one strand-splice in any 10 foot length of a stranded concentric-lay conductor or in any 10-foot length of any member in a rope-lay conductor; except that not more than one splice of an entire member shall be permitted in any 10 feet of a rope-lay conductor. Splices in members of a rope-lay construction shall be so finished that the conductor diameter is not increased at the point of brazing. In no case shall the whole conductor be spliced at one point.

5.2.1.1.c Conductor Elongation and Tensile Strength

5.2.1.1.c.(1) Elongation

The individual strands of the conductor or the whole conductor removed from finished wire shall have the following minimum elongation when measured in accordance with 8.5.

Soft annealed copper	10 percent
High-strength copper alloy	6 percent

5.2.1.1.c.(2) Tensile Strength (High-Strength Copper Alloy Only)

When high-strength copper alloy is specified, the individual strands of the conductor or the whole conductor removed from finished wire shall have a minimum tensile strength of 58,000 psi when measured in accordance with 8.5.

5.2.1.1.d Conductor Diameter

The diameter of the conductor shall be as specified in Table II.

5.2.1.2 Insulation

The insulation shall be constructed so that it can be readily removed by mechanical wire-stripping devices.

5.2.1.2.a Primary Insulation

The primary insulation of one or more layers shall be crosslinked extruded ·lkane-imide polymer. When one or more layers are employed a coating of modified imide polymer may be used between the layers. The insulation shall have a tensile strength of 7500 PSI (Min) and an elongation of 50% (Minimum) when tested per Para. 8.14.

5.2.1.2.b Coating

A coating of modified imide polymer shall be applied to the insulation. This coating shall be continuous and free from cracks, splits, blisters, and other defects when examined without aid of magnification.

5.2.2 FINISHED CABLE CONSTRUCTION

The construction of finished cable shall be as specified in the individual constructions. The required number of insulated wires determined by the class designation shall be spirally laid to provide as concentric a cable as possible. The lay of the individual wires shall be not less than eight nor more than fourteen times the major diameter of the cable. Fillers shall not be allowed.

5.2.2.1 Shield Construction and Coverage

The shield shall be a closely woven braid and shall comply with the following:

a. The individual shield strand size shall be as follows:

(1) Size 38 AWG strands shall be used over wire or cable having a major diameter of .250 inch or less.

(2) Size 36 AWG strands shall be used over cable having major diameter greater than .250 inch.

5.2.2.1 (Continued)

b. The shield shall provide a minimum coverage of 85 percent with coverage being determined by Para. 4.5.3 of MIL-C-7078B.

c. The shield shall be a push-back type.

(1) When the major diameter of the cable, prior to the application of shield, is less than 0.30 inch, the angle of the carriers of the shield with the axis of the cable shall be not less than 20 or more than 35 degrees.

(2) When the major diameter of the cable, prior to the application of shield is 0.30 inch or greater and the limitations of standard braiding equipment, with a practical number of ends per carrier, make compliance with paragraph 5.2.2.1.c.(1) impractical; the shield shall be suitable applied to assure a push-back characteristic.

5.2.2.2 Cable Jacket Construction

Cable jackets shall beextruded concentrically with the material and in the thickness as specified herein. When tested in accordance with 8.14 the jacket material shall have a tensile strength of 3500 PSI Min. and an elongation of 100% Min. The color of the jacket shall be white within the light and dark limits of MIL-STD-104A, Class 1 or Class 2.

5.3 FINISHED WIRE AND CABLE TYPE I THROUGH TYPE IX

The finished wire and cable shall conform to the additional requirements as follows:

5.3.1 FINISHED WIRE AND CABLE TYPE I THROUGH VII

TABLE III

LIGHTWEIGHT WIRE WALL THICKNESS (INCH)

AWG	MINIMUM	MAXIMUM
30	.005	.0073
28		.0073
26		.0080
24		.0080
22		.0080
20		.0085
18		.0090
16		.0100
14		.0130
12	.005	.0130

5.3.1.1 Type I, Class 1 through Class 5 Copper Conductor

5.3.1.1.a Type I, Class I Wire

The requirements of Type I, Class 1 wires are listed in Table III, Table IV, and Table XXI and as shown in Fig. 1.

The physical details of the conductor shall be as specified in Table II for tin coated copper wire.

5.3.1.1.b Type I, Class 2 or Greater Cable

The finished wires that compose the multi-conductor cable shall comply with all the requirements of this specification for Type I, Class 1 wire, and color coded per para 3.4. Additional requirements for the multi-conductor cable are listed in Table IV.

5.3.2 FINISHED WIRE AND CABLE TYPE VIII AND IX

TABLE X

NORMAL WEIGHT WIRE WALL THICKNESS

AWG	INCHES	
	MINIMUM	MAXIMUM
30	.009	.0113
28		.0113
26		.0120
24		.0120
22		.0125
20		.0125
18		.0125
16		.0125
14		.0165
12		.0170
10	.009	.0195
8	.015	.0230
6		.0265
4		.0305
2		.0330
1/0		.0385
2/0		.0435
3/0		.0455
4/0	.015	.0455

5.3.2.1 Type VIII, Class 1 through Class 5 Copper Conductor

5.3.2.1.a Type VIII, Class 1, Wire

The requirements of Type VIII, Class 1, wire are listed in Table X, Table XI, and Table XXI, and as shown in Fig. 7.

The physical details of the conductor shall be as specified in Table II for tin coated copper wire.

5.3.2.1.b Type VIII, Class 2 or Greater Cable

The finished wires that compose the multi-conductor cable shall comply with all the requirements of this specification for Type VIII, Class 1 wire, and color coded per para. 3.4. Additional requirements for the multi-conductor cable are listed in Table XI.

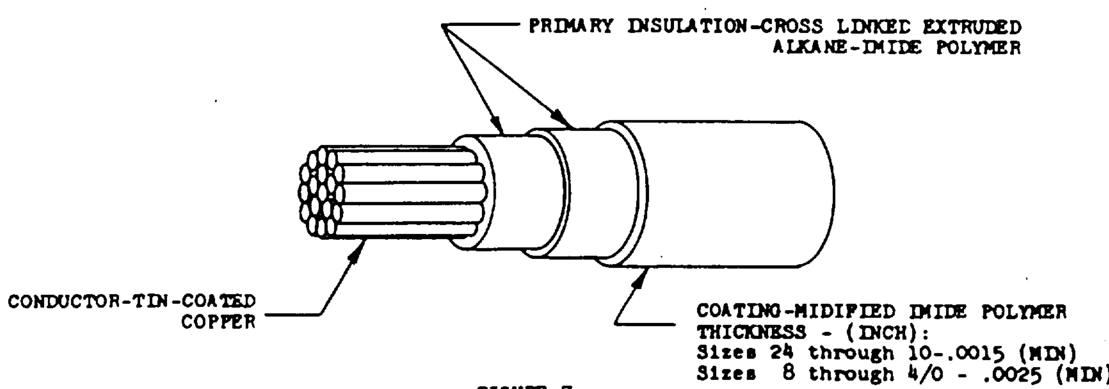

FIGURE 7

TABLE XI

CLASS	PART NUMBER	CONDUCTOR SIZE (AWG)	MAXIMUM OUTSIDE DIAMETER (INCH)	MAXIMUM WEIGHT (LBS/1000 FT)
1	W42/8/1-24	24	0.047	2.2
	W42/8/1-22	22	0.054	3.2
	W42/8/1-20	20	0.062	4.7
	W42/8/1-18	18	0.073	7.0
	W42/8/1-16	16	0.082	9.0
	W42/8/1-14	14	0.099	13.7
	W42/8/1-12	12	0.116	20.4
	W42/8/1-10	10	0.142	31.8
	W42/8/1-8	8	0.203	58.5
	W42/8/1-6	6	0.251	91.0
	W42/8/1-4	4	0.311	146.0
	W42/8/1-2	2	0.386	231.0
	W42/8/1-0	0	0.482	365.0
	W42/8/1-00	00	0.542	483.0
	W42/8/1-000	000	0.606	618.0
	W42/8/1-0000	0000	0.671	780.0
2	W42/8/2-24	24	0.095	4.4
	W42/8/2-22	22	0.108	6.5
	W42/8/2-20	20	0.124	9.5
	W42/8/2-18	18	0.146	14.1
	W42/8/2-16	16	0.163	18.4
	W42/8/2-14	14	0.197	28.4
	W42/8/2-12	12	0.232	42.5
3	W42/8/3-24	24	0.102	6.7
	W42/8/3-22	22	0.116	9.7
	W42/8/3-20	20	0.133	14.2
	W42/8/3-18	18	0.158	21.2
	W42/8/3-16	16	0.175	27.7
	W42/8/3-14	14	0.213	42.6
	W42/8/3-12	12	0.250	61.8
4	W42/8/4-24	24	0.130	8.9
	W42/8/4-22	22	0.146	12.7
	W42/8/4-20	20	0.169	19.5
	W42/8/4-18	18	0.200	28.3
	W42/8/4-16	16	0.223	37.0
	W42/8/4-14	14	0.271	56.9
	W42/8/4-12	12	0.323	85.5
5	W42/8/5-24	24	0.141	11.2
	W42/8/5-22	22	0.160	16.0
	W42/8/5-20	20	0.184	24.5
	W42/8/5-18	18	0.218	36.2
	W42/8/5-16	16	0.242	46.3
	W42/8/5-14	14	0.295	71.3
	W42/8/5-12	12	0.353	107.0

1. SCOPE

a. This specification covers crosslinked alkane-imide polymer insulated copper and copper alloy wire and cable. This specification requires qualification of products.

b. RATING

The wire of this specification is rated for the following conditions.

(1) When operating potentials do not exceed 600 volts (RMS).

(2) Where any combinations of ambient temperature and conductor current, for either intermittent or continuous service, does not produce a stabilized conductor temperature in excess of 302 F (150 C).

2. REFERENCES

Except where a specific issue is indicated, the noted issue of the following references shall be considered a part of this specification to the extent specified herein.

2.1 SPECIFICATIONS

2.1.1 FEDERAL

a.	TT-S-735, Type III	Standard Test Fluids; Hydrocarbon, March 1964
b.	UU-T-450B	Tissue, Facial, 24 Sept. 1963
c.	CCC-T-191b	Textile Test Methods, 15 May 1951
d.	C-F-206C	Felt Sheet, Cloth, Felt, Wool, Pressed, 30 July 1968 R

2.1.2 MILITARY

a.	MIL-C-7078B	Cable Electric Aerospace Vehicle General Specification for, 17 March, 1964
b.	MIL-T-5438	Tester; Abrasion, Electrical Cable, 19 Dec. 1949
c.	MIL-H-5606B	Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordnance, 26 June 1963
d.	MIL-A-6091C	Alcohol, Ethyl, Specially Denatured, 9 Feb. 1968 R
e.	MIL-L-7808E	Lubricating Oil, AircraftTurbine Engine, Synthetic Base, 13 March 1963
f.	MIL-L-23699	Lubricating Oil, Aircraft Turbine Engine, Synthetic Base, 1 March 1965
g.	MIL-D-26937A	Detergent, Synthetic, Anionic (Alkyl Benzene Sulfonate), 15 April 1963 R

2.2 STANDARDS

2.2.1 FEDERAL

a. FED-STD-228 — Cable and Wire, Insulated; Methods of Testing, 14 April 1967

2.2.2 MILITARY

a. MIL-STD-104A — Limits for Electrical Insulation Color, 12 July 1963

b. MIL-STD-105D — Sampling Procedures and Tables for Inspection by Attributes, 29 April 1963

c. MIL-STD-109A — Quality Assurance Terms and Definitions, 30 Oct. 1961

2.3 OTHER PUBLICATIONS

2.3.1 COMMERCIAL

a. Munsell Book of Color — Munsell Color Co., Baltimore, Maryland

2.3.2 BOEING

a. BMS 3-11C — Hydraulic Fluid, Fire Resistant R

2.4 AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM) R

a. B 33-63 — Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes

b. B 298-64 — Standard Specification for Silver-Coated Soft or Annealed Copper Wire

c. D 1371-68 — Recommended Practice for Cleaning Plastic Specimens for Insulation Resistance, Surface Resistance, and Volume Resistivity Testing

d. E 104-51 — Recommended Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions

(Copies of ASTM publications may be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103).

2.5 MISCELLANEOUS R

a. Alkaline Detergent Solvent (pH 10.0-10.5)(REF: Maintenance Manual, Chapter 12, Cleaning & Polishing Materials - Ordering/Dexcription/Use)

b. Oronite HyJet III, Chevron Chemical Co., San Francisco, California.

TABLE OF CONTENTS

3. CONFIGURATION

3.1 TYPES

a. Type I — Wire or Cable - 6 MIL (NOM) Insulation, Tinned Copper Conductor.

One insulated conductor or two or more insulated conductors laid in a suitable spiral to make a multiconductor cable.

b. Type II — Not Applicable.

c. Type III — Shielded and Jacketed Cable - 6 MIL (NOM) Insulation, Tinned Copper Conductor.

Type I wire or cable over which the following is applied:

First - An overall shield of tinned copper braid.
Second - A jacket of alkane-imide polymer.

d. Type IV — Jacketed Cable - 6 MIL (NOM) Insulation, Tinned Copper Conductor.

Type I cable (Class 2 or greater) over which an alkane-imide polymer jacket is applied.

e. Type V — Wire or Cable - 6 MIL (NOM) Insulation, Silver Coated Copper Alloy Conductor.

One insulated conductor or two or more insulated conductors laid in a suitable spiral to make a multiconductor cable.

f. Type VI — Shielded and Jacketed Cable - 6 MIL (NOM) Insulation, Silver Coated Copper Alloy Conductor.

Type V wire or cable over which the following is applied:

First - An overall shield of tinned copper braid.
Second - A jacket of alkane-imide polymer.

g. Type VII — Jacketed Cable - 6 MIL (NOM) Insulation, Silver Coated Copper Alloy Conductor.

Type V Cable (Class 2 or greater) over which an alkane-imide polymer jacket is applied.

h. Type VIII — Wire or Cable - 10 MIL (NOM) Insulation, Tinned Copper Conductor.

One insulated conductor or two or more insulated conductors laid in a suitable spiral to make a multiconductor cable.

i. Type IX — Wire or Cable - 10 MIL (NOM) Insulation, Silver Coated Copper Alloy Conductor.

One insulated conductor or two or more insulated conductors laid in a suitable spiral to make a multiconductor cable.

j. Type X — Wire or Cable - 8 MIL (NOM) Insulation, Tinned Copper Conductor.

k. Type XI — Wire or Cable - 8 MIL (NOM) Insulation, Silver Coated Copper Alloy Conductor.

m. Type XII — Shielded and Jacketed Cable - 8 MIL (NOM) Insulation, Tinned Copper Conductor.

Type X Wire or Cable over which the following is applied:

First - An overall shield of Tinned Copper Braid
Second - A jacket of Alkane-imide Polymer

n. Type XIII — Shielded and Jacketed Cable - 8 MIL (NOM) Insulation, Silver Coated Copper Alloy Conductor

Type XI wire or cable over which the following is applied:

First - An overall shield of Tinned Copper Braid.
Second - A jacket of Alkane-imide Polymer

3.2 CLASSES

The class designation shall be by arabic numerals which will indicate a single insulated wire or a number of insulated wires in a multiconductor cable.

Examples: Class 1 - A single insulated conductor.
Class 2 - Two spirally laid wires.
Class 24 - Twenty-four spirally laid wires.

3.3 SIZES

Wire sizes covered in this specification are listed in Table II.

3.4 COLOR CODE

3.4.1 ALL TYPES, CLASS 1 R

Unless otherwise specified on the purchase order the finished wire color shall be white.

3.4.2 ALL TYPES, CLASS 2 THROUGH 24 R

The finished color for wires in a multiconductor cable shall be as shown in Table I. On the eleventh through the twenty-fourth wire a stripe of the color shown in Table I shall be applied to the outer surface of the coating. The stripe shall be not less than .030 inch wide and shall make one complete turn around the wire in every two inches of axial length for wire sizes 30 through 12 and in every four inches of axial length for wire sizes 10 through 4/0. R

3.4.3 COLORS

The colors shall be within the light and dark limits specified in MIL-STD-104A Class 1 or Class 2, except as noted. The color, color striping, and identification shall withstand a minimum of 125 cycles (250 strokes) when tested per paragraph 8.9.

3.5 WIRE AND CABLE DESIGNATION

The designation for a wire or cable of this specification shall be as follows:

BMS 13-42A	TYPE	CLASS	SIZE
Material Specification No.	Type Designation Para. 3.1	Class Designation Para. 3.2	Size Para. 3.3

R

4. FORMS

Not applicable.

TABLE I

COLOR CODE FOR WIRES IN MULTICONDUCTOR CABLE

WIRE NUMBER	INSULATION COLOR	STRIPE COLOR
1	Red	----
2	Blue	----
3	Yellow	----
4	Green	----
5	Black	----
6	Purple	----
7	Orange	----
8	Brown	----
9	Pink *	----
10	White	----
11	White	Red
12	White	Blue
13	White	Yellow
14	White	Green
15	White	Black
16	White	Purple
17	White	Orange
18	White	Brown
19	White	Pink *
20	Red	Blue
21	Red	Yellow
22	Red	Green
23	Red	Black
24	Red	Purple

* Pink shall be between Munsell Renotation 2.5R 6.9/7.4 and 10RP 4.3/7.0 with the lighter value preferred.

5. REQUIREMENTS

a. The wire and cable furnished under this specification shall be a product which has been tested and has passed the qualification tests specified herein, prior to acceptance of production orders.

b. Where conflict exists between this specification and any specification referenced herein, this specification shall govern.

5.1 MATERIALS

5.1.1 CONDUCTOR MATERIALS

All strands used in the manufacture of the conductors shall be soft annealed copper conforming to ASTM Standards B33-63 or shall be high-strength copper alloy. Strands shall be free from lumps, kinks, splits, scraped or corroded surfaces and skin impurities. In addition, the strands shall conform to the following requirements as applicable.

5.1.1.1 Tin-Coated Copper Strands

The tin coating shall be as specified in ASTM Standard B33-63.

5.1.1.2 High-Strength Copper Alloy R

The strands shall conform to the requirements of 5.2.1.3 for elongation and tensile strength and shall be silver coated in accordance with ASTM Standard B 298-64 with not less than 40 microinches of silver.

5.1.2 SHIELD MATERIALS

Shield strands (as applicable) shall be in accordance with the requirements for conductor materials (5.1.1).

5.1.3 INSULATING MATERIAL

5.1.3.1 Insulation

All polymers used in any type of insulation shall be certified virgin material (5.1.3.1.1) containing no additives except those required as pigmentation for colors, lubricants used in extrusion, stabilizers, and fillers. R

5.1.3.1.1 Virgin Material

For purposes of this specification, virgin material shall be 100 percent new material which has been through only the processes essential to its manufacture and its application to the wire and cable and which has previously been through these essential R processes one time only. Any material which has previously been processed in any other manner is considered non-virgin material. This requirement shall apply to the manufacture of all ingredients and components used.

5.2 CONSTRUCTION

Construction of the wire and cable shall be as specified herein.

5.2.1 FINISHED WIRE CONSTRUCTION

5.2.1.1 Conductor Stranding

5.2.1.1.1 The stranding of conductors for wire sizes 30 through 10 AWG shall be as specified in Table II and shall be concentric in construction with a unidirectional lay or a true concentric lay.

5.2.1.1.1 (Continued)

a. Unidirectional lay shall be interpreted to be a center strand surrounded by one or more layers of helically wound strands. All layers shall have left-hand lay with the length of lay to be increased with each successive layer. The length of lay of the outer layer shall be not less than 8 times or more than 16 times the maximum conductor diameter.

b. True concentric lay shall be interpreted to be a center strand surrounded by two or more layers of helically wound strands with direction of lay being reversed in each successive layer and with the length of lay being increased with each successive layer. For the outer layer of strands the direction of lay shall be left-hand and the length of lay shall be not less than 8 times or more than 16 times the maximum conductor diameter. R

5.2.1.1 2 Wire sizes 8 through 0000 shall be rope-lay as specified in Table II and in a and b below. R

a. Rope-lay stranded conductors shall be laid up concentrically with a central core surrounded by one or more layers of helically wound members. It is optional for the direction of lay of successive layers to be alternately reversed (true concentric lay), or to be in the same direction (unidirectional lay). The length of lay of the outer layer of rope-lay stranded members forming the conductor shall be not less than 10 nor more than 14 times the outside diameter of the completed conductor. The direction of lay of the outside layer shall be either left or right hand.

b. Members of rope-lay stranded conductors: The length of lay of the wires composing the stranded members shall be not greater than 16 times the outside diameter of the member. Stranding or the individual members may be either concentric or bunch.

5.2.1.2 <u>Conductor Splices</u> R

Splices in individual strands or members shall be butt brazed. There shall be not more than one strand-splice in any 10 foot length of a stranded concentric-lay conductor or in any 10-foot length of any member in a rope-lay conductor; except that not more than one splice of an entire member shall be permitted in any 10 feet of a rope-lay conductor. Splices in members of a rope-lay construction shall be so finished that the conductor diameter is not increased at the point of brazing. In no case shall the whole conductor be spliced at one point.

TABLE II

DETAILS OF CONDUCTORS

Size (AWG)	Nominal Conductor Area (Circular Mils)	Stranding (Number of Strands X Strand Size)	Allowable No. of Missing Strands	Nominal Dia. of Individual Strands (Inch)	Diameter of Stranded Conductor		Max. Resistance of Finished Wire (OHMS/1000 ft. at 20 C)	
					Min. (Inch)	Max. (Inch)	Tin-Coated Soft or Annealed Copper	Silver-Coated High-Strength Copper Alloy
30	112	7 x 38	0	0.0040	0.0114	0.013		120.5
28	175	7 x 36	0	0.0050	0.0144	0.016		76.4
26	304	19 x 38	0	0.0040	0.018	0.021		44.4
24	475	19 x 36	0	0.0050	0.023	0.026	25.4	28.1
22	754	19 x 34	0	0.0063	0.029	0.033	15.9	17.6
20	1,216	19 x 32	0	0.0080	0.037	0.041	9.76	10.9
18	1,900	19 x 30	0	0.0100	0.046	0.051	6.22	
16	2,426	19 x 29	0	0.0113	0.052	0.058	4.82	
14	3,831	19 x 27	0	0.0142	0.066	0.073	3.05	
12	5,874	37 x 28	0	0.0126	0.082	0.090	2.00	
10	9,354	37 x 26	0	0.0159	0.103	0.114	1.26	
8	16,983	133 x 29	0	0.0113	0.157	0.173	0.702	
6	26,818	133 x 27	0	0.0142	0.198	0.217	0.444	
4	42,615	133 x 25	0	0.0179	0.250	0.274	0.279	
2	66,500	665 x 30	2	0.0100	0.320	0.340	0.183	
1	81,700	817 x 30	2	0.0100	0.360	0.380	0.149	
0	104,500	1,045 x 30	3	0.0100	0.405	0.425	0.116	
00	133,000	1,330 x 30	3	0.0100	0.455	0.480	0.091	
000	166,500	1,655 x 30	4	0.0100	0.515	0.540	0.071	
0000	210,900	2,109 x 30	5	0.0100	0.580	0.605	0.056	

5.2.1.3 Conductor Elongation and Tensile Strength

5.2.1.3.1 Elongation

The individual strands of the conductor or the whole conductor removed from finished wire shall have the following minimum elongation when measured in accordance with 8.5.

Soft annealed copper	10 percent
High-strength copper alloy	6 percent

5.2.1.3.2 Tensile Strength (High-Strength Copper Alloy Only)

When high-strength copper alloy is specified, the individual strands of the conductor or the whole conductor removed from finished wire shall have a minimum tensile strength of 58,000 psi when measured in accordance with 8.5.

5.2.1.4 Conductor Diameter

The diameter of the conductor shall be as specified in Table II.

5.2.1.5 Insulation

The insulation shall be constructed so that it can be readily removed by mechanical wire-stripping devices.

5.2.1.5.1 Primary Insulation

The primary insulation of one or more layers shall be crosslinked extruded alkane-imide polymer. When more than one layer is employed a coating of modified imide polymer may be used between the layers. The alkane-imide polymer shall be an off-white color readily distinguishable from the basic brown color of the imide coating.

5.2.1.5.2 Coating

A coating of modified imide polymer shall be applied over the insulation. This coating shall be continuous and free from cracks, splits, blisters, and other defects when examined without aid of magnification.

5.2.1.5.3 Insulation Elongation and Tensile Strength

The primary insulation and the coating shall have an elongation of 50 percent (minimum) when tested per 8.14 and shall have a tensile strength of 7500 PSI (minimum) for wire sizes 30 through 10 and 5000 PSI (minimum) for wire sizes 8 through 4/0 when tested per 8.14.

5.2.2 FINISHED CABLE CONSTRUCTION

The construction of finished cable shall be as specified in the individual Type and Class construction details. In multi-conductor cables the insulated wires as determined by the class designation shall be spirally laid to provide as concentric a cable as possible. The lay of the individual wires shall be not less than eight or more than sixteen times the major diameter of the cable. The direction of lay shall be left-hand. Fillers will not be allowed.

5.2.2.1 Shield Construction and Coverage

The shield shall be a closely woven braid and shall comply with the following:

a. The individual shield strand size shall be as follows:

(1) Size 38 strands shall be used over wire or cable having a major diameter of 0.300 inch or less.

(2) Size 36 strands shall be used over wire or cable having a major diameter greater than 0.300 inch and less than 0.400 inch.

(3) Size 34 strands shall be used over wire or cable having a major diameter of 0.400 inch or over.

R

5.2.2.1 (Continued)

b. The shield shall provide a minimum coverage of 85 percent with coverage being determined in accordance with 4.5.3 of MIL-C-7078B.

c. The shield shall be a push-back type.

(1) When the major diameter of the cable, prior to the application of shield, is less than 0.300 inch, the angle of the carriers of the shield with the axis of the cable shall be not less than 20 or more than 35 degrees.

(2) When the major diameter of the cable, prior to the application of shield is 0.300 inch or greater and the limitations of standard braiding equipment, with a practical number of ends per carrier, make compliance with paragraph 5.2.2.1.c.(1) impractical; the shield shall be suitably applied to assure a push-back characteristic.

5.2.2.2 Cable Jacket Construction

Cable jackets shall be crosslinked extruded alkane-imide polymer and shall be concentrically applied. Minimum jacket wall thickness shall be 0.006 inch when the cable beneath the jacket has an O.D. of 0.215 inch or less and shall be 0.007 inch when the cable beneath the jacket has an O.D. of more than 0.215 inch. When tested in accordance with 8.14 the jacket material shall have a tensile strength of 3500 PSI (min.) and an elongation of 100 percent (min.). Unless otherwise specified on the purchase order the color of the jacket shall be white within the light and dark limits of MIL-STD-104A, Class 1 or 2.

5.3 FINISHED WIRE AND CABLE - TYPE I THROUGH TYPE XIII

The finished wire and cable shall conform to the following additional requirements:

5.3.1 TYPE I, CLASS I WIRE

The requirements of Type I, Class 1 wire shall be as indicated in Table III and Table XXII and as shown in Fig. 1.

The physical and electrical details of the conductor shall be as specified in Table II for tin-coated copper wire. The wall thickness of the insulation shall be 0.005 inch (min.).

5.3.2 TYPE I, CLASS 2 OR GREATER CABLE

The finished wires that compose the multi-conductor cable shall comply with all the requirements of this specification for Type I, Class 1 wire and shall be color coded in accordance with 3.4. Additional requirements for the multi-conductor cable are listed in Table III.

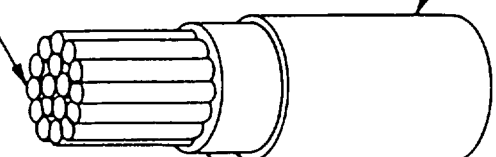

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FIGURE 1

TABLE III R

TYPE I WIRE AND CABLE - OUTSIDE DIAMETER AND WEIGHT R

CLASS	PART NO.*	COND. SIZE (AWG)	MAXIMUM OUTSIDE DIAMETER (INCH)	MAXIMUM WEIGHT (LBS/1000 FT.)
1	W42/1/1-24	24	0.039	2.0
	W42/1/1-22	22	0.045	2.8
	W42/1/1-20	20	0.054	4.3
	W42/1/1-18	18	0.064	6.4
	W42/1/1-16	16	0.072	8.4
	W42/1/1-14	14	0.090	13.0
	W42/1/1-12	12	0.108	19.7
2	W42/1/2-24	24	0.079	4.0
	W42/1/2-22	22	0.091	5.6
	W42/1/2-20	20	0.108	8.7
	W42/1/2-18	18	0.128	13.3
	W42/1/2-16	16	0.144	17.4
	W42/1/2-14	14	0.179	26.9
	W42/1/2-12	12	0.216	41.1
3	W42/1/3-24	24	0.085	6.1
	W42/1/3-22	22	0.098	8.5
	W42/1/3-20	20	0.116	13.0
	W42/1/3-18	18	0.138	20.1
	W42/1/3-16	16	0.155	26.1
	W42/1/3-14	14	0.193	40.4
	W42/1/3-12	12	0.233	61.7
4	W42/1/4-24	24	0.108	8.1
	W42/1/4-22	22	0.124	11.5
	W42/1/4-20	20	0.146	17.9
	W42/1/4-18	18	0.175	26.8
	W42/1/4-16	16	0.197	34.9
	W42/1/4-14	14	0.245	54.0
	W42/1/4-12	12	0.296	82.5
5	W42/1/5-24	24	0.117	10.1
	W42/1/5-22	22	0.135	14.4
	W42/1/5-20	20	0.160	22.4
	W42/1/5-18	18	0.190	33.5
	W42/1/5-16	16	0.215	43.7
	W42/1/5-14	14	0.268	67.6
	W42/1/5-12	12	0.328	103.3

* NOTE: Applicable Change Letter Not Shown

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5.3.3 TYPE III SHIELDED AND JACKETED CABLE CLASS 1 THROUGH CLASS 4

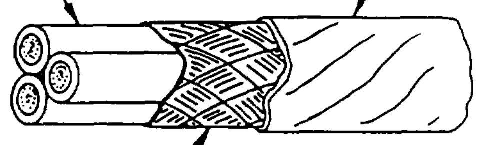
5.3.3.1 Basic Wire

The basic wire in Type III construction shall conform to all the requirements of Type I, Class 1 wire or Type 1, Class 2 or greater cable as applicable.

5.3.3.2 Finished Cable

The requirements of the finished cable shall be as indicated in Table IV, Table XXII and as shown in Figure 2.

The component wires shall be color coded in accordance with 3.4.



(TYPICAL FOR ALL CLASSES)

FIGURE 2

TABLE IV

TYPE III CABLE - OUTSIDE DIAMETER AND WEIGHT

CLASS	PART NO.*	CONDUCTOR SIZE (AWG)	MAXIMUM OUTSIDE DIAMETER (INCH)	MAXIMUM WEIGHT (LBS/1000 FT)
1	W42/3/1-24	24	0.075	5.3
	W42/3/1-22	22	0.081	6.4
	W42/3/1-20	20	0.089	8.5
	W42/3/1-18	18	0.099	11.4
	W42/3/1-16	16	0.108	13.9
	W42/3/1-14	14	0.125	19.8
	W42/3/1-12	12	0.143	28.0
2	W42/3/2-24	24	0.113	9.0
	W42/3/2-22	22	0.125	11.3
	W42/3/2-20	20	0.141	15.4
	W42/3/2-18	18	0.162	21.0
	W42/3/2-16	16	0.178	26.0
	W42/3/2-14	14	0.213	37.4
	W42/3/2-12	12	0.251	54.1
3	W42/3/3-24	24	0.119	11.7
	W42/3/3-22	22	0.132	15.0
	W42/3/3-20	20	0.149	20.8
	W42/3/3-18	18	0.172	28.9
	W42/3/3-16	16	0.189	36.0
	W42/3/3-14	14	0.229	52.9
	W42/3/3-12	12	0.270	76.8
4	W42/3/4-24	24	0.132	14.5
	W42/3/4-22	22	0.147	18.8
	W42/3/4-20	20	0.168	26.5
	W42/3/4-18	18	0.193	36.9
	W42/3/4-16	16	0.214	46.2
	W42/3/4-14	14	0.258	68.4
	W42/3/4-12	12	0.305	99.8

* NOTE: Applicable Change Letter Not Shown

5.3.4 TYPE IV, JACKETED CABLE CLASS 2 THROUGH CLASS 5

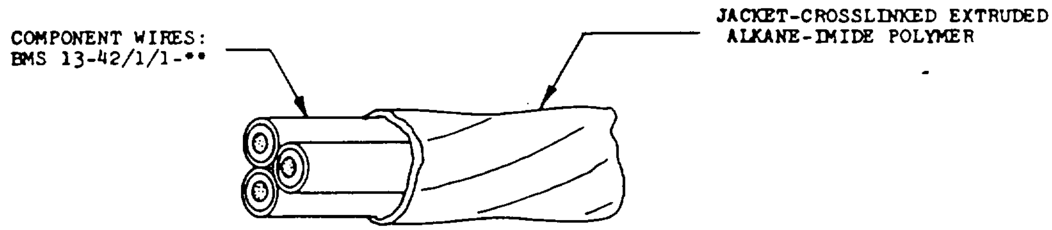
5.3.4.1 Basic Wire

The basic wires in Type IV construction shall conform to all the requirements of Type I, Class 2 or greater cable.

5.3.4.2 Finished Cable

The requirements of the finished cable shall be as indicated in Table V, Table XXII and as shown in Fig. 3.

The component wires shall be color coded in accordance with 3.4.



(TYPICAL FOR ALL CLASSES)

FIGURE 3

TABLE V

TYPE IV CABLE - OUTSIDE DIAMETER AND WEIGHT

CLASS	PART NUMBER*	CONDUCTOR SIZE (AWG)	MAXIMUM OUTSIDE DIAMETER (INCH)	MAXIMUM WEIGHT (LBS/1000 FT)
2	W42/4/2-24	24	0.094	5.2
	W42/4/2-22	22	0.107	7.1
	W42/4/2-20	20	0.123	10.5
	W42/4/2-18	18	0.143	15.2
	W42/4/2-16	16	0.160	19.5
	W42/4/2-14	14	0.194	29.5
	W42/4/2-12	12	0.233	44.6
3	W42/4/3-24	24	0.100	7.3
	W42/4/3-22	22	0.114	10.1
	W42/4/3-20	20	0.131	15.1
	W42/4/3-18	18	0.153	22.1
	W42/4/3-16	16	0.171	28.4
	W42/4/3-14	14	0.209	43.2
	W42/4/3-12	12	0.250	65.6
4	W42/4/4-24	24	0.114	9.5
	W42/4/4-22	22	0.129	13.2
	W42/4/4-20	20	0.149	19.8
	W42/4/4-18	18	0.175	29.1
	W42/4/4-16	16	0.195	37.5
	W42/4/4-14	14	0.240	57.7
	W42/4/4-12	12	0.287	86.9
5	W42/4/5-24	24	0.132	11.7
	W42/4/5-22	22	0.150	16.2
	W42/4/5-20	20	0.175	24.5
	W42/4/5-18	18	0.205	36.0
	W42/4/5-16	16	0.232	46.5
	W42/4/5-14	14	0.285	71.6
	W42/4/5-12	12	0.348	108.0

* NOTE: Applicable Change Letter Not Shown

5.3.5 TYPE V, CLASS 1 WIRE

The requirements of Type V, Class 1, wire shall be as indicated in Table VI, Table XXII and as shown in Figure 4.

The physical and electrical details of the conductor shall be as specified in Table II for silver coated high strength copper alloy wire. The wall thickness of the insulation shall be 0.005 inch (min.).

5.3.6 TYPE V, CLASS 2 OR GREATER CABLE

The finished wires that compose the multi-conductor cable shall comply with all the requirements of this specification for Type V, Class 1 wire and shall be color coded in accordance with 3.4. Additional requirements for the multi-conductor cable are listed in Table VI.

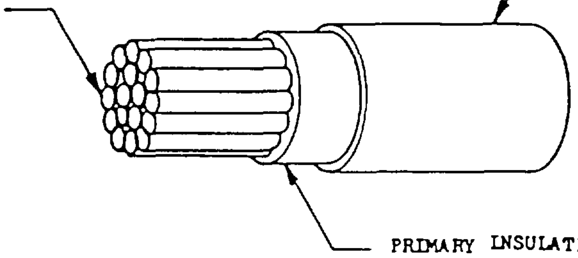


FIGURE 4

TABLE VI
TYPE V WIRE AND CABLE - OUTSIDE DIAMETER AND WEIGHT

CLASS	PART NUMBER*	CONDUCTOR SIZE (AWG)	MAXIMUM OUTSIDE DIAMETER (INCH)	MAXIMUM WEIGHT (LBS/1000 FT)
1	W42/5/1-30	30	0.026	0.59
	W42/5/1-28	28	0.029	0.87
	W42/5/1-26	26	0.034	1.3
	W42/5/1-24	24	0.039	2.0
	W42/5/1-22	22	0.045	2.8
	W42/5/1-20	20	0.054	4.3
2	W42/5/2-30	30	0.053	1.2
	W42/5/2-28	28	0.059	1.8
	W42/5/2-26	26	0.069	2.5
	W42/5/2-24	24	0.079	4.0
	W42/5/2-22	22	0.091	5.6
	W42/5/2-20	20	0.108	8.7
3	W42/5/3-30	30	0.057	1.8
	W42/5/3-28	28	0.063	2.6
	W42/5/3-26	26	0.074	3.8
	W42/5/3-24	24	0.085	6.1
	W42/5/3-22	22	0.098	8.5
	W42/5/3-20	20	0.116	13.0
4	W42/5/4-30	30	0.071	2.4
	W42/5/4-28	28	0.079	3.5
	W42/5/4-26	26	0.093	5.1
	W42/5/4-24	24	0.108	8.1
	W42/5/4-22	22	0.124	11.5
	W42/5/4-20	20	0.146	17.9

* NOTE: Applicable Change Letter Not Shown

5.3.7 TYPE VI, SHIELDED AND JACKETED CABLE, CLASS 1 THROUGH CLASS 4

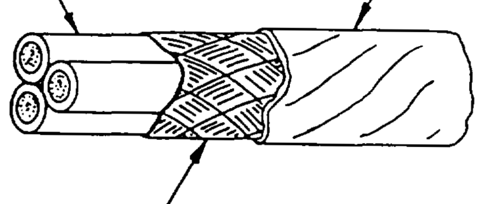
5.3.7.1 Basic Wire

The basic wire in Type VI construction shall conform to all the requirements of Type V, Class 1 wire or Type V, Class 2 or greater cable as applicable.

5.3.7.2 Finished Cable

The requirements of the finished cable shall be as indicated in Table VII, Table XXII and as shown in Fig. 5.

The component wires shall be color coded in accordance with 3.4.



(TYPICAL FOR ALL CLASSES)

FIGURE 5

TABLE VII

TYPE VI CABLE - OUTSIDE DIAMETER AND WEIGHT

CLASS	PART NUMBER *	CONDUCTOR SIZE (AWG)	MAXIMUM OUTSIDE DIAMETER (INCH)	MAXIMUM WEIGHT (LBS/1000 FT)
1	W42/6/1-30	30	0.058	2.6
	W42/6/1-28	28	0.061	3.0
	W42/6/1-26	26	0.070	4.2
	W42/6/1-24	24	0.075	5.3
	W42/6/1-22	22	0.081	6.4
	W42/6/1-20	20	0.089	8.5
2	W42/6/2-30	30	0.086	4.7
	W42/6/2-28	28	0.092	5.6
	W42/6/2/26	26	0.102	6.9
	W42/6/2-24	24	0.113	9.0
	W42/6/2-22	22	0.125	11.3
	W42/6/2-20	20	0.141	15.4
3	W42/6/3-30	30	0.090	5.7
	W42/6/3-28	28	0.096	7.0
	W42/6/3-26	26	0.108	8.8
	W42/6/3-24	24	0.119	11.7
	W42/6/3-22	22	0.132	15.0
	W42/6/3-20	20	0.149	20.8
4	W42/6/4-30	30	0.098	6.8
	W42/6/4-28	28	0.107	8.4
	W42/6/4-26	26	0.119	10.7
	W42/6/4-24	24	0.132	14.5
	W42/6/4-22	22	0.147	18.8
	W42/6/4-20	20	0.168	26.5

* NOTE: Applicable Change Letter Not Shown

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5.3.8 TYPE VII, JACKETED CABLE, CLASS 2 THROUGH CLASS 4

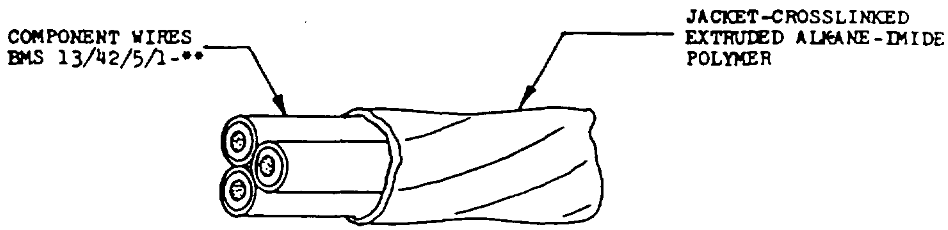
5.3.8.1 Basic Wire

The basic wires in Type VII construction shall conform to all the requirements of Type V, Class 2, or greater cable.

5.3.8.2 Finished Cable

The requirements of the finished cable shall be as indicated in Table VIII, Table XXII and as shown in Fig. 6.

The component wires shall be color coded in accordance with 3.4.



(TYPICAL FOR ALL CLASSES)
FIGURE 6

TABLE VIII
TYPE VII CABLE - OUTSIDE DIAMETER AND WEIGHT

CLASS	PART NUMBER*	CONDUCTOR SIZE (AWG)	MAXIMUM OUTSIDE DIAMETER (INCH)	MAXIMUM WEIGHT (LBS/1000 FT)
2	W42/7/2-30	30	0.068	2.0
	W42/7/2-28	28	0.074	2.7
	W42/7/2-26	26	0.084	3.6
	W42/7/2-24	24	0.094	5.2
	W42/7/2-22	22	0.107	7.1
	W42/7/2-20	20	0.123	10.5
3	W42/7/3-30	30	0.072	2.7
	W42/7/3-28	28	0.078	3.6
	W42/7/3-26	26	0.089	4.9
	W42/7/3-24	24	0.100	7.3
	W42/7/3-22	22	0.114	10.1
	W42/7/3-20	20	0.131	15.1
4	W42/7/4-30	30	0.080	3.4
	W42/7/4-28	28	0.088	4.6
	W42/7/4-26	26	0.100	6.4
	W42/7/4-24	24	0.114	9.5
	W42/7/4-22	22	0.129	13.2
	W42/7/4-20	20	0.149	19.8

* NOTE: Applicable Change Letter Not Shown

5.3.9 TYPE VIII, CLASS 1, WIRE

The requirements of Type VIII, Class 1, wire shall be as indicated in Table IX, Table XXII and as shown in Fig. 7.

The physical and electrical details of the conductor shall be as specified in Table II for tin coated copper wire. The wall thickness of the insulation shall be 0.009 inch (min.) for wire sizes 24 through 10 and 0.015 inch (min.) for wire sizes 8 through 4/0.

5.3.10 TYPE VIII, CLASS 2 OR GREATER CABLE

The finished wires that compose the multi-conductor cable shall comply with all the requirements of this specification for Type VIII, Class 1 wire and shall be color coded in accordance with 3.4. Additional requirements for the multi-conductor cable are listed in Table IX.

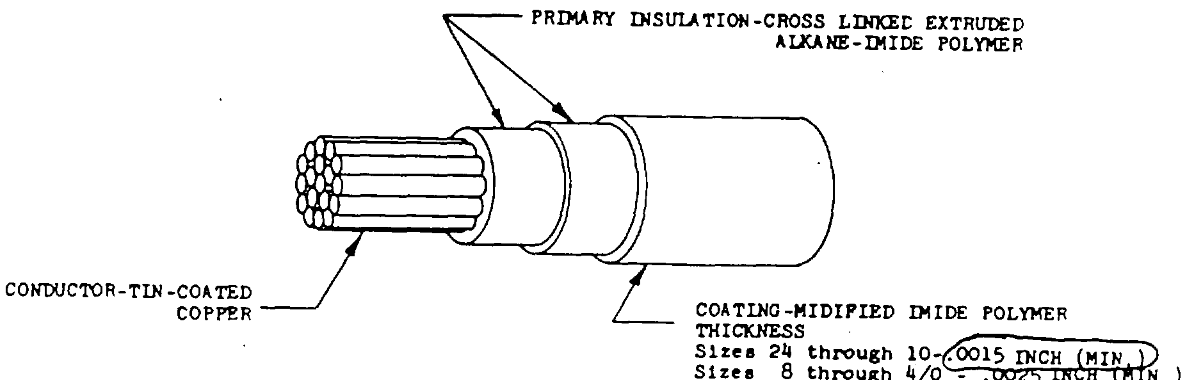


FIGURE 7

TABLE IX

TYPE VIII WIRE AND CABLE - OUTSIDE DIAMETER AND WEIGHT

CLASS	PART NUMBER*	CONDUCTOR SIZE (AWG)	MAXIMUM OUTSIDE DIAMETER (INCH)	MAXIMUM WEIGHT (LBS/1000 FT)
1	W42/8/1-24	24	0.047	2.2
	W42/8/1-22	22	0.054	3.2
	W42/8/1-20	20	0.062	4.7
	W42/8/1-18	18	0.075	7.0
	W42/8/1-16	16	0.084	9.0
	W42/8/1-14	14	0.099	13.7
	W42/8/1-12	12	0.116	20.4
	W42/8/1-10	10	0.142	31.8
	W42/8/1-8	8	0.203	58.5
	W42/8/1-6	6	0.251	91.0
	W42/8/1-4	4	0.311	146.0
	W42/8/1-2	2	0.386	231.0
	W42/8/1-0	0	0.482	365.0
	W42/8/1-00	00	0.542	483.0
	W42/8/1-000	000	0.606	618.0
	W42/8/1-0000	0000	0.671	780.0
2	W42/8/2-24	24	0.095	4.4
	W42/8/2-22	22	0.108	6.5
	W42/8/2-20	20	0.124	9.5
	W42/8/2-18	18	0.146	14.1
	W42/8/2-16	16	0.163	18.4
	W42/8/2-14	14	0.197	28.4
	W42/8/2-12	12	0.232	42.5
3	W42/8/3-24	24	0.102	6.7
	W42/8/3-22	22	0.116	9.7
	W42/8/3-20	20	0.133	14.2
	W42/8/3-18	18	0.158	21.2
	W42/8/3-16	16	0.175	27.7
	W42/8/3-14	14	0.213	42.6
	W42/8/3-12	12	0.250	61.8
4	W42/8/4-24	24	0.130	8.9
	W42/8/4-22	22	0.146	12.7
	W42/8/4-20	20	0.169	19.5
	W42/8/4-18	18	0.200	28.3
	W42/8/4-16	16	0.223	37.0
	W42/8/4-14	14	0.271	56.9
	W42/8/4-12	12	0.323	85.5
5	W42/8/5-24	24	0.141	11.2
	W42/8/5-22	22	0.160	16.0
	W42/8/5-20	20	0.184	24.5
	W42/8/5-18	18	0.218	36.2
	W42/8/5-16	16	0.242	46.3
	W42/8/5-14	14	0.295	71.3
	W42/8/5-12	12	0.353	107.0

* NOTE: Applicable Change Letter Not Shown

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5.3.11 TYPE IX, CLASS 1 WIRE

The requirements for Type IX Class 1 wire shall be as indicated in Table X, Table XXII and as shown in Figure 8.

The physical and electrical details of the conductor shall be as indicated in Table II for silver-coated high strength copper alloy wire. The wall thickness of the insulation shall be 0.009 inch (min.).

5.3.12 TYPE IX, CLASS 2 OR GREATER CABLE

The finished wires that compose the multi-conductor cable shall comply with all the requirements of this specification for Type IX, Class 1 wire and shall be color coded in accordance with 3.4. Additional requirements for the multi-conductor cable are listed in Table X.

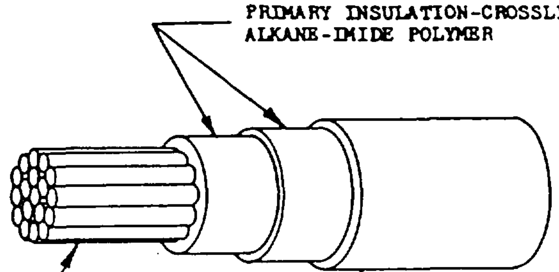

FIGURE 8

TABLE X

TYPE IX WIRE AND CABLE - OUTSIDE DIAMETER AND WEIGHT

CLASS	PART NUMBER*	CONDUCTOR SIZE (AWG)	MAXIMUM OUTSIDE DIAMETER (INCH)	MAXIMUM WEIGHT (LBS/1000 FT)
1	W42/9/1-30	30	0.034	0.86
	W42/9/1-28	28	0.037	1.1
	W42/9/1-26	26	0.042	1.6
	W42/9/1-24	24	0.047	2.2
	W42/9/1-22	22	0.054	3.2
	W42/9/1-20	20	0.062	4.7
2	W42/9/2-30	30	0.069	1.6
	W42/9/2-28	28	0.075	2.1
	W42/9/2-26	26	0.085	3.2
	W42/9/2-24	24	0.095	4.4
	W42/9/2-22	22	0.108	6.5
	W42/9/2-20	20	0.124	9.5
3	W42/9/3-30	30	0.074	2.4
	W42/9/3-28	28	0.081	3.1
	W42/9/3-26	26	0.091	4.8
	W42/9/3-24	24	0.102	6.7
	W42/9/3-22	22	0.116	9.7
	W42/9/3-20	20	0.133	14.2
4	W42/9/4-30	30	0.093	3.2
	W42/9/4-28	28	0.101	4.1
	W42/9/4-26	26	0.116	6.4
	W42/9/4-24	24	0.130	8.9
	W42/9/4-22	22	0.146	12.7
	W42/9/4-20	20	0.169	19.5
5	W42/9/5-30	30	0.101	4.0
	W42/9/5-28	28	0.111	5.2
	W42/9/5-26	26	0.126	8.0
	W42/9/5-24	24	0.141	11.2
	W42/9/5-22	22	0.160	16.0
	W42/9/5-20	20	0.184	24.5

* NOTE: Applicable Change Letter Not Shown

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5.3.13 TYPE X, CLASS 1, WIRE

The requirements of Type X, Class 1, wire shall be as indicated in Table XI, Table XXII and as shown in Fig. 9.

The physical and electrical details of the conductor shall be as specified in Table II for tin coated copper wire. The wall thickness of the insulation shall be 0.007 inch (min.).

5.3.14 TYPE X, CLASS 2 OR GREATER CABLE

The finished wires that compose the multi-conductor cable shall comply with all the requirements of this specification for Type X, Class 1 wire and shall be color coded in accordance with 3.4.

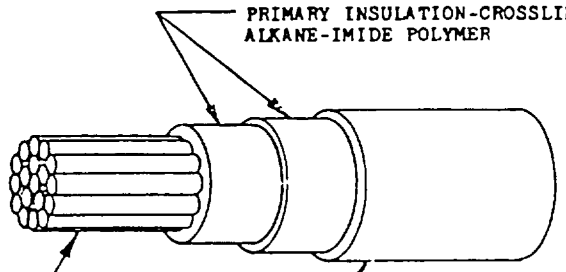


FIGURE 9

TABLE XI

TYPE X WIRE- OUTSIDE DIAMETER AND WEIGHT

CLASS	PART NO. *	COND. SIZE (AWG)	MAXIMUM OUTSIDE DIAMETER (INCH)	MAXIMUM WEIGHT (LBS/1000 FT.)
1	W42/10/1-24	24	0.043	2.1
	W42/10/1-22	22	0.050	3.0
	W42/10/1-20	20	0.058	4.5
	W42/10/1-18	18	0.069	6.7
	W42/10/1-16	16	0.076	8.7
	W42/10/1-14	14	0.094	13.3
	W42/10/1-12	12	0.112	20.0

* NOTE: Applicable Change Letter Not Shown

5.3.15 TYPE XI, CLASS 1 WIRE

The requirements for Type XI Class 1 wire shall be as indicated in Table XII, Table XXII and as shown in Figure 10.

The physical and electrical details of the conductor shall be as indicated in Table II for silver-coated high strength copper alloy wire. The wall thickness of the insulation shall be 0.007 inch (min.).

5.3.16 TYPE XI, CLASS 2 OR GREATER CABLE

The finished wires that compose the multi-conductor cable shall comply with all the requirements of this specification for Type XI, Class 1 wire and shall be color coded in accordance with 3.4.

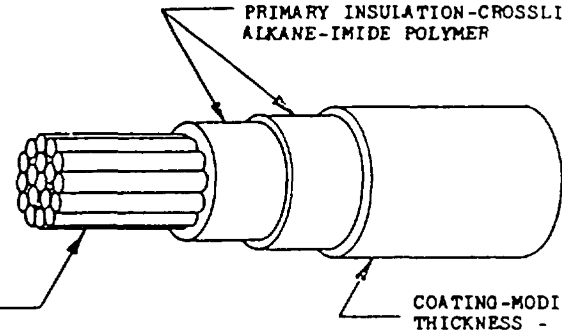


FIGURE 10

TABLE XII

TYPE XI WIRE - OUTSIDE DIAMETER AND WEIGHT

CLASS	PART NUMBER*	CONDUCTOR SIZE (AWG)	MAXIMUM OUTSIDE DIAMETER (INCH)	MAXIMUM WEIGHT (LBS/1000 FT)
1	W42/11/1-30	30	0.030	0.73
	W42/11/1-28	28	0.033	0.98
	W42/11/1-26	26	0.037	1.5
	W42/11/1-24	24	0.043	2.1
	W42/11/1-22	22	0.050	3.0
	W42/11/1-20	20	0.058	4.5

* NOTE: Applicable Change Letter Not Shown

5.3.17 TYPE XII SHIELDED AND JACKETED CABLE CLASS 1 THROUGH CLASS 4

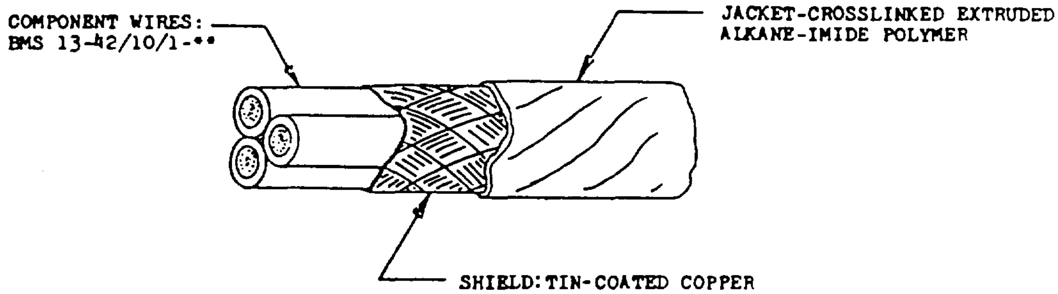
5.3.17.1 <u>Basic Wire</u>

The basic wire in Type XII construction shall conform to all the requirements of Type X, Class 1 wire or Type X, Class 2 or greater cable as applicable.

5.3.17.2 <u>Finished Cable</u>

The requirements of the finished cable shall be as indicated in Table XIII, Table XXII and as shown in Figure 11.

The component wires shall be color coded in accordance with 3.4.



(TYPICAL FOR ALL CLASSES)
FIGURE 11

TABLE XIII

TYPE XII WIRE AND CABLE - OUTSIDE DIAMETER AND WEIGHT

CLASS	PART NO. *	CONDUCTOR SIZE (AWG)	MAXIMUM OUTSIDE DIAMETER (INCH)	MAXIMUM WEIGHT (LBS/1000 FT)
1	W42/12/1-24	24	0.079	5.5
	W42/12/1-22	22	0.085	6.9
	W42/12/1-20	20	0.093	8.9
	W42/12/1-18	18	0.104	11.8
	W42/12/1-16	16	0.112	14.4
	W42/12/1-14	14	0.129	20.4
	W42/12/1-12	12	0.147	28.5
2	W42/12/2-24	24	0.121	9.4
	W42/12/2-22	22	0.133	12.0
	W42/12/2-20	20	0.149	15.9
	W42/12/2-18	18	0.172	21.7
	W42/12/2-16	16	0.186	26.9
	W42/12/2-14	14	0.221	38.2
	W42/12/2-12	12	0.261	55.2
3	W42/12/3-24	24	0.128	12.2
	W42/12/3-22	22	0.141	15.8
	W42/12/3-20	20	0.159	21.4
	W42/12/3-18	18	0.183	29.6
	W42/12/3-16	16	0.198	37.2
	W42/12/3-14	14	0.237	54.6
	W42/12/3-12	12	0.278	78.0
4	W42/12/4-24	24	0.142	15.1
	W42/12/4-22	22	0.158	20.0
	W42/12/4-20	20	0.178	27.3
	W42/12/4-18	18	0.205	38.0
	W42/12/4-16	16	0.226	48.0
	W42/12/4-14	14	0.270	70.3
	W42/12/4-12	12	0.320	102.0

* NOTE: Applicable Change Letter Not Shown

5.3.18 TYPE XIII. SHIELDED AND JACKETED CABLE, CLASS 1 THROUGH CLASS 4

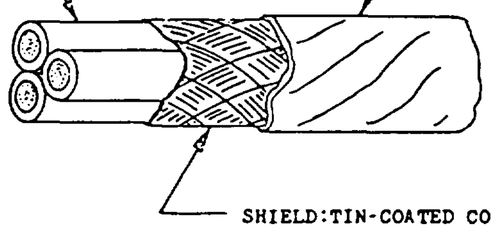
5.3.18.1 Basic Wire

The basic wire of Type XIII construction shall conform to all the requirements of Type XI, Class 1 wire or Type XI, Class 2 or greater cable as applicable.

5.3.18.2 Finished Cable

The requirements of the finished cable shall be as indicated in Table XIV, Table XXII and as shown in Fig. 12.

The component wires shall be color coded in accordance with 3.4.



(TYPICAL FOR ALL SIZES)

FIGURE 12

TABLE XIV

TYPE XIII WIRE AND CABLE - OUTSIDE DIAMETER AND WEIGHT

CLASS	PART NUMBER *	CONDUCTOR SIZE (AWG)	MAXIMUM OUTSIDE DIAMETER (INCH)	MAXIMUM WEIGHT LBS/1000 FT)
1	W42/13/1-30 W42/13/1-28 W42/13/1-26 W42/13/1-24 W42/13/1-22 W42/13/1-20	30 28 26 24 22 20	0.066 0.069 0.073 0.079 0.085 0.093	3.4 3.8 4.6 5.5 6.9 8.6
2	W42/13/1-30 W42/13/2-28 W42/13/2-26 W42/13/2-24 W42/13/2-22 W42/13/2-20	30 28 26 24 22 20	0.094 0.100 0.109 0.121 0.133 0.149	5.5 6.2 7.8 9.4 12.0 15.9
3	W42/13/3-30 W42/13/3-28 W42/13/3-26 W42/13/3-24 W42/13/3-22 W42/13/3-20	30 28 26 24 22 20	0.098 0.105 0.115 0.128 0.141 0.159	6.6 7.7 9.9 12.2 15.8 21.4
4	W42/13/4-30 W42/13/4-28 W42/13/4-26 W42/13/4-24 W42/13/4-22 W42/13/4-20	30 28 26 24 22 20	0.109 0.117 0.127 0.142 0.158 0.178	8.0 9.3 12.2 15.1 20.0 27.3

* NOTE: Applicable Change Letter Not Shown

5.4 PERFORMANCE REQUIREMENTS

5.4.1 ACCELERATED AGING

5.4.1.1 Finished Wire

A specimen of wire shall be conditioned for 7 hours at 250 ± 3 C (482 ± 5 F) in accordance with 8.2.1 using the mandrels and weights shown in Table XV. The finished wire shall show no cracking when tested in accordance with 8.16.2 and no dielectric breakdown when tested in accordance with 8.16.3.

5.4.1.2 Finished Cable (Type III, IV, VI, VII, XII and XIII)

A specimen of cable shall be conditioned for 7 hours at 250 ± 3 C (482 ± 5 F) in accordance with 8.2.2. There shall be no cracking of the cable jacket and for shielded cable there shall be no dielectric breakdown of the cable jacket when tested in accordance with 8.16.3.

TABLE XV

ACCELERATED AGING AND LIFE CYCLE

WIRE SIZE (AWG)	TYPE I AND V		TYPE VIII AND IX		TYPE X AND XI	
	MANDREL DIA. (IN.)	WEIGHT (LB)	MANDREL DIA. (IN.)	WEIGHT (LB)	MANDREL DIA. (IN.)	WEIGHT (LB)
30	3/8	.50	1/2	.75	1/2	.50
28	3/8	.50	1/2	.75	1/2	.50
26	1/2	.50	1/2	1.00	1/2	.75
24	1/2	.75	1/2	1.50	1/2	1.00
22	3/4	.75	3/4	2.50	3/4	1.50
20	3/4	.75	3/4	4.00	3/4	2.00
18	1	1.00	1	4.00	1	2.00
16	1	1.00	1	4.00	1	2.00
14	1-1/2	1.50	1-1/2	4.00	1-1/2	2.00
12	2	1.50	2	4.00	2	2.00
10	-	-	3	4.00	-	-
8	-	-	3	6.00	-	-
6	-	-	4	6.00	-	-
4	-	-	5	6.00	-	-
2	-	-	6	8.00	-	-
0	-	-	8	8.00	-	-
00	-	-	10	10.00	-	-
000	-	-	15	10.00	-	-
0000	-	-	15	10.00	-	-

5.4.2 BLOCKING

Adjacent layers, turns or specimens of the wire or cable shall not adhere to one another when tested in accordance with 8.3. Conditioning temperature and time shall be 200 ± 3 C (392 ± 5 F) for 6 hours.

5.4.3 CONCENTRICITY

The concentricity of the finished wire and cable shall be 70 percent (minimum) when tested in accordance with 8.4.

5.4.4 CONDUCTOR RESISTANCE

The resistance of the conductor shall be no greater than the values indicated in Table II when measured in accordance with 8.6.

5.4.5 DEFORMATION

The finished wire shall meet the minimum dielectric strength and deformation requirements as indicated in the applicable section of Table XVI, when tested in accordance with 8.7.

TABLE XVI

DEFORMATION

TYPE	WIRE SIZE (AWG)	STATIC WEIGHT (LB)	DIELECTRIC STRENGTH (KV MINIMUM)		DEFORMATION (% MAXIMUM)	
			70 ± 5 F	200 ± 4 F	70 ± 5 F	200 ± 4 F
I AND V	30	2.0	3.0	2.0	8	25
	28	2.0	3.0	2.0	8	25
	26	2.0	5.0	2.5	8	25
	24	2.0	5.0	2.5	8	25
	22	2.5	6.0	3.0	12	16
	20	4.0	7.0	4.0	12	16
	18	4.0	7.0	4.0	12	16
	16	4.0	7.0	4.0	10	12
	14	5.0	8.0	4.5	10	12
	12	5.0	8.0	4.5	10	12
VIII AND IX	30	2.0	5.0	2.5	18	38
	28	2.0	5.0	2.5	18	38
	26	3.0	5.0	2.5	18	38
	24	3.0	5.0	2.5	18	38
	22	5.0	6.0	3.0	20	35
	20	5.0	7.0	4.0	20	35
	18	5.0	7.0	4.0	20	35
	16	8.0	7.0	4.0	20	35
	14	8.0	8.0	4.5	20	35
	12	10.0	8.0	4.5	20	35
	10	10.0	8.0	4.5	20	35
	8	15.0	10.0	6.0	12	20
	6	15.0	10.0	6.0	12	20
	4	15.0	10.0	6.0	12	20
	2	15.0	10.0	6.0	12	20
	0	15.0	10.0	6.0	12	20
	00	15.0	12.0	8.0	12	20
	000	15.0	12.0	8.0	12	20
	0000	15.0	12.0	8.0	12	20
X AND XI	30	2.0	4.0	2.25	13	32
	28	2.0	4.0	2.25	13	32
	26	2.5	5.0	2.5	13	32
	24	2.5	5.0	2.5	13	32
	22	3.75	6.0	3.0	16	26
	20	4.5	7.0	4.0	16	26
	18	4.5	7.0	4.0	16	26
	16	6.0	7.0	4.0	15	24
	14	6.5	8.0	4.5	15	24
	12	7.5	8.0	4.5	15	24

5.4.6 DIELECTRIC STRENGTH

When tested in accordance with 8.8 the finished cable shall withstand the dielectric strength test without breakdown when 1500 volts at 60 H_Z is applied for 5 seconds in turn between each conductor and all other conductors (and the shield when applicable) electrically connected together.

5.4.7 FLAMMABILITY

When tested in accordance with 8.10 the wire or cable shall be self-extinguishing within 30 seconds from the time of removal of the applied flame. The burned distance shall not exceed 3 inches and there shall be no flaming of the tissue paper.

5.4.8 HUMIDITY RESISTANCE

When tested in accordance with 8.11 the minimum insulation resistance in megohms/ 1000 feet shall be: 10,000 for wire sizes 30 through 22, 5000 for wire sizes 20 through 10 and 500 for wire sizes 8 through 4/0.

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5.4.9 IMMERSION

When tested in accordance with 8.12 the finished wire or cable shall show no cracking when tested in accordance with 8.16.2, shall have a diameter increase not greater than 5 percent and shall have no dielectric breakdown when tested in accordance with 8.16.3. The specimens shall be immersed for 24 hours in each fluid at 70 ± 2 C (158 ± 4 F) except TT-S-135, Type III which shall be at 23 ± 3 C (73 ± 5 F). Additional specimens of wire shall also meet the immersion test requirements listed above after immersion in Oronite Hyjet III*, hydraulic fluid for 4 hours at 200 ± 4 F (93 ± 3 C).

*REFERENCE: BMS 3-11C

5.4.10 IMPULSE DIELECTRIC

One hundred percent of the finished wire or shielded cable shall withstand the impulse dielectric test in accordance with 8.13 without dielectric breakdown. All lengths of wire in which failures occur shall be rejected. (When the supplier performs this test only the defective section shall be removed from the length of wire). The test impulse peak voltage shall be as follows:

a. Type I and V wire: 11.0 KV

b. Type III, VI, XII and XIII cable: 8.0 KV

c. Type VIII and IX wire: 13.0 KV

d. Type X and XI wire: 12.0 KV

5.4.11 INSULATION RESISTANCE

5.4.11.1 Insulation Resistance at Room Temperature

When tested in accordance with 8.15.1 the minimum insulation resistance in megohms/1000 feet shall be: 10,000 for wire sizes 30 through 22, 5000 for wire sizes 20 through 10 and 500 for wire sizes 8 through 4/0.

5.4.11.2 Insulation Resistance at Elevated Temperature

The insulation resistance at elevated temperature shall be not less than 5.0 megohms/1000 feet when tested in accordance with 8.15.2 and 8.15.2.1 and there shall be no dielectric breakdown of theinsulation when tested in accordance with 8.15.2.2.

5.4.12 LIFE CYCLE

5.4.12.1 Finished Wire

When tested in accordance with 8.16.1.1 using the mandrels and weights shown in Table XV, the finished wire shall show no cracking in the bend test, no dielectric breakdown, no pitting, and the marking shall be legible. The test temperature and time shall be 200 ± 3 C (392 ± 5 F) for 168 hours.

5.4.12.2 Finished Cable (Types III, IV, VI, VII, XII and XIII)

When tested in accordance with 8.16.1.2 the cable jacket shall show no cracking in the bend test, no pitting and no dielectric breakdown. The test temperature and time shall be 392 ± 5 F (200 ± 3 C) for 168 hours. Test for dielectric breakdown is not required for Types IV and VII.

5.4.13 LOW TEMPERATURE (COLD BEND)

5.4.13.1 Finished Wire

When tested in accordance with 8.17.1 using the mandrels and weights shown in Table XVII, there shall be no cracking of the insulation and no dielectric breakdown in the dielectric test of 8.16.3.

5.4.13.2 Finished Cable

When tested in accordance with 8.17.2 using the mandrels shown in Table XVII, there shall be no cracking of the jacket and no dielectric breakdown of the jacket when tested per 8.16.3. The dielectric test is not required for Type IV and VII cable.

5.4.14 MARKABILITY

The outer surface of the wire shall provide a finish which will retain a mark imprinted by a hot stamping machine without a pre-etch or post cure by the user. When hot stamped and tested in accordance with 8.18 the imprint on the wire after 20 strokes shall be legible and without loss of any portion of any character. There shall be no dielectric breakdown at the marked areas.

TABLE XVII

LOW TEMPERATURE (COLD BEND)

TYPE	WIRE SIZE (AWG)	SPECIMEN LENGTH (FT)	MANDREL DIA. (IN.)	WEIGHT (LB)
I and V	30	1.0	3/8	0.5
	28	1.0	3/8	0.5
	26	1.0	1/2	0.5
	24	1.0	1/2	0.5
	22	1.0	3/4	1.0
	20	1.0	3/4	1.0
	18	1.0	1	1.0
	16	1.0	1	1.0
	14	1.5	1-1/2	3.0
	12	1.5	2	3.0
VIII and IX	30	1.0	1	2.0
	28	1.0	1	2.0
	26	1.0	1	3.0
	24	1.0	1	3.0
	22	1.0	1	3.0
	20	1.0	1	4.0
	18	1.5	1-1/2	4.0
	16	1.5	1-1/2	5.0
	14	1.5	2	5.0
	12	1.5	2	5.0
	10	2.0	3	5.0
	8	2.5	4	6.0
	6	3.0	5	10.0
	4	3.5	6	10.0
	2	5.0	8	15.0
	0	6.0	10	15.0
	00	7.0	12	20.0
	000	10.0	18	20.0
	0000	10.0	18	20.0
X and XI	30	1.0	3/4	1.0
	28	1.0	3/4	1.0
	26	1.0	3/4	1.5
	24	1.0	1	2.0
	22	1.0	1	2.0
	20	1.0	1	2.0
	18	1.0	1-1/2	2.0
	16	1.0	1-1/2	3.0
	14	1.5	2	4.0
	12	1.5	2	4.0
III, IV, VI, VII, XII and XIII (All Classes)	CABLE DIA. (IN)			
	Up to 0.125	See 8.17.2	3	See 8.17.2
	0.126 to 0.250		6	
	0.251 to 0.360		10	
	0.361 to 0.750		18	

5.4.15 NOTCH SENSITIVITY

When tested in accordance with Paragraph 8.19 using the mandrel diameters listed in Table XVIII no dielectric failure shall occur. R

TABLE XVIII R

NOTCH SENSITIVITY (TYPE VIII, IX, X AND XI) R

WIRE SIZE (AWG)	MANDREL DIAMETER (INCHES)
30	1/2
28	1/2
26	1
24	1
22	1
20	1
18	1-1/2
16	1-1/2
14	2
12	2
10	3
8	4
6	5
4	6
2	8
0	10
00	12
000	18
0000	18

R

The notch depth for Type VIII and IX wire shall be 0.004 inch. R

The notch depth for Type X and XI wire shall be 0.003 inch. R

R

5.4.16 SCRAPE ABRASION RESISTANCE

The insulation scrape abrasion resistance in any of the four tests made shall be not less than 25 cycles (50 strokes) for size 1/0 AWG and smaller and 28 cycles (56 strokes) for size 2/0 AWG and larger when tested in accordance with 8.20 at 23 ± 3 C (73 ± 5 F). The total weight of the tester head and the scraper blade shall be as shown in Table XIX.

TABLE XIX

SCRAPE ABRASION

WIRE SIZE (AWG)	TYPE I AND V	TYPE VIII AND IX	TYPE X AND XI
	WEIGHT (LB)	WEIGHT (LB)	WEIGHT (LB)
30	0.5	1.0	0.75
28	0.5	1.0	0.75
26	1.0	1.0	0.87
24	1.0	2.0	1.5
22	1.25	2.0	1.62
20	1.25	3.0	2.12
18	1.25	3.0	2.12
16	1.50	3.0	2.25
14	2.25	3.0	2.62
12	2.25	4.0	3.12
10	-	4.0	-
8	-	6.0	-
6	-	6.0	-
4	-	10.0	-
2	-	10.0	-
0	-	10.0	-
00	-	10.0	-
000	-	10.0	-
0000	-	10.0	-

5.4.17 SHRINKAGE

When tested in accordance with 8.21 the shrinkage shall not exceed .06 inch in 12 inches. The test temperature shall be 200 ± 3 C (392 ± 5 F) for a period of 6 hours.

5.4.18 SMOKE TEST

When tested in accordance with 8.22 there shall be no visible smoke with the conductor at 250 ± 3 C (482 ± 5 F) for 15 minutes.

5.4.19 SURFACE RESISTANCE

When tested in accordance with 8.23 the surface resistance shall be not less than 500 megohm-inches for both readings.

R

5.4.20 TAPE ABRASION

The insulation tape abrasion resistance shall be not less than the values shown in Table XX when tested in accordance with 8.24.2.

5.4.21 THERMAL SHOCK RESISTANCE

The insulation on a specimen of finished wire when tested in accordance with 8.25 shall not shrink more than 0.06 inches. The elevated temperature shall be 150 ± 3 C (302 ± 5 F).

5.4.22 TIN COATING

The tin coating on the conductor of finished wire shall not show evidence of combining with foreign substances that would have an adverse effect on the electrical properties or solderability of the conductor.

TABLE XX

TAPE ABRASION
(PROCEDURE II)

TYPE	WIRE SIZE (AWG)	MINIMUM RESISTANCE (INCHES OF TAPE)	WEIGHT SUPPORT BRACKET	WEIGHT (LBS)	TENSION LOAD (LBS)
I AND V	30	18	A	0.125	1
	28	18	A	0.125	1
	26	22	A	0.125	1
	24	22	A	0.125	1
	22	22	A	0.125	1
	20	30	A	0.125	1
	18	30	A	0.125	1
	16	18	A	0.250	2
	14	18	B	0.250	2
	12	18	B	0.250	2
VIII AND IX	30	24	A	0.75	1
	28	24	A	0.75	1
	26	30	A	1.00	1
	24	30	A	1.00	1
	22	30	A	1.00	1
	20	30	A	1.00	1
	18	30	A	1.00	1
	16	18	B	3.00	2
	14	18	B	3.00	2
	12	18	B	3.00	2
	10	24	C	4.25	2
	8	30	C	4.25	2
	6	30	C	4.25	2
	4	30	C	4.25	2
	2	30	C	4.25	2
	0	30	C	4.25	2
	00	30	C	4.25	2
	000	30	C	4.25	2
	0000	30	C	4.25	2
X AND XI	30	18	A	0.50	1
	28	18	A	0.50	1
	26	30	A	0.50	1
	24	30	A	0.50	1
	22	30	A	0.50	1
	20	30	A	0.50	1
	18	30	A	0.50	1
	16	18	B	1.25	2
	14	18	B	1.25	2
	12	18	B	1.25	2

5.4.23 VISUAL AND DIMENSIONAL INSPECTION

The following items shall be the minimum inspection requirements:

a. Conductor

(1) Diameter

(2) Number of Strands

(3) Strand Coating

(4) Type of Stranding

(5) Diameter of Strands

b. Finished Wire or Cable

(1) Maximum diameter of finished wire or cable.

(2) Construction of finished wire or cable to conform to Type and Class designation.

(3) Color uniformity of insulation coating or cable jacket.

(4) Color-code identification for individual wires of a multi-conductor cable applied as specified.

(5) Continuity, uniform application of insulations and jackets on wire or cable.

(a) Variations in color which do not exceed the light-dark limits established by MIL-STD-104A, are acceptable.

(b) Discolorations due to foreign materials are not acceptable; i.e.:

(1) Overheated or scorched insulations or jackets.

(2) Dust, grease or oil contamination.

(c) Voids in the insulation or jacket which can be detected without magnification or any other aid, are not acceptable.

(d) Lumps or bumps in tightly fitting jackets that do not increase the cable diameter in excess of the completed maximum outside diameter, are acceptable.

(e) Metallic or gritty particles in the insulation or jacket, are not acceptable.

(6) Thickness of wire insulation and cable jacket where applicable.

(7) Push-back characteristic for shield on Type III, VI, XII and XIII cable. R

5.4.24 WICKING

When tested in accordance with 8.27 the dye solution shall not wick more than 0.250 inch between the primary insulation and the coating or between any layers in the primary insulation.

5.4.25 WORKMANSHIP

All details of workmanship shall be in accordance with high-grade wire and cable manufacturing practices. The finished wire or cable shall be uniform in color and dimensions and free of foreign material or abraded surfaces.

5.4.26 WRAP-BACK TEST

When tested in accordance with 8.28 at a temperature of 200 ± 3 C (392 ± 5 F) for 6 hours the wire insulation shall show no cracking.

6. QUALIFICATION

Wire and cable of this specification shall be subject to approval by the using Division Engineering Department of The Boeing Company.

6.1 QUALIFICATION REQUEST

A manufacturer's request to submit his product for approval under this specification shall be directed to the Engineering Department of the using Division of The Boeing Company through the Materiel Section or Department of that Division.

After receiving written authorization from the Materiel Section, the manufacturer shall submit the reports and materials required in 6.2 and 6.3.

6.2 QUALIFICATION REPORT

The manufacturer shall submit six copies of a report, certified by a responsible engineer or officer of the company, which shall contain the following:

a. The quantitative results of all of the qualification tests on all of the qualification specimens. These results shall verify that the basic wire and finished cable specimens satisfactorily passed all of the qualification requirements of this specification.

b. Detailed description of test methods.

c. Physical details of each size of any Type or Class wire which shall include the following:

(1) Manufacturer's Part Number.

(2) Detailed description of construction.

(3) Maximum production weights and diameters of finished wire. R

(4) Actual weights and diameters of wire tested.

6.3 QUALIFICATION MATERIALS

For qualification tests the manufacturer submitting his product for approval shall supply the following;

a. 150 feet each of Type VIII, Class 1, Size 20, 10 and 4 wire.

b. 100 feet of Type V and Type XI, Class 1, Size 26 wire. R

c. 100 feet of Type I and Type X, Class 1, Size 22 and 16 wire. R

d. 50 feet of Type III, Class 2, Size 20 cable.

6.4 Approvals granted to this specification will be contingent upon the following conditions:

a. A manufacturer shall be prepared to produce all Types, Classes and sizes of wire and cable of this specification.

b. After initial approval, changes in design, material or manufacturing methods shall not be made without prior written approval from the using Division Engineering Department of The Boeing Company.

c. Deviations from the requirements of this specification without written authorization from the using Division Engineering Department of The Boeing Company, shall be cause for rejection of wire and cable and removal of a vendor's name as an approved source.

7. # QUALITY CONTROL

7.1 CLASSIFICATION OF TESTS

The testing and inspection of wire and cable of this specification shall be classified as follows:

a. Supplier Qualification Tests

Supplier Qualification Tests are those performed by the manufacturer on the specified qualification samples when submitting his product for approval under this specification. R

b. Supplier Inspection Tests

Supplier Inspection Tests are those tests performed by the supplier on each lot of wire or cable that is manufactured in accordance with the requirements of this specification and submitted to the purchaser for acceptance. R

c. Purchaser Inspection Tests

Purchaser Inspection Tests are those tests performed by the purchaser on the finished wire or cable, submitted for acceptance under a purchase order, to determine compliance with the requirements of this specification. R

7.2 QUALIFICATION TESTS

The finished wire or cable shall meet all of the requirements specified in Section 5. and 9. of this specification. The supplier qualification tests shall consist of all the tests listed in Table XXII, as applicable to wire or to cable. R

7.3 SUPPLIER QUALITY CONTROL

7.3.1 SAMPLING

Unless otherwise specified, samples of sufficient length shall be selected at random from each inspection lot of finished wire or finished multiconductor cable to provide at least three specimens for each of the supplier tests. An inspection lot for wire shall be defined as a maximum of 100,000 feet of the same type and size selected from one manufacturing lot. An inspection lot for multiconductor cable shall be defined as a maximum of 100,000 feet of finished cable of the same type, class and size selected from one manufacturing lot. A manufacturing lot shall be defined as each size of wire or one week's production of each size wire produced under substantially the same conditions.

7.3.2 TESTS

The Supplier Inspection Tests shall consist of the tests indicated as Test Group I and II in Table XXII. R

7.3.3 INSPECTION LEVELS AND ACCEPTABLE QUALITY LEVELS (AQL) (GROUPS I AND II TESTS)

For Group I (minor characteristics), the inspection level shall be S-2 and the AQL shall be 6.5 percent in accordance with MIL-STD-105D; for Group II (major characteristics), the inspection level shall be S-3 and the AQL shall be 1.5 percent. MIL-STD-109A shall apply for definitions of inspection terms.

7.3.4 REPORTS

Each shipment of finished wire or cable shall be accompanied by a test report identified by lot number and purchase order number. A duplicate of this report shall be mailed to the purchaser, attention of buyer whose name appears on the purchase order, on or before the day of each shipment. The report shall include the following items:

a. Details the average production weight (or weights), determined for the supplier's inspection lot (lots) of finished wire or cable from which this shipment was taken, in pounds per thousand feet.

7.3.4 (Continued)

b. Certification that the finished wire or cable has been manufactured in accordance with the requirements of this specification and that the supplier's inspection lot (or lots) of wire and cable from which this shipment was taken has successfully passed the Supplier tests.

The manufacturer shall keep the quantitative results of all Inspection Tests on file and available to authorized representatives of The Boeing Company for two years after delivery of the finished wire or cable.

7.4 PURCHASER QUALITY CONTROL

7.4.1 Random samples shall be selected from each supplier's inspection lot received within a shipment in accordance with purchaser sampling procedures. Each sample shall be of sufficient length to conduct all acceptance tests.

7.4.2 The purchaser shall subject each supplier inspection lot of wire or cable received within a shipment to the tests of Section 5.4.23 and any other tests listed in Table XXII deemed necessary by Quality Control to assure that production material meets the requirements of this specification.

7.5 ACCEPTANCE, REJECTION AND RETEST

Acceptance or rejection of any lot of wire or cable manufactured in accordance with the requirements of this specification shall be based upon the Supplier tests and the Purchaser tests. Failure of any test specimen or inspection lot to pass the requirements of a specific test shall be cause for rejection of the inspection lot. Action in case of failure shall be in accordance with paragraph 6.4 of MIL-STD-105D.

7.6 SOURCE INSPECTION

When buyer elects to perform inspection at the supplier's facility, paragraph 7.4 is optional.

8. TEST METHODS

8.1 EXAMINATION OF PRODUCT

All samples of wire and cable shall be examined carefully to determine conformance to this specification.

8.2 ACCELERATED AGING

8.2.1 FINISHED WIRE

One inch of insulation shall be removed from each end of a 24-inch specimen of the finished wire. The central portion of the specimen then shall be bent at least halfway around a horizontally placed stainless steel mandrel of the diameter specified in Table XV. Each end of the conductor shall be loaded with the weight specified in Table XV so that the portion of the insulation between the conductor and the mandrel is under compression while the conductor is under tension. This specimen, so prepared on the mandrel, shall be conditioned in an air-circulating oven for the time and at the temperature specified in 5.4.1.1. The velocity of air past the specimen (measured at room temperature) shall be between 100 and 200 feet per minute. After conditioning, the oven shall be shut off, opened, and the specimen allowed to cool in the oven for at least one hour. When cool, the specimen shall be freed from tension, removed from the mandrel, and straightened. The specimen then shall be subjected to the bend test (8.16.2) followed by the dielectric test (8.16.3).

8.2.2 FINISHED CABLE R

The length of the specimen to be tested shall be 24 inches. Two inches of the jacket shall be removed from each end of a shielded specimen. The specimen shall then be conditioned hanging freely in an air circulating oven for the time and at the temperature specified in 5.4.1.2. The velocity of air past the specimen (measured at room temperature) shall be between 100 and 200 feet per minute. After conditioning, the oven shall be shut off, the door opened and the specimen allowed to cool in the oven for at least one hour. When cool, the center portion of the specimen shall be wrapped a minimum of 180 degrees around a mandrel with a diameter 25 times the overall diameter of the finished cable. The specimen shall then be visually examined, without aid of magnification, for cracks. A shielded specimen shall then be subjected to the dielectric test (8.16.3) with the bent portion submerged.

8.3 BLOCKING

8.3.1 WIRE SIZES 14 AND SMALLER

One end of a specimen of finished wire of sufficient length to perform the test, shall be affixed to a metal spool of the appropriate barrel diameter for the applicable wire size. The specimen shall then be wound helically on the spool for at least three closely-wound layers with the adjacent turns in close contact with one another. The tension for winding shall be equal to the cold bend test weight specified for the same size wire in Table XVII. The free end of the speci- R
men shall then be affixed to the spool so as to prevent unwinding or loosening of the turns or layers. The spool and the specimen shall be conditioned in an air oven for the time and the temperature specified in 5.4.2. At the end of the R
conditioning period, the spool and specimen shall be removed from the oven and allowed to cool to room temperature. After cooling, the specimen shall be unwound manually, and examined for evidence of blocking.

8.3.2 WIRE SIZES 12 AND LARGER AND CABLE

Three 24-inch specimens of finished wire or cable shall be tightly secured in a bundle, so that surface contact will be maintained throughout the test. The bundle shall be secured at both ends and in the middle with preshrunk high-temperature lacing tape. The bundle then shall be conditioned in an air oven for the time and at the temperature specified in 5.4.2. After conditioning, the R
lacing tape shall be removed and the specimens separated and examined for blocking.

8.4 CONCENTRICITY

The concentricity of the insulation of the finished wire or cable shall be determined in accordance with the procedures of 8.4.1 and 8.4.2 as applicable. All wall-thickness measurements shall be determined under suitable magnification. A wall-thickness measurement shall be the radial distance between the outer rim of the insulation and the outermost rim of the outermost strand of the concentric lay conductor or shield (as applicable), or between the outer rim of the insulation and the outermost rim of the outermost strand of the stranded member of the rope-lay conductor.

8.4.1 WIRE SIZES 30 THROUGH 10 AND CABLE

The concentricity of the insulation of the finished wire or cable shall be determined by first locating and recording the minimum wall thickness measured on a cross section of the insulation or jacket (as applicable). The maximum wall thickness of this same cross section of the insulation shall be measured and recorded. The ratio of the minimum wall thickness to the maximum wall thickness shall define the percent concentricity.

8.4.2 WIRE SIZES 8 THROUGH 0000

The concentricity of the insulation of the finished wire shall be determined by first locating and recording the minimum wall thickness measured on a cross section of the insulation. From this point on the outer rim of the insulation at which the minimum wall thickness was measured, three reference points 90 degrees apart on the outside rim of the insulation shall be established. At each of these three reference points the nearest member of the rope-lay conductor shall be selected and the insulation wall thickness between the member and the outer rim of the insulation shall be measured. The average of the four readings shall be considered to be the average wall thickness. The ratio of the minimum wall thickness to the average wall thickness shall define the percent concentricity.

8.5 CONDUCTOR ELONGATION AND TENSILE STRENGTH

8.5.1 ALL WIRE SIZES

Elongation and tensile strength tests shall be performed on individual strands taken from the conductors of finished wire in accordance with Method 3211 of FED-STD-228 using a 12-inch specimen length, 10-inch bench marks and a 10-inch initial jaw separation. Soft annealed copper shall be pulled at 10 inches per minute; high-strength copper alloy shall be pulled at 2 inches per minute.

8.5.2 WIRE SIZES 22 AND SMALLER

In case of failure to meet the required elongation, sizes 22 and smaller may be pulled as a whole conductor. The elongation and tensile strength shall be calculated from the values recorded when the first strand of the whole conductor breaks.

8.6 CONDUCTOR RESISTANCE

The DC resistance of the conductor shall be measured in accordance with Method 6021 of FED-STD-228, except that the wires shall be tested dry, without immersion.

8.7 DEFORMATION TEST

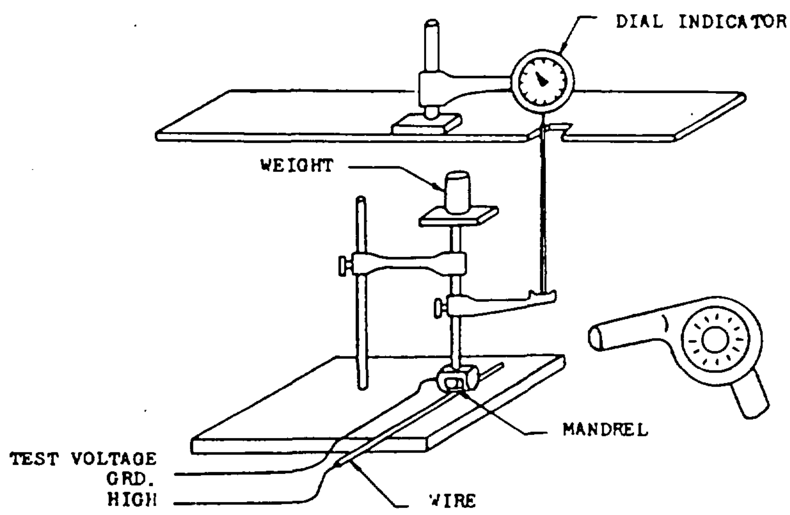
The deformation test shall be conducted using a test device as suggested in Figure 13. R

a. The specimen shall be long enough for conductor isolation from ground. R

b. The weight shall be as specified in Table XVI. R

c. The hardened steel mandrel diameter shall be the same as the diameter of the test specimen +.010, -.005 in.

d. The dielectric strength and deformation measurements shall be made after a minimum of 15 minutes impression time at each specified temperature. Dielectric strength shall be tested by applying the voltage as shown in Table XVI between the wire conductor and the test fixture mandrel. The test voltage shall be increased from 0 to the specified value at a uniform rate of no more than 500 volts/second.



DEFORMATION TEST APPARATUS

FIGURE 13 R

NOTE: All metal parts of the test apparatus shall be grounded. R

8.8 DIELECTRIC STRENGTH

One hundred percent of all finished cable in shipment reels, spools, or coils shall be tested at the voltage specified in 5.4.6 applied in turn between each conductor of the multiple-conductor cable and all other conductors electrically connected together and to the shield where applicable. R

8.9 DURABILITY OF CODING

The durability of product identification, color, and color striping applied to the wire for coding shall be evaluated at 23 ± 3 C (73 ± 5 F) as follows: R

8.9.1 TESTING APPARATUS R

A General Electric Repeated-Scrape Abrasion tester or equivalent shall be used. The tester shall be designed to hold a short specimen of finished wire firmly clamped in a horizontal position with the upper longitudinal surface of the specimen fully exposed. The instrument shall be capable of rubbing a smooth cylindrical steel mandrel 0.025 inch in diameter, repeatedly over the upper surface of the wire, in such position that the longitudinal axes of the mandrel and the specimen are at right angles to each other with cylindrical surfaces in contact. A weight affixed to a fixture above the rubbing mandrel shall control the force exerted normal to the surface of the insulation. A motor-driven, reciprocating-cam mechanism and counter shall be used to deliver an accurate number of abrading strokes in a direction parallel to the axis of the specimen. The length of the stroke shall be 3/8 inch and the frequency of the stroke shall be 60 cycles (120 strokes) per minute.

8.9.2 TESTING PROCEDURE R

A specimen of wire shall be mounted in the specimen clamp and a 500-gram weight shall be applied through the rubbing mandrel to the marked surface. The counter shall be set at zero and the drive motor started. The specimen shall be observed throughout the progress of the test and, as soon as a continuous line of the color, color stripe or printed marking is removed under the abrading mandrel, the number of abrading cycles shall be recorded.

8.10 FLAMMABILITY R

The test specimen shall be 24 inches in length and shall be marked 8 inches from the lower end to indicate the central point for flame application. The specimen shall be placed at an angle of 60 degrees with the horizontal within a chamber as described in Federal Specification CCC-T-191b, Method 5902. The specimen shall be parallel to and approximately 6 inches from the front of the chamber. The upper end of the specimen shall pass over a pulley and shall have the approximate weight specified for accelerated aging in Table XV, attached to it so that the specimen is held tautly throughout the flammability test. A piece of facial tissue conforming to Federal Specification UU-T-450, not less than 8 x 8 inches shall be suspended tightly and horizontally, and centered 9-1/2 inches directly below the test mark on the specimen and at least 1/2 inches away from the table top. A flame from a Bunsen burner shall be applied for 30 seconds at the test mark. The Bunsen burner shall be mounted underneath the test mark on the specimen, perpendicular to the specimen, and at an angle of 30 degrees to the vertical plane of the specimen as shown in Figure 14. The Bunsen burner shall have a 1/4-inch inlet a nominal bore of 3/8 inch, and a length of approximately 4 inches from top to primary inlets. The burner shall be adjusted to produce a 3-inch-high flame with an inner cone approximately one-third of the flame height. The temperature of the hottest portion of the flame, as measured with an accurate thermocouple pyrometer, shall be 955 ± 30 C (1751 ± 54 F). The burner shall be positioned so that the hottest portion of the flame is applied to the test mark on the wire. The distance of flame travel upward along the wire from the test mark and the time of burning after removal of the flame shall be recorded. Any burning particles or drippings which cause the tissue paper to burst into flame shall be recorded. Charred holes or charred spots in the tissue paper caused by burning particles do not constitute failure. Breaking of the wire specimens shall not be considered as failure.

8.11 HUMIDITY RESISTANCE

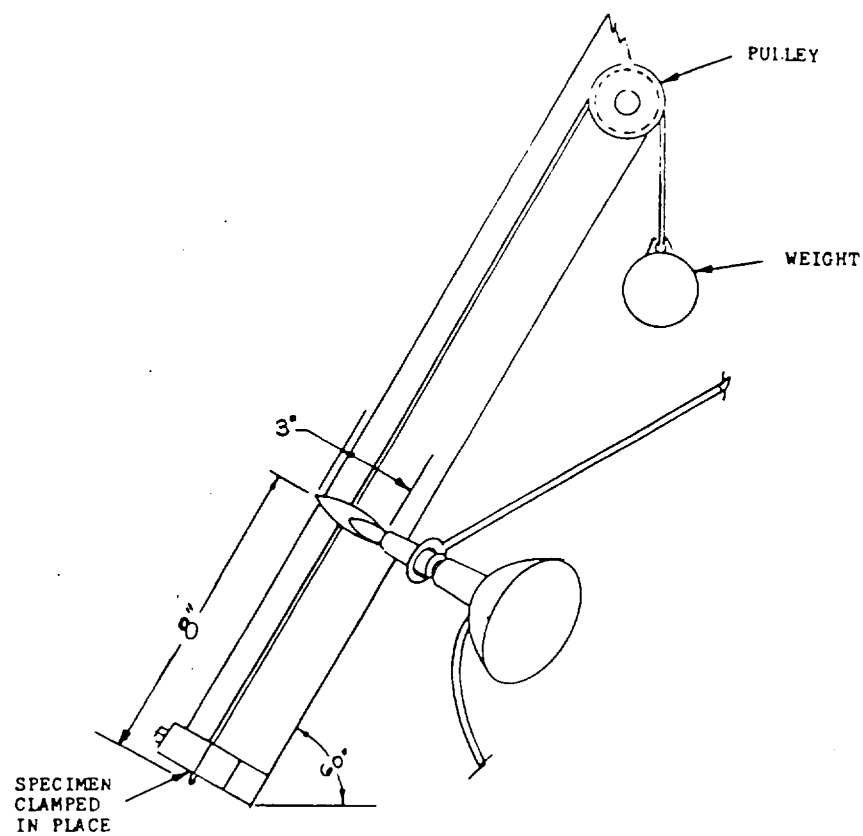
A 52-foot specimen of wire shall be subjected to the following:

8.11.1 APPARATUS

The apparatus shall consist of a test chamber capable of maintaining an internal temperature of 70 ± 2 C (158 ± 4 F) and an internal relative humidity of 95 ± 5 percent. The test chamber shall be capable of being so sealed as to retain the total moisture content in the test space. The heat loss from the chamber shall be sufficient to reduce the internal temperature from the above specified operating temperature to not more than 38 C (100 F) within a period of 16 hours from the time of removal of the source of heat. Distilled or demineralized water shall be used to obtain the required humidity.

8.11.2 PROCEDURE

The specimen shall be placed in the test chamber and the temperature and relative humidity raised over a 2 hour period to the values specified in 8.11.1 and maintained at such for a period of 6 hours. At the end of the 6-hour period the heat shall be shut off. During the following 16-hour period, the temperature must drop to 38 C (100 F) or lower. At the end of the 16-hour period, heat shall be again supplied for a 2-hour period to stabilize at 70 ± 2 C (158 ± 4 F). This cycle (2 hours heating, 6 hours at high temperature, 16 hours cooling) shall be repeated fifteen times so that the total time of the test is 360 hours. At the end of the fifteenth cycle, the 50-foot center section of the specimen shall be immersed in a 5-percent solution of sodium chloride in water at 23 ± 3 C (73 ± 5 F). The insulation resistance of the specimen shall be measured by applying a potential of 250 to 500 volts DC between the conductor of the specimen and the solution, after 1 minute of electrification at this potential. The insulation resistance shall be converted to megohms/1000 feet by the calculation shown in 8.15.



FLAMMABILITY-TEST APPARATUS
(SHOWN WITHOUT CHAMBER)

FIGURE 14

R

R

8.12 IMMERSION

Six 24 inch specimens of wire or cable shall be measured to determine their initial diameters and then shall be immersed to within 6 inches of their ends in each of the following fluids (using a separate specimen for each fluid), for the time and temperature specified in 5.4.9. R

a. Hydraulic fluid, fire resistant, BMS 3-11C. R

b. Hydraulic fluid, petroleum base, aircraft missile, and ordnance, MIL-H-5606 B.

c. Standard test fluid, TT-S-735, Type III.

d. Lubricating oil, aircraft turbine engine, synthetic base, MIL-L-7808 E.

e. Lubricating oil, aircraft turbine engines, synthetic base, MIL-L-23699.

f. Alkaline detergent solvent (pH 10.0-10.5). R

(Reference: Maintenance Manual, Chapter 12, Cleaning and Polishing Materials - Ordering/Description/Use)

During immersion tests, the radius of bend of the specimen shall be not less than fourteen times the maximum specified diameter of the wire or cable under test. Upon removal from the fluids, the specimen shall remain for 1 hour in free air at room temperature. The diameters then shall be again measured and compared to the initial diameters. One inch of insulation shall be removed from each end of each specimen and the specimen shall be subjected to the bend test (8.16.2), followed by the dielectric test (8.16.3). R

8.13 IMPULSE DIELECTRIC

8.13.1 TEST EQUIPMENT

The electrode head through which the wire or cable is passed in the impulse dielectric test shall be as shown in either Figure 15 or Figure 16. The characteristics of the test impulse and of the equipment auxiliary to the electrode head shall be as follows: R

a. Test Impulse

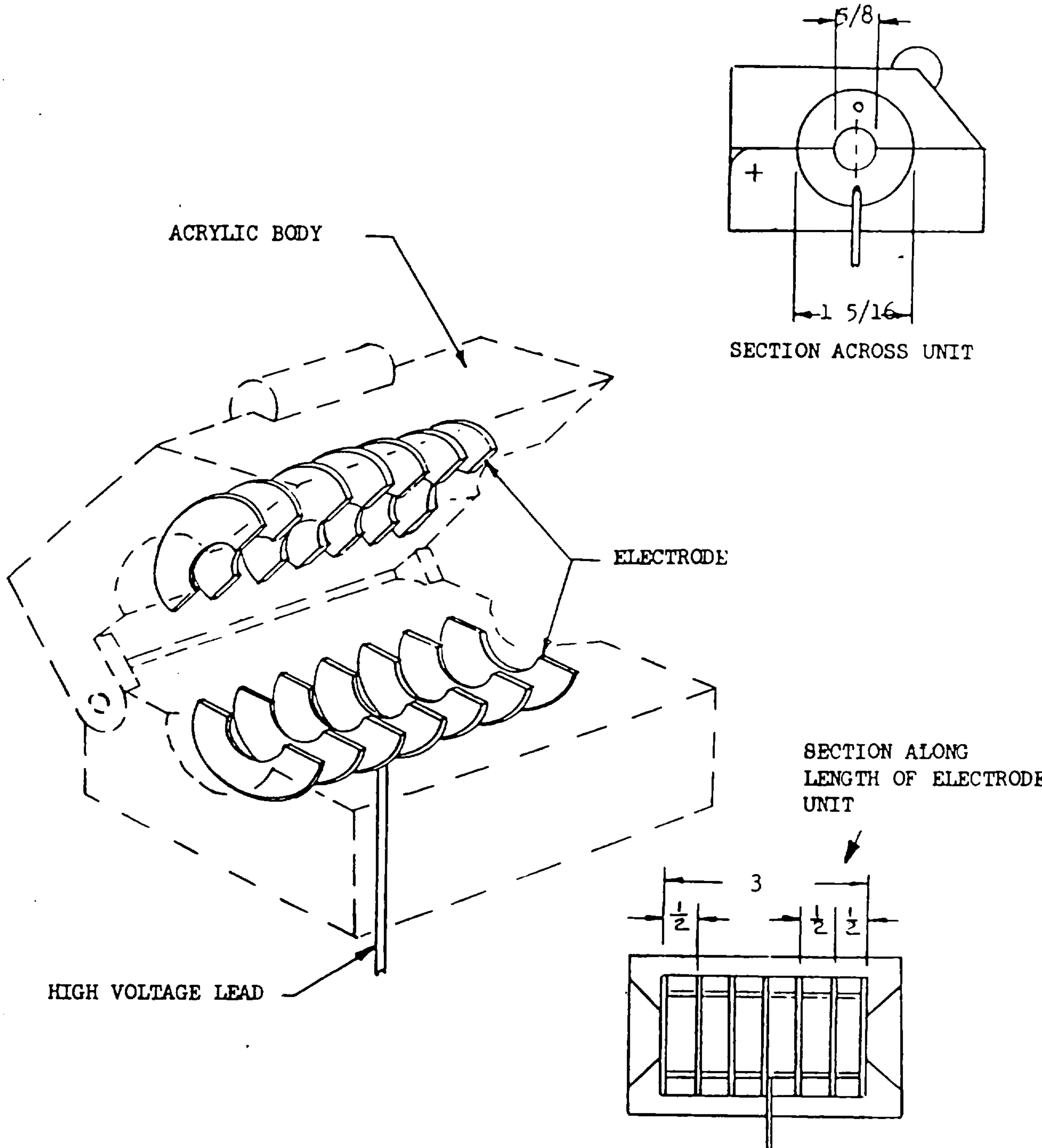
The wave form of the voltage supplied to the electrode head shall consist of a sharp rise pulse followed by a highly damped wave train. The sharp rise of the impulse wave front shall reach 90 percent of the specified peak value in less than 10 microseconds, and shall reach peak value in less than 20 microseconds. Fluctuations of the actual peak value, due to variations of input power to the generator, shall not exceed ± 2 percent of the specified peak value. The peak value shall not show more than a 5-percent reduction in the event of an increase of capacitive load to 50 picofarads, during operation, from an initial load of 25 picofarads between electrode and instrument ground. The pulse duration including the damped portion of the wave, shall be between 40 and 250 microseconds. The pulse repetition rate at the electrode shall be a minimum of 170 pulses per second and a maximum of 500 pulses per second. Visible or audible corona shall be evident in the electrode structure when operating at the specified voltage.

b. Voltmeter

Connected to the electrode head there shall be a peak-reading instrument voltmeter indicating continually the potential of the electrode with or without a grounded test wire in the chamber. The peak-reading voltmeter shall show full deflection at a peak value not exceeding 25 kilovolts and shall have an accuracy of ± 3 percent of the specified operating value. This meter shall be capable of maintaining calibration for an adequate period, preferably a minimum of one month.

c. Wire Guides

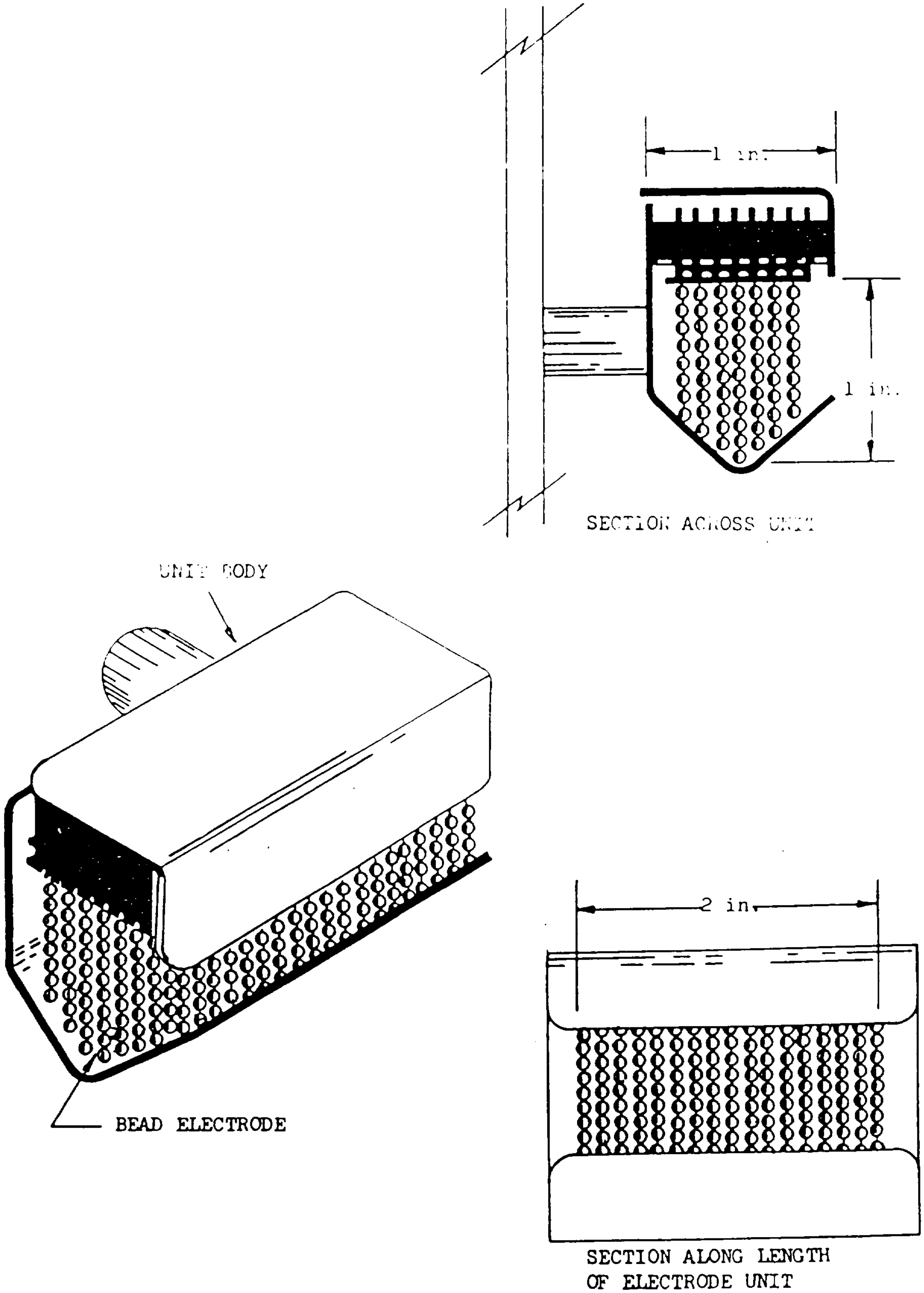
When using the electrode head shown in Figure 15, there shall be guides external to the electrode head to provide axial centering of the wire or cable in the chamber. The guides shall be such as to center the wire or cable in the electrode head within 0.025 inch or 25 percent of the wire or cable diameter, whichever is greater, without damage to the wire or cable and without obstructing free access of air to the electrode head.



ELECTRODE HEAD FOR IMPULSE DIELECTRIC TEST

FIGURE 15

REF: SLAUGHTER CO., PULSED H-F IONIZATION TESTER MODEL 654.



MINIATURE BEAD-CHAIN ELECTRODE HEAD FOR IMPULSE DIELECTRIC TEST
FIGURE 16

8.13.1 (Continued)

d. Failure Detection Circuit

There shall be a failure-detection circuit to give a visible or audible indication of insulation failure, automatically de-energize the electrode head, and stop progress of the wire or cable through the electrode.

The detecting circuit shall be sufficiently sensitive to indicate a fault when the electrode is arced to ground through a 0.5 megohm resistor and shall be capable of detecting a fault which lasts for the duration of only one impulse. The high voltage, when turned off by a failure-detection circuit, shall remain off until reset manually.

8.13.2 CALIBRATION OF EQUIPMENT

The impulse test equipment shall be calibrated by means of a peak detecting voltmeter connected directly between the electrode head and ground. The impulse generator shall be energized and the voltage control of the impulse generator shall be adjusted until the reading on the calibration voltmeter is the specified potential, at which point the reading on the instrument voltmeter shall be observed and recorded. This calibration shall be repeated for each specified peak potential. Calibration may be accomplished without a test wire in the electrode head, in which case the voltage control on the impulse generator may require a different setting for each wire size in order to give the desired reading on the instrument voltmeter; or the calibration may be made with a load of 20 to 60 picofarads. The equipment may also be calibrated against an oscilloscope with a calibrated and compensated attenuator. Either method shall have an accuracy of ± 2 percent. The pulse wave form shall be monitored by means of an oxcilloscope connected to the electrode head at suitable test points.

8.13.3 TEST PROCEDURE

The wire or cable, in the finished state or in the stage of manufacture for which the test is specified, shall be threaded through the centering guides and the electrode head. The conductor or shield, as applicable, shall be grounded. With the electrode energized to the peak voltage specified in 5.4.10, the wire or cable shall be passed through the chamber at such speed that every part of the wire or cable shall be subjected to at least 3 impulses of the test voltage while within the electrode head. The number of impulses that any part of the wire or cable shall be subjected to, including setup, shall not be greater than 1000.

8.14 <u>INSULATION ELONGATION AND TENSILE STRENGTH</u>

Specimens of the entire insulation shall be carefully removed from the conductor and tested for tensile strength and elongation in accordance with FED-STD-228, Methods 3021 and 3031, respectively, using one-inch bench marks and one-inch initial jaw separation and at a jaw separation speed of 2 inches per minute. For cable jackets, the method shall be the same, but only the cable jacket shall be tested.

8.15 <u>INSULATION RESISTANCE</u>

8.15.1 INSULATION RESISTANCE AT ROOM TEMPERATURE

The uninsulated ends of a wire or cable specimen at least 26 feet in length shall be connected to a DC terminal and the specimen shall be immersed to within 6 inches of its ends in a water bath, at 23 ± 3 C (73 ± 5 F), containing 0.5 to 1.0 percent of an anionic wetting agent. The specimen shall remain immersed for not less than 4 hours, after which a voltage of not less than 250 volts nor more than 500 volts shall be applied between the conductor or the shield (as applicable) and the water bath which serves as the other DC terminal. The insulation resistance shall be determined after one minute of electrification at this voltage and shall be expressed as megohms/1000 feet by the following calculation:

$$\text{Megohms/1000 feet} = \frac{\text{Total specimen resistance (megohms)} \times \text{immersed length (feet)}}{1000}$$

8.15.2 INSULATION RESISTANCE AT ELEVATED TEMPERATURE

One inch of insulation shall be removed from one end of a 12-foot specimen of the finished wire. The center 10-foot portion of the specimen shall be tightly wrapped with lead or aluminum foil tape. The tape shall have a minimum overlap of 50% and shall be secured at both ends to prevent unwinding. Suitable test leads shall be connected to the uninsulated end of the specimen and to one end of the tape. The specimen shall then be placed in an oven that has been stabilized for one hour at 150 ± 3 C (302 ± 5 F). After the specimen has been maintained at this temperature for a period of 15 minutes the following tests shall be made:

(NOTE: THE FOIL TAPE SHALL BE THE GROUNDED ELECTRODE)

8.15.2.1 Insulation Resistance

The conductor of the wire specimen shall also be grounded for at least 5 seconds before the resistance measurement is made. The resistance shall be measured on the specimen after a one minute electrification with a direct current voltage of not less than 250 volts nor more than 500 volts. The test shall be made with a megohm bridge or with a galvanometer and a suitable source of direct current.

8.15.2.2 Dielectric

1000 volts at commercial frequency shall be applied between the wire conductor and the lead or aluminum foil tape for one minute.

8.16 LIFE CYCLE

8.16.1 AIR OVEN

8.16.1.1 Finished Wire

One inch of the insulation shall be removed from each end of a 24-inch specimen of finished wire which includes a product identification marking. The central portion of the specimen then shall be bent at least halfway around a horizontally-placed stainless steel mandrel of the diameter specified in Table XV. The product identification marking shall be located on the hanging vertical section of the specimen. Each end of the conductor shall be loaded with the weight specified in Table XV, so that the portion of the insulation between the conductor and the mandrel is under compression while the conductor is under tension. This specimen, so prepared on the mandrel, shall be conditioned in an air-circulating oven for the time and at the temperature specified in 5.4.12.1. The velocity of air past the specimen (measured at room temperature) shall be between 100 and 200 feet per minute. After conditioning, the oven shall be shut off, the door opened and the specimen allowed to cool in the oven for at least one hour. When cool, the wire specimen shall be freed from tension, removed from the mandrel. straightened, and examined for legibility of product identification. The specimen then shall be subjected to the bend test (8.16.2), followed by the dielectric test (8.16.3). The insulation then shall be removed and the conductor examined for pitting. Darkening of the tin coating caused by normal air oxidation shall not be cause for rejection.

8.16.1.2 Finished Cable

The length of the specimen to be tested shall be 24 inches. Two inches of the jacket shall be removed from each end of a shielded specimen. The specimen shall then be conditioned hanging freely in an air circulating oven for the time and temperature specified in paragraph 5.4.12.2. The velocity of air past the specimens (measured at room temperature) shall be between 100 and 200 feet per minute. After conditioning, the oven shall be shut off, the door opened and the specimens allowed to cool in the oven for at least one hour. When cool, the center portion of each specimen shall be wrapped a minimum of 180 degrees around a mandrel with a diameter 25 times the overall diameter of the finished cable. The specimens then shall be visually examined, without the aid of magnification, for cracks. A shielded specimen shall then be subjected to the dielectric test specified in 8.16.3, with the bent portion submerged.

8.16.2 BEND TEST

At a temperature maintained at 23 ± 3 C (73 ± 5 F), one end of the specimen shall be secured to the mandrel and the other end to the weight specified in Table XV. The mandrel shall be rotated until the full length of the specimen is wrapped around the mandrel and is under the specified tension with adjoining coils in contact. The mandrel then shall be rotated in reverse direction until the full length of the specimen which was outside during the first wrapping is now next to themandrel. This procedure shall be repeated until two bends in each direction have been formed in the same section of the specimen. The outer surface of the specimen then shall be observed for cracking of the insulation. Checks, crazing of flaking in the color coating shall not constitute failure.

8.16.3 DIELECTRIC TEST

The uninsulated ends of the conductor or shield (as applicable) shall be connected together and the specimen shall be immersed in a 5-percent solution of sodium chloride in water at a temperature of 23 ± 3 C (73 ± 5 F) so that only the insulation at the stripped ends protrudes 1-1/2 inches from the surface of the solution. After immersion for 1 hour, 2500 volts, 60 Hz (for wire) or 1000 volts, 60 Hz (for cable) shall be applied between the conductor or the shield (as applicable) and an electrode in contact with the solution. This voltage shall be gradually increased at a uniform rate from zero to the specified voltage in 1/2 minute, maintained at the voltage for 5 minutes for wire or 1 minute for shielded cable, and gradually reduced to zero in 1/2 minute.

8.17 LOW TEMPERATURE (COLD BEND)

8.17.1 FINISHED WIRE

One end of a wire specimen shall be secured to a rotatable mandrel in a cold chamber and the other end to a weight. Specimen length, mandrel size, and weight shall be as specified in Table XVII. Provision shall be made for rotating the mandrel by means of a handle or control located outside the chamber. The specimen and the mandrel shall be conditioned at -65 ± 2 C (-85 ± 4 F) for 4 hours. At the end of this time and while both mandrel and specimen are still at this low temperature, the specimen shall be wrapped helically, for at least two turns around the mandrel without opening the chamber. The bending shall be accomplished at a uniform rate of 2 ± 1 RPM. At the completion of this test the specimen shall be removed from the cold box and then from the mandrel without straightening. The specimen shall be examined for cracks in the insulation. The insulation shall then be removed for a distance of 1 inch from each end of the specimen and the specimen shall be subjected to the dielectric test (8.16.3) with the bent portion submerged.

8.17.2 FINISHED CABLE

Cable specimens shall be tested as described in 8.17.1 except that the weight used shall be sufficient to keep the specimen vertical and tangent to the mandrel during the bending operation. The mandrel diameter shall be as shown in Table XVII and the specimen length shall be no less than 3 times the circumference of the mandrel. After removal from the cold box the cable jacket shall be examined for cracks. For shielded cable 1 inch the jacket shall be removed at each end of the specimen and the specimen shall be subjected to the dielectric test (8.16.3) with the bent portion submerged.

8.18 MARKABILITY

Specimens shall be tested for markability in the as received condition. A twelve foot specimen selected at random shall be marked using normal handling procedures. A Kingsley (or equivalent) hot embossing single step process machine shall be used to imprint the specimen with characters 1 through 5 and A through D. No post cure for the marking is allowed. The marking foil shall be Kingsley No. K-486 (or equivalent), color black and shall be applied to the specimen using a type temperature of 500 ± 50 F. The pressure, and dwell time shall be adjusted to obtain the best pigment transfer from the foil and the best marking permanence.

After allowing the specimen to cool for at least 2 minutes, the marked wire shall be mounted in the specimen clamp of a General Electric Repeated Scrape Abrasion Tester, Type 5120401 (or equivalent), so the rubbing member will contact the marking. A two-pound weight, including the weight of the fixture, shall be applied through the rubbing member to the imprinted marking. The rubbing member shall be a 3/16 inch wide micarta block with 1/32 corner radii, covered with new 0.040 inch thick felt conforming to Federal Specification C-F-206C, Type III, Class 7A1, color grey (American Felt Co. No. 3425, color 183). The speed of the reciprocating abrading head shall be 30 to 60 cycles per minute. Not less than six tests per specimen shall be made. After the specimen has been abraded, it shall meet the requirements of the Dielectric Test 8.16.3.

8.19 NOTCH SENSITIVITY

One inch of the insulation shall be removed from each end of five 24-inch specimens of finished wire. At the approximate center of each specimen the insulation shall be notched (cut) to the depth indicated. The notch shall be made with a commercial grade stainless steel safety razor mounted in a suitable guide to control the depth of the notch. The specimens shall then be wrapped 360° around a mandrel of the size shown in Table XVIII, with the notch on the outside of the bend. The specimen shall then be removed from the mandrel and subjected to the dielectric test 8.16.3. R R R

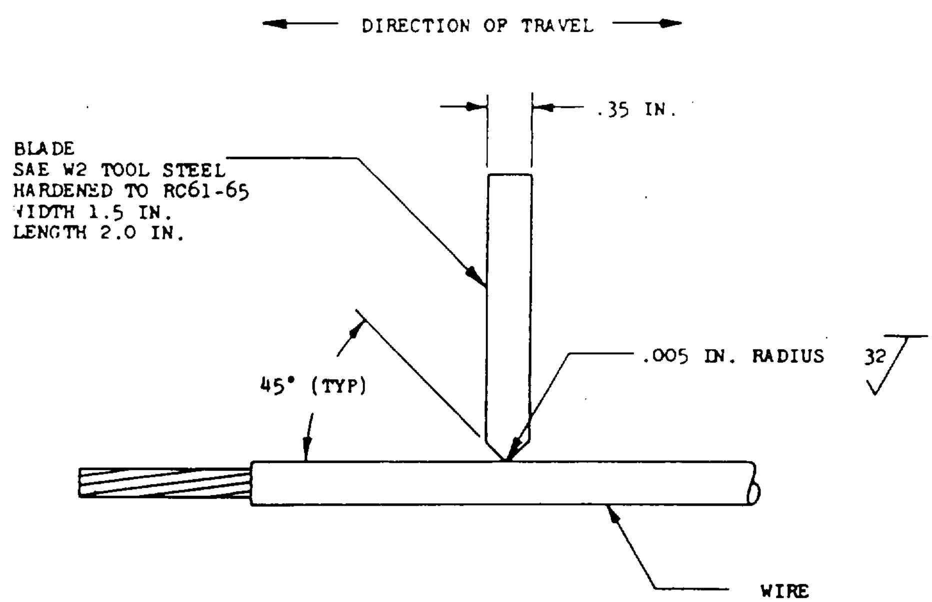
8.20 SCRAPE ABRASION

8.20.1 APPARATUS

The scrape abrasion tester shall consist of a device which abrades the surface of the wire insulation by means of a weighted scraping fixture. The scraping action shall be in both directions along the longitudinal axis of the wire for a distance of no less than 2 inches and at a speed of 30 to 60 cycles per minute. The scraping device that contacts the wire surface shall be a hardened steel blade as shown in Figure 17. During the scraping action the vertical axis of the blade shall be maintained at 90 ± 2° to the centerline of the test specimen. The test specimen shall be held taut and straight by clamps on a flat supporting anvil. The device shall be equipped with an electrical circuit designed so that when the scraping blade abrades through the wire insulation and contacts the wire conductor the machine will stop. R R

8.20.2 PROCEDURE

One inch of insulation shall be removed from one end of a 24-inch specimen of the finished wire. The test specimen shall be clamped in the tester and subjected to the abrasion test using the weight specified in Table XIX. Four tests shall be performed on the specimen with the specimen being moved forward 4 inches and rotated 90 degrees between each test. Scrape abrasion resistance shall be the number of cycles required for the scraping blade to abrade through the wire insulation and stop the machine. R R



SCRAPE ABRASION BLADE R

FIGURE 17 R

R

8.21 SHRINKAGE

A 12-inch specimen of the finished wire shall be cut so that the insulation and conductor are flush at both ends. The specimen shall then be conditioned in an air circulating oven for the time and at the temperature specified in 5.4.17. At the end of this time, the specimen shall be removed from the oven and allowed to cool to room temperature. Shrinkage of the insulation shall then be measured as the greatest distance which any layer of the insulation has receded from either end of the conductor. The measurement obtained at the end showing the greater shrinkage shall be considered the shrinkage of the specimen.

8.22 SMOKE TEST

This test shall be conducted in still air at an ambient temperature of 23 ± 3 C (73 ± 5 F). The specimen shall consist of a 15-foot length of finished wire, cleaned in accordance with the procedure for Group I materials in ASTM D 1371-68. The specimen shall be subsequently handled with maximum care, preferably with clean gloves, to avoid even the slightest contamination, including direct contact with the fingers. The specimen of wire shall be suspended so that the central 10-foot section is horizontal and unsupported. Two 1/4 inch cylinders of insulation shall be removed from the specimen so that the bared conductor sections are centered on the specimen with their inside edges 10 feet apart. Care should be taken not to damage any of the conductor strands. One end of the specimen shall be suitably weighted in order that a minimum of sagging will occur throughout the test. The resistance of the central 10-foot section of the conductor shall be measured at room temperature using a Kelvin Bridge or equivalent. From the following equation, calculate the E/I ratio necessary to raise the conductor temperature to the value specified in 5.4.18.

$$\frac{E}{I} = R_a \left[1 + \frac{T-t_a}{K+t_a}\right]$$

Where: E = measured voltage drop over the central 10-foot section of the specimen (volts)

I = measured current (amps)

t_a = measured room ambient temperature (degrees centigrade)

R_a = measured resistance of central 10-foot section of the specimen at temperature t_a (ohms)

T = 250 ± 3 C

$\frac{E}{I}$ = calculated resistance of the central 10-foot section of specimen at temperature T (ohms)

K = temperature coefficient of resistance factor of conductor material (degrees centigrade)

234.5 for tin-coated copper

279.0 for silver-coated high-strength copper alloy

A measured electric current shall be established in the conductor by applying a voltage across the ends of the conductor, being careful to ensure good electrical contact. The voltage drop shall be measured over the central 10-foot section of the conductor. The current shall be adjusted so that the conductor temperature stabilizes at 250 ± 3 C. This conductor temperature shall be maintained for 15 minutes during which time the specimen shall be examined for evidence of visible smoke. A flat-black background shall be used for this test.

8.23 SURFACE RESISTANCE

8.23.1 SPECIMENS

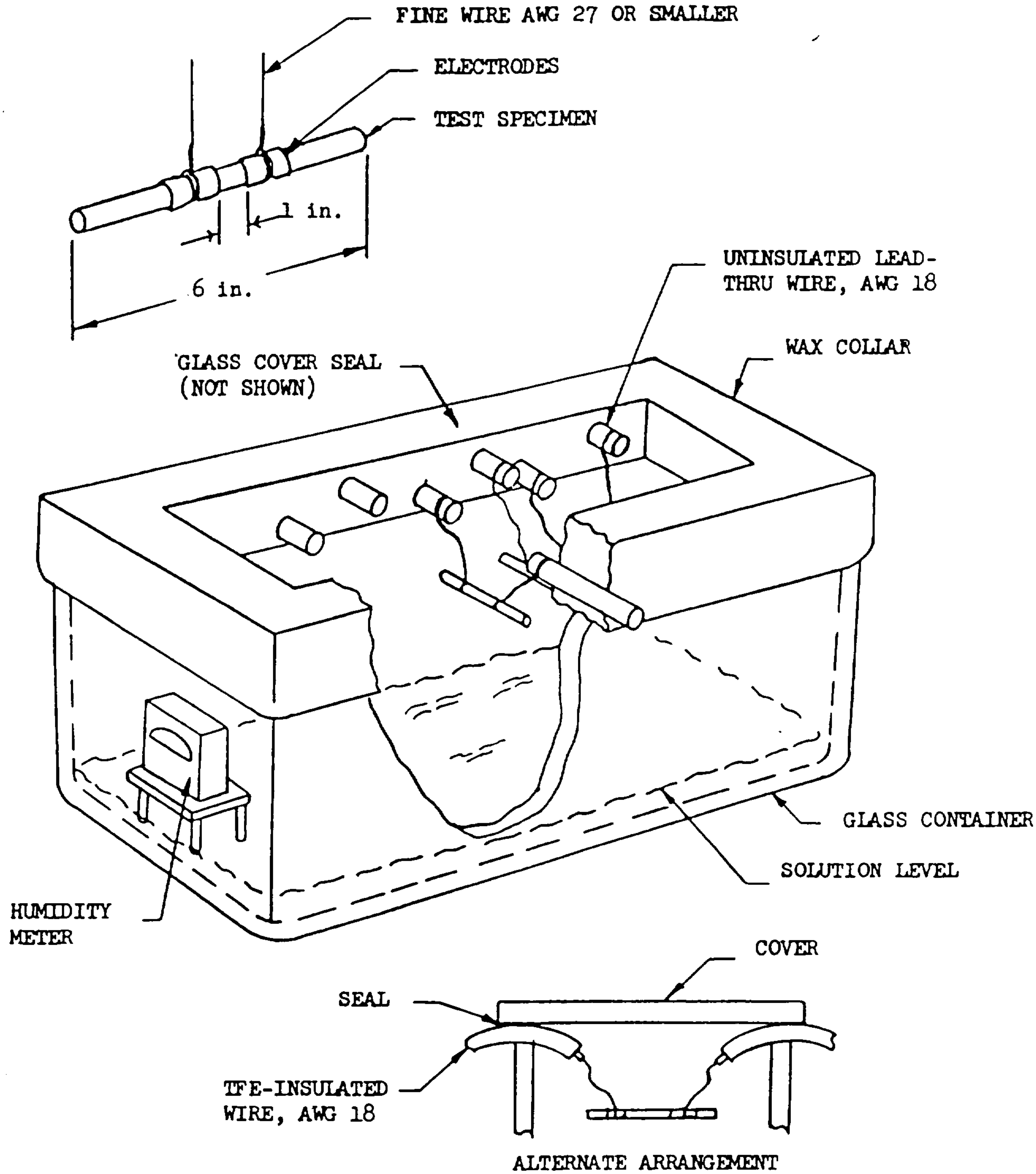
The specimens shall consist of 6-inch lengths of finished wire, cleaned in accordance with the procedure for Group I materials in ASTM D 1371. The specimens shall subsequently be handled with maximum care, preferably with clean gloves, to avoid even the slightest contamination, including direct contact with the fingers. Each cleaned specimen shall be provided, near its center, with two electrodes spaced 1.0 ± 0.05 inch apart between their nearest edges. Each electrode shall be approximately 1/2 inch wide and shall consist of conductive silver paint (Du Pont 4817 or equivalent) painted around the circumference of the specimen. Electrical connection to the dry electrodes may be made by wrapping several turns of fine (AWG size 27 or finer) tin-coated copper wire around the electrode, leaving a free end of the fine wire of sufficient length for soldering to the electrical lead wires inside the test chamber.

8.23.2 TEST CHAMBER

The test chamber shall be a Blue M Co., Model FR-1000A or equivalent or shall be as shown in Figure 18. Ambient conditions for this test shall be a relative humidity of 95 ± 5 percent and a temperature of 23 ± 3 C (73 ± 5 F). The test chamber shown in Figure 18 is a tightly covered rectangular glass vessel containing a reservoir of aqueous solution to maintain the required relative humidity (see ASTM E 104) and a humidity gage, when applicable, observable from outside the chamber, to indicate the relative humidity actually obtained. On the two long sides of the vessel, tin-coated AWG size 18 solid copper lead-wires penetrate and are permanently sealed into the paraffin wax collar shown in Figure 14, at intervals of approximately 1 inch and at least 1 inch from any edge. As an alternate the leads may be insulated with polytetrafluoroethylene (TFE) and brought outside of the chamber through paraffin wax, silicone stopcock grease, or TFE bushings, provided at least 2 inches of TFE insulation extend beyond the seal inside the chamber. The chamber cover is lubricated with silicone stopcock grease to minimize interchange of air. The electrical resistance of the chamber, measured across the lead wires under the specified test conditions of relative humidity and temperature but with no specimens in place, shall be a minimum of one million megohms. R R

8.23.3 PROCEDURE

With the specimens and electrodes prepared as specified in 8.23.1 the electrodes shall be connected to the lead wires in the test chamber. In all cases, the wire specimens shall be installed so that their ends are a minimum of one inch from the walls of the chamber. The cover of the chamber shall be put in place, and the test assemblies shall be conditioned for 96 hours at the relative humidity and temperature specified in 8.23.2. The resistance between the electrodes shall then be measured using a DC voltage of 200 to 500 volts, while the specimens are still within the test chamber after a 1-minute electrification. The surface resistance shall be computed by multiplying the measured resistance value by the measured overall diameter of the specimen in inches. Following the initial resistance measurement, a 2500 volt rms 60 Hz voltage shall be applied between electrodes for a period of 1 minute. There shall be no evidence of distress such as arcing, smoking or burning, flashover, or dielectric failure. After a discharge interval of 15 to 20 minutes following the voltage test, the surface resistance shall be remeasured and computed. Both values of computed surface resistance shall be greater than the minimum specified in 5.4.19. R R R R



TYPICAL SURFACE-RESISTANCE TEST CHAMBER

FIGURE 18

8.24 TAPE ABRASION

8.24.1 PROCEDURE I

The test shall be conducted on an abrasion testing machine conforming to MIL-T-5438, except that the machine shall be modified or supplemented by a device to determine the lengthwise tension of the wire specimen when it is clamped into the machine. The abrasive tape shall be as specified in MIL-T-5438. One inch of the insulation shall be removed from one end of a 30-inch specimen of the finished wire and this end shall be connected to the detection circuit of the tester. The specimen shall be clamped into the tester, using the lengthwise tensile load, the weight-support bracket and the vertical weight specified in Table XX. The specimen shall then be abraded. At the start of each measurement the center of a conducting stripe shall be at the point of contact with the wire. The reading of each measurement shall be the length of abrasive tape in inches to come in contact with the wire insulation to the point where the machine stops. After each reading the specimen shall be moved forward 2 inches and rotated clockwise 90 degrees. Eight readings shall be obtained for each specimen. An average shall be obtained by calculating the arithmetic mean of all the readings which are individually less than the arithmetic mean of all the eight readings per specimen. This average shall define the abrasion resistance of the specimen under test.

8.24.2 PROCEDURE II

The test method shall be in accordance with Procedure I, except that the abradant of the abrasive cloth tape shall be aluminum oxide, grit 400, and the detection cross stripes of conductive silver paint on the tape shall be 1/4 inch wide, spaced 3 inches apart, center to center.

8.25 THERMAL SHOCK RESISTANCE

8.25.1 PREPARATION OF SPECIMEN

A specimen of wire, five feet long shall be prepared by carefully removing 1 inch of insulation from each end of the wire. A razor blade or equivalent, held perpendicular to the axis of the wire, shall be used to cut the insulation for the removal operation. The length of exposed conductor at each end of the specimen shall be measured to the nearest 0.01 inch. The specimen shall be formed into a loose coil not less than 1 foot in diameter. The specimen shall then be laid on a wire screen for handling throughout the test.

8.25.2 TEST PROCEDURE

The specimen shall be conditioned for 30 minutes in a preheated air-circulating oven at the temperature specified in 5.4.21. The specimen then shall be removed from the oven and within two minutes placed in a chamber which has been precooled to -55 ± 2 C (-67 ± 4 F). It shall be exposed to this temperature for 30 minutes, after which it shall be removed and allowed a minimum of 30 minutes to return to room temperature, 20 to 25 C (68 to 77 F). At the conclusion of this cycle, the distance from the end of each layer of insulation to the end of the conductor shall be measured to the nearest 0.01 inch. This thermal shock cycle and the measurements shall be repeated for an additional three cycles (a total of four cycles). Any measurement varying from the original measurement by more than the amount specified in 5.4.21 shall constitute failure. Flaring of any layer shall also constitute failure.

8.26 WEIGHT

The weight of finished wire or cable shall be determined by Procedure I, (8.26.1). Wire or cable failing to meet the weight requirements for the applicable wire construction when tested in accordance with Procedure I shall be subjected to Procedure II (8.26.2). All reels or spools of wire or cable failing to meet the requirements for the applicable wire construction when tested in accordance with Procedure II shall be rejected. The sampling plans of 7.3.1 are not applicable in Procedure II.

8.26.1 PROCEDURE I

The length and weight of a specimen at least 10 feet long shall be accurately measured with the resultant measurements converted to pounds per 1000 feet.

8.26.2 PROCEDURE II

The net weight of the finished wire or cable on each reel or spool shall be obtained by subtracting the tare weight of the reel or spool from the gross weight of the reel or spool containing the finished wire or cable. The net weight of wire or cable on each reel or spool shall be divided by the accurately determined length of finished wire or cable on that reel or spool and the result converted to pounds per 1000 feet. When wood or other moisture-absorbent materials are used for reel or spool construction, weight determinations shall be made under essentially the same conditions of relative humidity.

8.27 WICKING

A specimen of each finished wire size to be tested shall be cut 6 ± 1/16 inches with square ends. The specimen shall be vertically immersed for two inches of its length in the fluorescent dye solution defined below, contained in an open test tube and conditioned for 24 hours at room temperature in a draft-free room. The fluorescent dye solution shall be prepared by dissolving 0.02 gram of Rhodamine B dye in a mixture of 2 liters of distilled water, 30 cc of ethyl alcohol conforming to MIL-A-6091, and 3 cc of an anionic wetting agent conforming to MIL-D-26937. After this conditioning, the specimen shall be removed from the fluorescent dye solution and excess solution on the surface shall be removed immediately from the two inches immersed by wiping gently with a clean, dry, lint-free cloth. The coating shall be removed from the specimen and the outside of the primary insulation and the inside of the coating shall be examined for evidence of fluorescent dye using an ultraviolet source. For Types VIII, IX, X and XI wire the primary insulation shall also be examined for wicking between extrusion layers. The distance that the fluorescent dye has wicked above the two-inch portion of immersed specimen shall be recorded as the distance of wicking.

8.28 WRAP-BACK TEST

For wire sizes 14 and smaller, a 12-inch specimen of finished wire shall be bent back on itself at the mid-portion, on a radius not less than the radius of the wire, and one end of the specimen shall be wound tightly around the other end as a mandrel for a total of four close turns. The ends of the specimen shall be left unsecured to permit unhampered relaxation of the turns. For wire sized 12 and larger, the midportion of a 12 to 24 inch specimen of finished wire shall be wrapped around a mandrel for 4 close turns and the ends secured to the mandrel. The mandrel diameter shall be approximately 10 times the finished wire diameter. The specimen shall then be conditioned in an air oven at the time and temperature specified in 5.4.26. At the end of this period, the specimen shall be visually examined, without the aid of magnification for cracks.

9. MATERIAL IDENTIFICATION

9.1 TYPE I, III, V, VI AND VIII THROUGH XIII CLASS 1

Type I, III, V, VI and VIII through XIII, Class 1 wire or cable shall be identified by permanent printed marking applied to the outer surface of the finished wire or component wire as applicable. The marking shall be placed at intervals along the length of the wire. Spacing between the last and the first letter of adjacent marking shall be 6 inches (nominal) on wire sizes 14 and larger and 3 inches (nominal) on wire sizes 16 and smaller.

The printed identification shall consist of the following:

a. Wire Part Number

b. Manufacturer's Code Number or Trade Mark

EXAMPLE: W42A/1/1-20 XXXXX

INDICATES: BMS 13-42A Type I Class 1 Size 20
Manufacturer's Code Number

9.2 TYPE I THROUGH XIII, CLASS 2 OR GREATER CABLE

Type I through XIII, Class 2 or greater cable shall be identified as outlined in 9.1 but only on the red wire. The cable identification shall be imprinted on the wire at intervals of 6 inches (nominal) and shall consist of the following:

a. Wire Part Number

b. Manufacturer's Code Number Or Trade Mark

EXAMPLE: W42A/3/4-20 XXXXX

INDICATES: BMS 13-42A Type III Class 4 Size 20
Manufacturer's Code Number

9.3 MARKING COLOR AND SIZE

The color of the marking on Class 1 wire or cable shall be as near as possible to the light green limit of MIL-STD-104A, Class 1. The color of the marking on the red wire in Class 2 or greater cable shall be black within the limits of MIL-STD-104A, Class 1. The characters shall be permanent and of sufficient size to be legible. When the finished wire diameter is 0.054 inch or less the identification marking shall be applied with the vertical axes of the characters lengthwise of the wire. The print shall meet the requirements of 3.4.3 when tested in accordance with 8.9.

10. PACKAGING AND MARKING

10.1 PACKAGING AND PACKING

10.1.1 WIRE AND CABLE

Wire and cable shall be delivered wound on reels or spools in accordance with 10.1.2. Unless otherwise specified in the purchase order, the minimum acceptable finished wire lengths shall conform to Table XXI. The wire shall be wound on the reel or spool in such a manner that all ends are accessible.

TABLE XXI

FINISHED WIRE LENGTHS (TYPE I V AND VIII THROUGH XI)

WIRE SIZE RANGE	MINIMUM PERCENTAGE OF FOOTAGE IN SHIPMENT WITH LENGTHS GREATER THAN:					
	5000 FEET	2500 FEET	1000 FEET	500 FEET	250 FEET	100 FEET
30 - 26		10	70	95	98	100
24 - 20	1[illegible]	30	80	95	100	
18		10	70	95	98	100
16			60	80	90	100
14 - 10			40	70	80	100
8 - 4					60	100
2 - 0000						100

10.1.2 REELS AND SPOOLS

Reels and spools shall be of a non-returnable type. Each reel or spool shall have an appropriate diameter for the respective wire size. In no case shall the barrel of the reel or spool have a diameter less than 3-1/2 inches. Reels and spools shall be suitably finished to prevent corrosion under typical storage and handling conditions.

10.1.3 CONTAINERS

Unless otherwise specified in the purchase order, electric wire or cable shall be delivered in standard commercial containers so constructed as to ensure acceptance by common or other carrier for safe transportation at the lowest rate to the point of delivery.

10.1.4 MARKING

Each package and each reel or spool shall be durably and legibly marked to give the following information:

a. Boeing Material Specification 13-42A R

   Type , Class , Size

b. Manufacturer's Part Number

c. Total and individual Wire or Cable Length in Feet

d. Order of Individual Wire or Cable Lengths as Put on Shipping Reel

e. Purchase Order Number

f. Manufacturer's Name

g. Date of Manufacture

h. Manufacturer's Lot Number

   NOTE: b, c, d, g, and h may be omitted on containers used for the shipping of reels or spools.

R

TABLE XXII

QUALIFICATION, SUPPLIER AND PURCHASER INSPECTION TEST

TYPE I, V AND VIII THROUGH XI WIRE

TEST	REQUIREMENTS	TEST METHOD	TEST GROUP
ACCELERATED AGING	5.4.1.1	8.2.1	II
BLOCKING	5.4.2	8.3	
COLOR	3.4.	8.1	I
COLOR AND COLOR STRIPING DURABILITY	3.4	8.9	
CONCENTRICTY	5.4.3	8.4	II
CONDUCTOR DIAMETER	5.2.1.4	8.1	I
CONDUCTOR ELONGATION AND TENSILE STRENGTH	5.2.1.3	8.5	
CONDUCTOR RESISTANCE	5.4.4	8.6	
CONDUCTOR STRANDING	5.2.1.1.	8.1	I
DEFORMATION	5.4.5	8.7	
DURABILITY OF IDENTIFICATION	9.3	8.9	
FINISHED WIRE DIAMETER	APPLICABLE WIRE TYPE & CLASS	8.1	I
FLAMMABILITY	5.4.7	8.10	
HUMIDITY RESISTANCE	5.4.8	8.11	
IDENTIFICATION OF PRODUCT	9.	8.1	I
IMMERSION	5.4.9	8.12	
IMPULSE DIELECTRIC	5.4.10	8.13	II
INSULATION ELONGATION AND TENSILE STRENGTH	5.2.1.5.3	8.14	II
INSULATION RESISTANCE	5.4.11	8.15	II
LIFE CYCLE	5.4.12.1	8.16.1.1	
LOW TEMPERATURE (COLD BEND)	5.4.13.1	8.17.1	
MARKABILITY	5.4.14	8.18	
NOTCH SENSITIVITY	5.4.15 [1]	8.19	
REMOVABILITY OF INSULATION	5.2.1.5	8.1	
SCRAPE ABRASION	5.4.16	8.20	
SHRINKAGE	5.4.17	8.21	II
SMOKE	5.4.18	8.22	
SURFACE RESISTANCE	5.4.19	8.23	
TAPE ABRASION	5.4.20	8.24.2	
THERMAL SHOCK RESISTANCE	5.4.21	8.25	
VISUAL AND DIMENSIONAL	5.4.23	8.1	I
WEIGHT	APPLICABLE WIRE TYPE & CLASS	8.26	II
WICKING	5.4.24	8.27	
WORKMANSHIP	5.4.25	8.1	I
WRAP-BACK	5.4.26	8.28	II
TIN COATING	5.4.22 [2]	8.1	II

[1] Applicable to Type VIII through XI only.

[2] Applicable to Type I VIII and X only.

TABLE XXII (Continued)

QUALIFICATION, SUPPLIER AND PURCHASER INSPECTION

TYPE III, IV, VI, VII, XII AND XIII CABLE

TEST	REQUIREMENTS	TEST METHOD	TEST GROUP
ACCELERATED AGING	5.4.1.2 [3]	8.2.2	
BLOCKING	5.4.2	8.3	
COLOR	3.4	8.1 & 8.9	I
DIELECTRIC STRENGTH	5.4.6	8.8	II
DIMENSIONS	APPLICABLE CABLE TYPE & CLASS	8.1	I
DURABILITY OF IDENTIFICATION	9.3	8.9	
FLAMMABILITY	5.4.7	8.10	
IMMERSION	5.4.9	8.12	
IMPULSE DIELECTRIC	5.4.10 [5]	8.13	II
IDENTIFICATION OF PRODUCT	9.	8.1	I
JACKET CONCENTRICITY	5.4.3	8.4	
JACKET ELONGATION AND TENSILE STRENGTH	5.2.2.2	8.14	
LIFE CYCLE	5.4.12.2 [3]	8.16.1.2	
LOW TEMPERATURE (COLD BEND)	5.4.13.2 [3]	8.17.2	
SHIELD COVERAGE	5.2.2.1	4.5.3 [4]	
VISUAL AND DIMENSIONAL	5.4.23	8.1	I
WEIGHT	APPLICABLE CABLE TYPE & CLASS	8.26	II
WORKMANSHIP	5.4.25	8.1	I

[3] The dielectric breakdown test is not required for Type IV and VII cable.

[4] of MIL-C-7078

[5] Applicable to Type III, VI, XII and XIII only.

1. **SCOPE**

a. This specification covers crosslinked alkane-imide polymer insulated copper and copper alloy wire and cable. This specification requires qualification of products.

b. RATING

The wire of this specification is rated for the following conditions.

(1) When operating potentials do not exceed 600 volts (RMS).

(2) Where any combinations of ambient temperature and conductor current, for either intermittent or continuous service, does not produce a stabilized conductor temperature in excess of 302 F (150 C).

2. **REFERENCES**

Except where a specific issue is indicated, the noted issue of the following references shall be considered a part of this specification to the extent specified herein.

2.1 SPECIFICATIONS

2.1.1 FEDERAL

a.	TT-S-735, Type III	Standard Test Fluids; Hydrocarbon, March 1964
b.	UU-T-450B	Tissue, Facial, 24 Sept. 1963
c.	CCC-T-191b	Textile Test Methods, 15 May 1951
d.	C-F-206C	Felt Sheet, Cloth, Felt, Wool, Pressed, 30 July 1968

2.1.2 MILITARY

a.	MIL-C-7078B	Cable Electric Aerospace Vehicle General Specification for, 17 March, 1964
b.	MIL-T-5438	Tester; Abrasion, Electrical Cable, 19 Dec. 1949
c.	MIL-H-5606B	Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordnance, 26 June 1963
d.	MIL-A-6091C	Alcohol, Ethyl, Specially Denatured, 9 Feb. 1968
e.	MIL-L-7808E	Lubricating Oil, AircraftTurbine Engine, Synthetic Base, 13 March 1963
f.	MIL-L-23699	Lubricating Oil, Aircraft Turbine Engine, Synthetic Base, 1 March 1965
g.	MIL-D-26937A	Detergent, Synthetic, Anionic (Alkyl Benzene Sulfonate), 15 April 1963
h.	MIL-C-572F	Cords, Yarns and Monofiliments Organic Synthetic Fiber 10 June 1969 R

2.2 STANDARDS

2.2.1 FEDERAL

a. FED-STD-228 — Cable and Wire, Insulated; Methods of Testing, 14 April 1967

2.2.2 MILITARY

a. MIL-STD-104A — Limits for Electrical Insulation Color, 12 July 1963

b. MIL-STD-105D — Sampling Procedures and Tables for Inspection by Attributes, 29 April 1963

c. MIL-STD-109A — Quality Assurance Terms and Definitions, 30 Oct. 1961

2.3 OTHER PUBLICATIONS

2.3.1 COMMERCIAL

a. Munsell Book of Color — Munsell Color Co., Baltimore, Maryland

2.3.2 BOEING

a. BMS 3-11C — Hydraulic Fluid, Fire Resistant

2.4 AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

a. B 33-63 — Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes

b. B 298-64 — Standard Specification for Silver-Coated Soft or Annealed Copper Wire

c. D 1371-68 — Recommended Practice for Cleaning Plastic Specimens for Insulation Resistance, Surface Resistance, and Volume Resistivity Testing

d. E 104-51 — Recommended Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions

(Copies of ASTM publications may be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103).

2.5 MISCELLANEOUS

a. Alkaline Detergent Solvent (pH 10.0-10.5)(REF: Maintenance Manual, Chapter 12, Cleaning & Polishing Materials - Ordering/Dexcription/Use)

b. Oronite HyJet III, Chevron Chemical Co., San Francisco, California.

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TABLE OF CONTENTS

3. CONFIGURATION

3.1 TYPES

a. Type I — Wire or Cable - 6 MIL (NOM) Insulation, Tinned Copper Conductor.

One insulated conductor or two or more insulated conductors laid in a suitable spiral to make a multiconductor cable.

b. Type II — Not Applicable.

c. Type III — Shielded and Jacketed Cable - 6 MIL (NOM) Insulation, Tinned Copper Conductor.

Type I wire or cable over which the following is applied:

First - An overall shield of tinned copper braid.
Second - A jacket of alkane-imide polymer.

d. Type IV — Jacketed Cable - 6 MIL (NOM) Insulation, Tinned Copper Conductor.

Type I cable (Class 2 or greater) over which an alkane-imide polymer jacket is applied.

e. Type V — Wire or Cable - 6 MIL (NOM) Insulation, Silver Coated Copper Alloy Conductor.

One insulated conductor or two or more insulated conductors laid in a suitable spiral to make a multiconductor cable.

f. Type VI — Shielded and Jacketed Cable - 6 MIL (NOM) Insulation, Silver Coated Copper Alloy Conductor.

Type V wire or cable over which the following is applied:

First - An overall shield of tinned copper braid.
Second - A jacket of alkane-imide polymer.

g. Type VII — Jacketed Cable - 6 MIL (NOM) Insulation, Silver Coated Copper Alloy Conductor.

Type V Cable (Class 2 or greater) over which an alkane-imide polymer jacket is applied.

h. Type VIII — Wire or Cable - 10 MIL (NOM) Insulation, Tinned Copper Conductor.

One insulated conductor or two or more insulated conductors laid in a suitable spiral to make a multiconductor cable.

i. Type IX — Wire or Cable - 10 MIL (NOM) Insulation, Silver Coated Copper Alloy Conductor.

One insulated conductor or two or more insulated conductors laid in a suitable spiral to make a multiconductor cable.

j. Type X — Wire or Cable - 8 MIL (NOM) Insulation, Tinned Copper Conductor.

k. Type XI — Wire or Cable - 8 MIL (NOM) Insulation, Silver Coated Copper Alloy Conductor.

m. Type XII — Shielded and Jacketed Cable - 8 MIL (NOM) Insulation, Tinned Copper Conductor.

Type X Wire or Cable over which the following is applied:

First - An overall shield of Tinned Copper Braid
Second - A jacket of Alkane-imide Polymer

n. Type XIII — Shielded and Jacketed Cable - 8 MIL (NOM) Insulation, Silver Coated Copper Alloy Conductor

Type XI wire or cable over which the following is applied:

First - An overall shield of Tinned Copper Braid.
Second - A jacket of Alkane-imide Polymer

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3.2 CLASSES (SIZES 30 THROUGH 4)

The class designation shall be by arabic numerals which will indicate a single insulated wire or a number of insulated wires in a multiconductor cable.

Examples: Class 1 - A single insulated conductor.
Class 2 - Two spirally laid wires.
Class 24 - Twenty-four spirally laid wires.

3.3 SIZES

Wire sizes covered in this specification are listed in Table II.

3.4 COLOR CODE

3.4.1 ALL TYPES, CLASS 1 R

Unless otherwise specified on the purchase order the finished wire color shall be white, for sizes 30 through 4 and brown for sizes 2 through 4/0.

3.4.2 ALL TYPES, CLASS 2 THROUGH 24, SIZES 30 THROUGH 4 R

The finished color for wires in the multiconductor cable shall be as shown in Table I. On the eleventh through the twenty-fourth wire a stripe of the color shown in Table I shall be applied to the outer surface of the coating. The stripe shall be not less than .030 inch wide and shall make one complete turn around the wire in every two inches of axial length for wire sizes 30 through 12 and in every four inches of axial length for wire sizes 10 through 4.

TABLE I

COLOR CODE FOR WIRES IN MULTICONDUCTOR CABLE

WIRE NUMBER	INSULATION COLOR	STRIPE COLOR
1	Red	----
2	Blue	----
3	Yellow	----
4	Green	----
5	Black	----
6	Purple	----
7	Orange	----
8	Brown	----
9	Pink *	----
10	White	----
11	White	Red
12	White	Blue
13	White	Yellow
14	White	Green
15	White	Black
16	White	Purple
17	White	Orange
18	White	Brown
19	White	Pink *
20	Red	Blue
21	Red	Yellow
22	Red	Green
23	Red	Black
24	Red	Purple

* Pink shall be between Munsell Renotation 2.5R 6.9/7.4 and 10RP 4.3/7.0 with the lighter value preferred.

3.4.3 COLORS R

3.4.3.1 Class 1 Wire and Class 2 Through 24 Cable, Sizes 30 Through 4

The colors shall be within the light and dark limits specified in MIL-STD-104A Class 1 or Class 2, except as noted. The color and color striping shall withstand a minimum of 125 cycles (250 strokes) when tested per paragraph 8.9.

3.4.3.2 Class 1 Wire, Size 2 Through 4/0

The color shall be within the Munsell color renotation 5.0 YR 5.0/4.0 and 5.0R 3.0/6.0

3.5 WIRE AND CABLE DESIGNATION

The designation for a wire or cable of this specification shall be as follows: R

BMS 13-42B	TYPE	CLASS	SIZE
Material Specification No.	Type Designation Para. 3.1	Class Designation Para. 3.2	Size Para. 3.3

4. FORMS

Not applicable.

5. REQUIREMENTS

a. The wire and cable furnished under this specification shall be a product which has been tested and has passed the qualification tests specified herein, prior to acceptance of production orders.

b. Where conflict exists between this specification and any specification referenced herein, this specification shall govern.

5.1 MATERIALS

5.1.1 CONDUCTOR MATERIALS

All strands used in the manufacture of the conductors shall be soft annealed copper conforming to ASTM Standards B33-63 or shall be high-strength copper alloy. Strands shall be free from lumps, kinks, splits, scraped or corroded surfaces and skin impurities. In addition, the strands shall conform to the following requirements as applicable.

5.1.1.1 Tin-Coated Copper Strands

The tin coating shall be as specified in ASTM Standard B33-63.

5.1.1.2 High-Strength Copper Alloy

The strands shall conform to the requirements of 5.2.1.3 for elongation and tensile strength and shall be silver coated in accordance with ASTM Standard B 298-64 with not less than 40 microinches of silver

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5.1.2 SHIELD MATERIALS

Shield strands (as applicable) shall be in accordance with the requirements for conductor materials (5.1.1).

5.1.3 INSULATING MATERIAL

5.1.3.1 Insulation

All polymers used in any type of insulation shall be certified virgin material (5.1.3.1.1) containing no additives except those required as pigmentation for colors, lubricants used in extrusion, stabilizers, and fillers.

5.1.3.1.1 Virgin Material

For purposes of this specification, virgin material shall be 100 percent new material which has been through only the processes essential to its manufacture and its application to the wire and cable and which has previously been through these essential processes one time only. Any material which has previously been processed in any other manner is considered non-virgin material. This requirement shall apply to the manufacture of all ingredients and components used.

5.2 CONSTRUCTION

Construction of the wire and cable shall be as specified herein.

5.2.1 FINISHED WIRE CONSTRUCTION

5.2.1.1 Conductor Stranding

5.2.1.1.1 The stranding of conductors for wire sizes 30 through 10 AWG shall be as specified in Table II and shall be concentric in construction with a unidirectional lay or a true concentric lay.

5.2.1.1.1 (Continued)

a. Unidirectional lay shall be interpreted to be a center strand surrounded by one or more layers of helically wound strands. All layers shall have left-hand lay with the length of lay to be increased with each successive layer. The length of lay of the outer layer shall be not less than 8 times or more than 16 times the maximum conductor diameter.

b. True concentric lay shall be interpreted to be a center strand surrounded by two or more layers of helically wound strands with direction of lay being reversed in each successive layer and with the length of lay being increased with each successive layer. For the outer layer of strands the direction of lay shall be left-hand and the length of lay shall be not less than 8 times or more than 16 times the maximum conductor diameter.

5.2.1.1.2 Wire sizes 8 through 0000 shall be rope-lay as specified in Table II and in a and b below.

a. Rope-lay stranded conductors shall be laid up concentrically with a central core surrounded by one or more layers of helically wound members. It is optional for the direction of lay of successive layers to be alternately reversed (true concentric lay), or to be in the same direction (unidirectional lay). The length of lay of the outer layer of rope-lay stranded members forming the conductor shall be not less than 10 nor more than 14 times the outside diameter of the completed conductor. The direction of lay of the outside layer shall be either left or right hand.

b. Members of rope-lay stranded conductors: The length of lay of the wires composing the stranded members shall be not greater than 16 times the outside diameter of the member. Stranding or the individual members may be either concentric or bunch.

5.2.1.2 <u>Conductor Splices</u>

Splices in individual strands or members shall be butt brazed. There shall be not more than one strand-splice in any 10 foot length of a stranded concentric-lay conductor or in any 10-foot length of any member in a rope-lay conductor; except that not more than one splice of an entire member shall be permitted in any 10 feet of a rope-lay conductor. Splices in members of a rope-lay construction shall be so finished that the conductor diameter is not increased at the point of brazing. In no case shall the whole conductor be spliced at one point.

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TABLE II

DETAILS OF CONDUCTORS

Size (AWG)	Nominal Conductor Area (Circular Mils)	Stranding (Number of Strands X Strand Size)	Allowable No. of Missing Strands	Nominal Dia. of Individual Strands (Inch)	Diameter of Stranded Conductor		Max. Resistance of Finished Wire (OHMS/1000 ft. at 20 C)	
					Min. (Inch)	Max. (Inch)	Tin-Coated Soft or Annealed Copper	Silver-Coated High-Strength Copper Alloy
30	112	7 x 38	0	0.0040	0.0114	0.013		120.5
28	175	7 x 36	0	0.0050	0.0144	0.016		76.4
26	304	19 x 38	0	0.0040	0.018	0.021		44.4
24	475	19 x 36	0	0.0050	0.023	0.026	25.4	28.1
22	754	19 x 34	0	0.0063	0.029	0.033	15.9	17.6
20	1,216	19 x 32	0	0.0080	0.037	0.041	9.76	10.9
18	1,900	19 x 30	0	0.0100	0.046	0.051	6.22	
16	2,426	19 x 29	0	0.0113	0.052	0.058	4.82	
14	3,831	19 x 27	0	0.0142	0.066	0.073	3.05	
12	5,874	37 x 28	0	0.0126	0.032	0.090	2.00	
10	9,354	37 x 26	0	0.0159	0.103	0.114	1.26	
8	16,983	133 x 29	0	0.0113	0.157	0.173	0.702	
6	26,818	133 x 27	0	0.0142	0.198	0.217	0.444	
4	42,615	133 x 25	0	0.0179	0.250	0.274	0.279	
2	66,500	665 x 30	2	0.0100	0.320	0.340	0.183	
1	81,700	817 x 30	2	0.0100	0.360	0.380	0.149	
0	104,500	1,045 x 30	3	0.0100	0.405	0.425	0.116	
00	133,000	1,330 x 30	3	0.0100	0.455	0.480	0.091	
000	166,500	1,655 x 30	4	0.0100	0.515	0.540	0.071	
0000	210,900	2,109 x 30	5	0.0100	0.580	0.605	0.056	

5.2.1.3 Conductor Elongation and Tensile Strength

5.2.1.3.1 Elongation

The individual strands of the conductor or the whole conductor removed from finished wire shall have the following minimum elongation when measured in accordance with 8.5.

Soft annealed copper	10 percent
High-strength copper alloy	6 percent

5.2.1.3.2 Tensile Strength (High-Strength Copper Alloy Only)

When high-strength copper alloy is specified, the individual strands of the conductor or the whole conductor removed from finished wire shall have a minimum tensile strength of 58,000 psi when measured in accordance with 8.5.

5.2.1.4 Conductor Diameter

The diameter of the conductor shall be as specified in Table II.

5.2.1.5 Insulation

The insulation shall be constructed so that it can be readily removed by mechanical wire-stripping devices.

5.2.1.5.1 Primary Insulation

The primary insulation of one or more layers shall be crosslinked extruded alkane-imide polymer. When more than one layer is employed a coating of modified imide polymer may be used between the layers. The alkane-imide polymer shall be an off-white color readily distinguishable from the basic brown color of the imide coating or the brown color of the jacket as applicable. R

5.2.1.5.2 Coating or Jacket R

For wire sizes 30 through 4 a coating of modified imide polymer shall be applied over the primary insulation. This coating shall be continuous and free from cracks, splits, blisters, and other defects when examined without aid of magnification.

For wire sizes 2 through 4/0 an aromatic polyamide fiber braid jacket shall be applied over the primary insulation. The braid material shall conform to MIL-C-572F, Type P, shall be woven in such a manner as to provide complete coverage and shall be impregnated with a clear polyimide lacquer.

5.2.1.5.3 Insulation Elongation and Tensile Strength R

For wire sizes 30 through 4 the primary insulation and the coating shall have an elongation of 50 percent (minimum) when tested in accordance with 8.14 and shall have a tensile strength of 7500 psi (minimum) for wire sizes 30 through 10 and 5000 psi (minimum) for wire sizes 8 through 4 when tested in accordance with 8.14.

For wire sizes 2 through 4/0 the primary insulation (with jacket removed) shall have an elongation of 100% (minimum) when tested in accordance with 8.14.

5.2.2 FINISHED CABLE CONSTRUCTION

The construction of finished cable shall be as specified in the individual Type and Class construction details. In multiconductor cables the insulated wires as determined by the class designation shall be spirally laid to provide as concentric a cable as possible. The lay of the individual wires shall be not less than eight or more than sixteen times the major diameter of the cable. The direction of lay shall be left-hand. Fillers will not be allowed.

5.2.2.1 Shield Construction and Coverage

The shield shall be a closely woven braid and shall comply with the following:

a. The individual shield strand size shall be as follows:

   1. Size 38 strands shall be used over wire or cable having a major diameter of 0.300 inch or less.

   2. Size 36 strands shall be used over wire or cable having a major diameter greater than 0.300 inch and less than 0.400 inch.

   3. Size 34 strands shall be used over wire or cable having a major diameter of 0.400 inch or over.

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5.2.2.1 (Continued)

b. The shield shall provide a minimum coverage of 85 percent with coverage being determined in accordance with 4.5.3 of MIL-C-7078B.

c. The shield shall be a push-back type.

(1) When the major diameter of the cable, prior to the application of shield, is less than 0.300 inch, the angle of the carriers of the shield with the axis of the cable shall be not less than 20 or more than 35 degrees.

(2) When the major diameter of the cable, prior to the application of shield is 0.300 inch or greater and the limitations of standard braiding equipment, with a practical number of ends per carrier, make compliance with paragraph 5.2.2.1.c.(1) impractical; the shield shall be suitably applied to assure a push-back characteristic.

5.2.2.2 Cable Jacket Construction

Cable jackets shall be crosslinked extruded alkane-imide polymer and shall be concentrically applied. Minimum jacket wall thickness shall be 0.006 inch when the cable beneath the jacket has an O.D. of 0.215 inch or less and shall be 0.007 inch when the cable beneath the jacket has an O.D. of more than 0.215 inch. When tested in accordance with 8.14 the jacket material shall have a tensile strength of 3500 PSI (min.) and an elongation of 100 percent (min.). Unless otherwise specified on the purchase order the color of the jacket shall be white within the light and dark limits of MIL-STD-104A, Class 1 or 2.

5.3 FINISHED WIRE AND CABLE - TYPE I THROUGH TYPE XIII

The finished wire and cable shall conform to the following additional requirements:

5.3.1 TYPE I, CLASS I WIRE

The requirements of Type I, Class 1 wire shall be as indicated in Table III and Table XXII and as shown in Fig. 1.

The physical and electrical details of the conductor shall be as specified in Table II for tin-coated copper wire. The wall thickness of the insulation shall be 0.005 inch (min.).

5.3.2 TYPE I, CLASS 2 OR GREATER CABLE

The finished wires that compose the multi-conductor cable shall comply with all the requirements of this specification for Type I, Class 1 wire and shall be color coded in accordance with 3.4. Additional requirements for the multi-conductor cable are listed in Table III.

5.3.9 TYPE VIII, CLASS 1, WIRE

The requirements of Type VIII, Class 1, wire shall be as indicated in Table IX, Table XXII and as shown in Fig. 7, and 7A.

The physical and electrical details of the conductor shall be as specified in Table II for tin coated copper wire. The wall thickness of the insulation shall be 0.009 inch (min.) for wire sizes 24 through 10 and 0.015 inch (min.) for wire sizes 8 through 4/0.

5.3.10 TYPE VIII, CLASS 2 OR GREATER CABLE

The finished wires that compose the multi-conductor cable shall comply with all the requirements of this specification for Type VIII, Class 1 wire and shall be color coded in accordance with 3.4. Additional requirements for the multi-conductor cable are listed in Table IX.

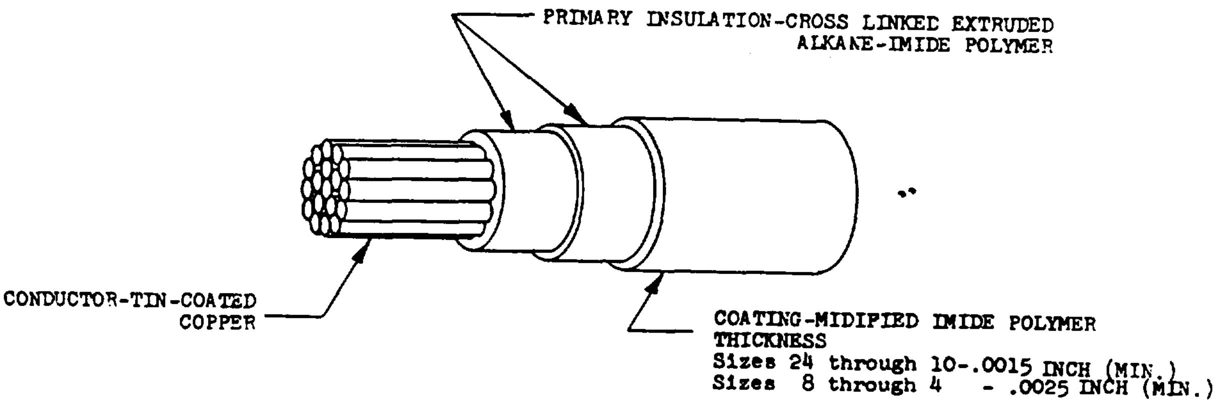

FIGURE 7 - WIRE SIZES 24 THROUGH 4

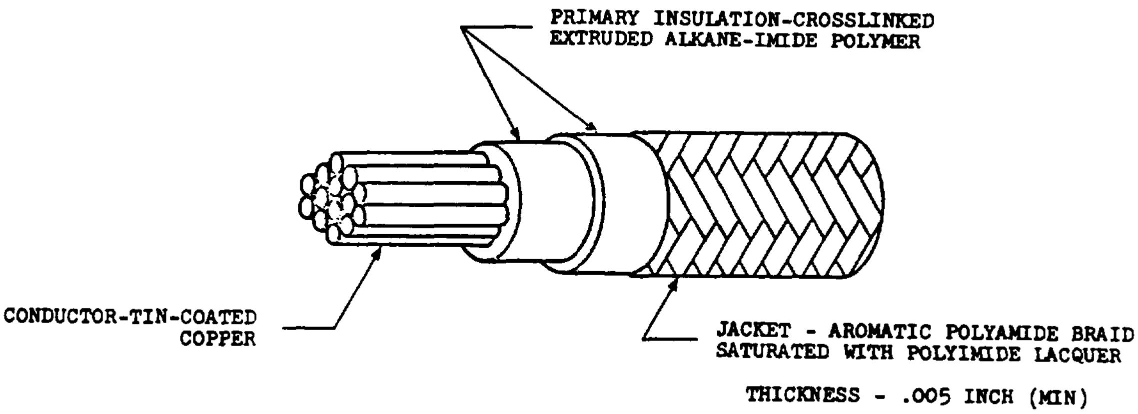

FIGURE 7A - WIRE SIZES 2 THROUGH 4/0

TABLE IX

TYPE VIII WIRE AND CABLE - OUTSIDE DIAMETER AND WEIGHT

CLASS	PART NUMBER*	CONDUCTOR SIZE (AWG)	MAXIMUM OUTSIDE DIAMETER (INCH)	MAXIMUM WEIGHT (LBS/1000 FT)
1	W42/8/1-24	24	0.047	2.2
	W42/8/1-22	22	0.054	3.2
	W42/8/1-20	20	0.062	4.7
	W42/8/1-18	18	0.075	7.0
	W42/8/1-16	16	0.084	9.0
	W42/8/1-14	14	0.099	13.7
	W42/8/1-12	12	0.116	20.4
	W42/8/1-10	10	0.142	31.3
	W42/8/1-8	8	0.203	58.5
	W42/8/1-6	6	0.251	91.0
	W42/8/1-4	4	0.311	146.0
	W42/8/1-2	2	0.399	231.0
	W42/8/1-0	0	0.497	365.0
	W42/8/1-00	00	0.560	483.0
	W42/8/1-000	000	0.628	618.0
	W42/8/1-0000	0000	0.698	730.0
2	W42/8/2-24	24	0.095	4.4
	W42/8/2-22	22	0.108	6.5
	W42/8/2-20	20	0.124	9.5
	W42/8/2-18	18	0.146	14.1
	W42/8/2-16	16	0.163	18.4
	W42/8/2-14	14	0.197	28.4
	W42/8/2-12	12	0.232	42.5
3	W42/8/3-24	24	0.102	6.7
	W42/8/3-22	22	0.116	9.7
	W42/8/3-20	20	0.133	14.2
	W42/8/3-18	18	0.158	21.2
	W42/8/3-16	16	0.175	27.7
	W42/8/3-14	14	0.213	42.6
	W42/8/3-12	12	0.250	61.8
4	W42/8/4-24	24	0.130	8.9
	W42/8/4-22	22	0.146	12.7
	W42/8/4-20	20	0.169	19.5
	W42/8/4-18	18	0.200	28.3
	W42/8/4-16	16	0.223	37.0
	W42/8/4-14	14	0.271	56.9
	W42/8/4-12	12	0.323	85.5
5	W42/8/5-24	24	0.141	11.2
	W42/8/5-22	22	0.160	16.0
	W42/8/5-20	20	0.184	24.5
	W42/8/5-18	18	0.218	36.2
	W42/8/5-16	16	0.242	46.3
	W42/8/5-14	14	0.295	71.3
	W42/8/5-12	12	0.353	107.0

R
R

* NOTE: Applicable Change Letter Not Shown

APPENDIX II

MIL-W-81044/16

Wire Specification

MIL-W-81044/16B
NOTICE 1
11 March 1977

MILITARY SPECIFICATION SHEET

WIRE, ELECTRIC, CROSSLINKED ALKANE-IMIDE POLYMER INSULATED, TIN-COATED COPPER, NORMAL WEIGHT, 600-VOLT, 150°C

Specification Sheet MIL-W-81044/16B, dated 31 December 1973, is hereby cancelled due to discontinuance of manufacture of the insulation material. There is no superseding document.

There is no exact replacement for the wire covered by this specification sheet. Substitutions for this wire should be made in accordance with the functional requirements of the specific project or application.

Preparing activity:

Navy - AS

☆U.S. GOVERNMENT PRINTING OFFICE: 1977—703-020/2371

FSC 6145

MIL-W-81044/16B
31 December 1973
SUPERSEDING
MIL-W-81044/16A(AS)
20 February 1970

MILITARY SPECIFICATION SHEET

WIRE, ELECTRIC, CROSSLINKED ALKANE-IMIDE POLYMER INSULATED, TIN-COATED COPPER, NORMAL WEIGHT, 600-VOLT, 150°C

This specification is approved for use by all Departments and Agencies of the Department of Defense.

The complete requirements for procuring the wire described herein shall consist of this document and the issue in effect of Specification MIL-W-81044.

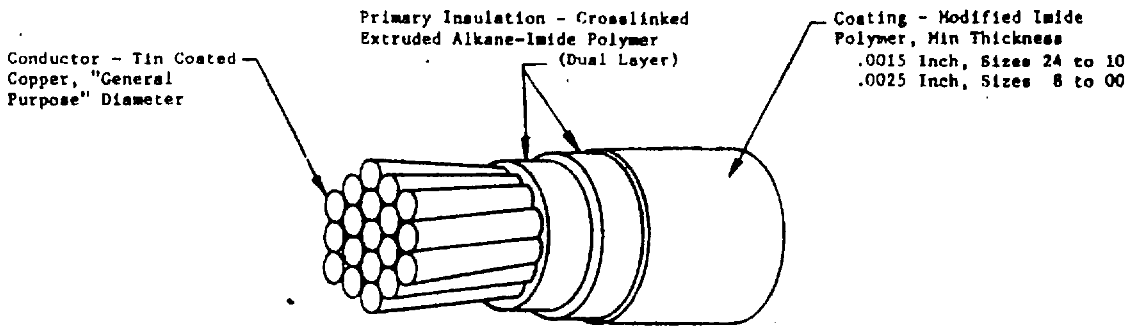

TABLE I. CONSTRUCTION DETAILS

Part No. 1/	Wire size	Stranding (Number of strands X AWG gage of strands)	Diameter of stranded conductor (inches) (B)		Finished wire			
					Resistance at 20°C (68°F) (ohms/1000 ft) (max) (B)	Diameter (inches)	Weight (lbs/1000 ft)	
			(min)	(max)			(nom) 2/	(max)
M81044/16-24-*	24	19 X 36	.023	.026	26.2	.045 ±.002	2.1	2.2
M81044/16-22-*	22	19 X 34	.029	.033	16.2	.051 ±.003	3.0	3.2
M81044/16-20-*	20	19 X 32	.037	.041	9.88	.059 ±.003	4.6	4.7
M81044/16-18-*	18	19 X 30	.046	.051	6.23	.070 ±.003	6.8	7.0
M81044/16-16-*	16	19 X 29	.052	.058	4.81	.078 ±.004	8.7	9.0
M81044/16-14-*	14	19 X 27	.065	.073	3.06	.095 ±.004	13.4	13.7
M81044/16-12-*	12	37 X 28	.084	.090	2.02	.112 ±.004	20.1	20.4
M81044/16-10-*	10	37 X 26	.106	.114	1.26	.136 ±.006	31.3	31.8
M81044/16-8-*	8	133 X 29	.158	.173	.701	.195 ±.008	56.7	58.5
M81044/16-6-*	6	133 X 27	.198	.217	.445	.241 ±.010	88.6	91.0
M81044/16-4-*	4	133 X 25	.250	.274	.280	.301 ±.010	141.	146.
M81044/16-2-*	2	665 X 30	.320	.340	.183	.374 ±.012	224.	231.
M81044/16-0-*	0	1045 X 30	.405	.425	.116	.470 ±.012	354.	365.
M81044/16-00-*	00	1330 X 30	.450	.475	.091	.526 ±.016	460.	483.

1/ PART NO.: The asterisks in the part number column, Tables I and II, shall be replaced by color code designators in accordance with MIL-STD-681. Examples: Size 20, white - M81044/16-20-9; white with orange stripe - M81044/16-20-93.

2/ Nominal values are for information only. Nominal values are not requirements.

(B) denotes changes

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TABLE II. PERFORMANCE DETAILS

Part No.	Abrasion resistance (Procedure II)				Bend testing				
					Mandrel diameter (inches) (+3%)			Test load (lbs) (+3%)	
	Resistance (inches of tape) (min) (initial and after immersion)	Weight support bracket	Weight (lbs)	Tension load (lbs)	Life cycle test and accelerated aging test 1/	Cold bend test	Wrap test 2/	Life cycle test and accelerated aging test 1/	Cold bend test
M81044/16-24-*	30	A	1.0	1.0	.50	1.0	-	1.5	3.0
M81044/16-22-*	30	A	1.0	1.0	.75	1.0	-	2.5	3.0
M81044/16-20-*	35	A	1.0	1.0	.75	1.0	-	4.0	4.0
M81044/16-18-*	35	A	1.0	1.0	1.00	1.5	-	4.0	4.0
M81044/16-16-*	21	B	3.0	2.0	1.00	1.5	-	4.0	5.0
M81044/16-14-*	21	B	3.0	2.0	1.50	2.0	-	4.0	5.0
M81044/16-12-*	21	B	3.0	2.0	2.0	2.0	-	4.0	5.0
M81044/16-10-*	37	C	4.25	2.0	3.0	3.0	-	4.0	5.0
M81044/16-8-*	40	C	4.25	2.0	3.0	4.0	.75	4.0	6.0
M81044/16-6-*	40	C	4.25	2.0	4.0	5.0	1.00	4.0	10.0
M81044/16-4-*	60	C	4.25	2.0	5.0	6.0	1.25	4.0	10.0
M81044/16-2-*	60	C	4.25	2.0	6.0	8.0	3.0	6.0	15.0
M81044/16-0-*	60	C	4.25	2.0	8.0	10.0	4.0	6.0	15.0
M81044/16-00-*	60	C	4.25	2.0	10.0	12.0	6.0	8.0	20.0

1/ Also for bend tests after immersion.

2/ Mandrel wrap test not applicable to sizes 10 and smaller.

WIRE RATINGS AND ADDITIONAL REQUIREMENTS

TEMPERATURE RATING: 150°C (302°F) max continuous conductor temperature
VOLTAGE RATING: 600 volts (rms) at sea level
ACCELERATED AGING: Oven temperature, 250 ±2°C (482 ±3.6°F) for 7 hours (Same exposure for identification legibility)
(B) BLOCKING: 200 ±2°C (392 ±3.6°F)
COLOR: In accordance with MIL-STD-104, Class 1; white preferred
FLAMMABILITY: 30 seconds (max); 3.0 inches (max); no flaming of tissue paper
HUMIDITY RESISTANCE (Insulation resistance after humidity exposure):
Sizes 10 and smaller, 5000 megohms for 1000 ft (min)
Sizes 8 and larger, 2000 megohms for 1000 ft (min)
IDENTIFICATION OF PRODUCT: Not required for size 24
IDENTIFICATION, STRIPING, OR BANDING DURABILITY: 125 cycles (250 strokes) (min), 150 grams weight
(B) IMPULSE DIELECTRIC TEST:
Primary insulation (when test is used in lieu of spark test): 6.0 kilovolts (peak), 100% test
Finished wire: 8.0 kilovolts (peak), 100% test
INSULATION RESISTANCE:
Sizes 10 and smaller, 5000 megohms for 1000 ft (min)
Sizes 8 and larger, 2000 megohms for 1000 ft (min)
LIFE CYCLE: Oven temperature, 200 ±2°C (392 ±3.6°F) for 168 hours
MINIMUM WALL THICKNESS: 8.0 mils
PHYSICAL PROPERTIES OF INSULATION: (Entire insulation pulled at 2 inches per minute)
Tensile strength: 7500 psi (min) for sizes 24 through 10
5000 psi (min) for sizes 8 through 00
Elongation: 50% (min), all sizes
POLYIMIDE CURE TEST: Test required for sizes 10 and smaller
PROPELLANT RESISTANCE: Test not required
SHRINKAGE: 0.125 inch max at 200 ±2°C (392 ±3.6°F)

SMOKE: 250 ±2°C (482 ±3.6°F)
SPARK TEST OF PRIMARY INSULATION: 3000 volts (rms), 60Hz, 100% test
SURFACE RESISTANCE: 500 megohms-inches (min), initial and final readings
THERMAL SHOCK: Oven temperature, 150 ±2°C (302 ±3.6°F)
Max change in measurement: 0.060 inch
WET DIELECTRIC TEST: 2500 volts (rms)
WICKING: No requirement
(B) WRAP TEST:
Sizes 10 and smaller, "wrap back" test required
Sizes 8 and larger, mandrel wrap test required

PATENT NOTICE: Raychem Corporation has granted to the Government an irrevocable royalty-free immunity from suit or other charge of infringement based on the claims including method claims of any patent, domestic or foreign, now held or to be held in the future by Raychem Corporation insofar, but only insofar, as said claims relate to an electric wire having an insulating coating comprising a crosslinked extruded alkane-imide polymer layer and a modified imide polymer layer. This grant to the Government extends to the manufacturers of such electric wire either for the Government or for use in equipment to be delivered to the Government. Such grant is binding on Raychem Corporation, its successors and assigns.

Custodians:
Navy - AS
Army - EL
Air Force - 11

Preparing activity:
Navy - AS
(Project No. 6145-0340-10)

Review activities:
Navy - EC
Army - AT, AV, MI, MU
Air Force - 80
DSA - IS
NSA

User activities:
Navy - MC, OS
Army -
Air Force -

☆U.S. GOVERNMENT PRINTING OFFICE: 1974-713-150/3358

Review/user information is current as of the date of this document. For future coordination of changes to this document, draft circulation should be based on the information in the current Federal Supply Classification Listing of DOD Standardization Documents.

INCH-POUND

MIL-W-81044B
AMENDMENT 3
30 June 1990
SUPERSEDING
AMENDMENT 2
19 June 1980

MILITARY SPECIFICATION

WIRE, ELECTRIC, CROSSLINKED POLYALKENE, CROSSLINKED ALKANE-IMIDE POLYMER, OR POLYARYLENE INSULATED, COPPER OR COPPER ALLOY

This amendment forms a part of Military Specification MIL-W-81044B, dated 31 December 1973, and is approved for use by all Departments and Agencies of the Department of Defense.

PAGE 1

Delete the title and replace it with:

"WIRE, ELECTRICAL, CROSSLINKED POLYALKENE, CROSSLINKED ALKANE-IMIDE POLYMER, OR POLYARLYENE INSULATED, COPPER OR COPPER ALLOY"

Add the following at the bottom of the page:

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commanding Officer, Naval Air Engineering Center (Code 53), Systems Engineering and Standardization Department, Lakehurst, NJ 08733-5100 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

PAGE 2

2.1 Under "SPECIFICATIONS, Military", delete the following documents:

MIL-T-5438	Tester; Abrasion, Electrical Cable
MIL-P-7254	Propellant, Nitric Acid
MIL-P-26536	Propellant, Hydrazine
MIL-P-26539	Propellant, Nitrogen Tetroxide
MIL-P-27402	Propellant, Hydrazine-uns-Dimethylydrazine (50% N_2H_4 -50% UDMH)

AMSC-N/A FSC 6145
DISTRIBUTION STATEMENT A. Approved for public release, distribution is unlimited.

PAGE 2 (continued)

Delete referenced Military Specification:

MIL-D-26937	Detergent Synthetic, Anionic (Alkyl Benzene Sulfonate)

It has been cancelled and has been superseded by the following document:

P-D-410	Type I, Dishwashing Compound, Hand

PAGE 3

Under STANDARDS, Military, add the following document reference:

MIL-STD-202	Test Methods for Electronic and Electrical Component Parts

2.2 Change the document identifiers and issue dates of the referenced ASTM documents in the paragraph and throughout the specification to read as follows:

ANSI/ASTM B 33
ANSI/ASTM B 298
ANSI/ASTM B 355

PAGE 4

3.1 Delete paragraph and substitute the following:

"3.1 Specification sheets. The requirements for the individual wires under this specification shall be as specified herein and in accordance with the applicable specification sheet. In the event of any conflict between the requirements of this specification and those of the specification sheet, the requirements of the specification sheet shall govern except as follows:

a. All specification sheet references to tape abrasion or resistance to propellants shall be considered as cancelled.

b. All specification sheet requirements for blocking shall be at the rated temperature of the wire of that specification sheet (for example: the blocking test temperature of MIL-W-81044/12 shall be 150°C in lieu of 225°C)."

PAGE 9

TABLE II:

Solderability (when applicable)	3.6.10	4.7.5.27

PAGE 10

TABLE II under "EXAMINATION OR TEST," delete "Abrasion resistance, initial;" also the applicable entries under "REQUIREMENT" and under "METHOD."

TABLE II under "REQUIREMENT," opposite "Immersion tests," delete "Meet initial abrasion requirements after immersion."

PAGE 11

TABLE II under "EXAMINATION OR TEST," delete "Propellant resistance (When required in specification sheet);" also, the applicable entries under "REQUIREMENT" and under "METHOD."

3.6.3 (continued from page 8) Delete "Specification sheet part number" as first item of the identification and substitute:

"Specification sheet part number, except that inclusion of the color code portion of the part number is not required. At the option of the supplier, the color code portion of the part number may be included but, if included, it shall be included in full, not in part."

Add after first sentence of 3.6.3:

"The identification mark shall not be applied by hot stamp marking or other methods which significantly penetrate the insulation."

PAGE 12

Add the following paragraph:

"3.6.10 Solderability. Conductors of finished wires that have tin coated copper strands, silver coated copper strands, or silver coated high strength copper alloy strands shall be tested for solderability as specified in 4.7.5.27. The requirement for acceptable solder coverage of the stranded conductor shall be as defined in MIL-STD-202, Method 208. The test is not applicable to finished wires with nickel coated copper strands or nickel coated high strength alloy strands."

PAGE 15

TABLE IV, Group II, add:

Solderability (Tin plated conductors only)	3.6.10	4.7.5.27

PAGE 16

TABLE IV under "EXAMINATION OR TEST," delete "Abrasion resistance, initial;" also the applicable entries under "REQUIREMENT" and under "METHOD."

PAGE 19

TABLE VI:

Solderability (Silver plated conductors)	3.6.10	4.7.5.27

TABLE VI: Under "TEST," delete "Propellant resistance (When required in specification sheet);" also, the applicable entries under "REQUIREMENT" and under "METHOD."

PAGE 27

4.7.5.11 In the fifth sentence, replace "temperature specified" with "rated temperature specified (see 3.1)."

PAGES 28 AND 29

Paragraph 4.7.5.14, line 8: Change "MIL-D-26937" to read "P-D-410."

4.7.5.15 through 4.7.5.15.2 Delete entirely.

PAGE 32

4.7.5.21 Delete the last two sentences of the paragraph.

PAGE 34

4.7.5.25 Delete entirely.

Add the following paragraph:

"4.7.5.27 Solderability. Five specimens shall be prepared by removing the insulation from finished wires. The exposed conductors of these wires shall be tested for solderability using Method 208 of MIL-STD-202. The specimens shall be tested without steam aging using a type RMA flux."

PAGE 37

6.3 Delete the last sentence of the paragraph and substitute the following:

"The activity responsible for the Qualified Products List is the Naval Air Systems Command, Washington, DC 20361; however, application for qualification of products should be made to the Commanding Officer, Naval Avionics Center (Code 444), 6000 East 21st Street, Indianapolis, IN 46219-2189, who has been designated Naval Air Systems Command agent for establishing this Qualified Products List."

Supersession Note: This amendment supersedes and completely replaces Amendment 2 of 19 June 1980, which is cancelled as of the issue date of Amendment 3.

Custodians:
Navy - AS
Army - CR
Air Force - 85

Review activities:
Navy - EC, OS
Army - AR, AT, AV, EA, MI
Air Force - 85
DLA - IS
NSA

User activities:
Navy - MC
Army - ME

Preparing Activity:
Navy - AS
(Project No. 6145-1140)

A-33-09

MIL-W-81044B
31 December 1973
SUPERSEDING
MIL-W-81044A(AS)
22 December 1967

MILITARY SPECIFICATION

* WIRE, ELECTRIC, CROSSLINKED POLYALKENE, CROSSLINKED ALKANE-IMIDE POLYMER, OR POLYARYLENE INSULATED, COPPER OR COPPER ALLOY

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

* 1.1 Scope - This specification covers single conductor electric wires made as specified in the applicable specification sheet with tin-coated, silver-coated, or nickel-coated copper or copper alloy conductors insulated with crosslinked polyalkene, crosslinked alkane-imide polymer, or polyarylene. The crosslinked polyalkene, crosslinked alkane-imide polymer, or polyarylene may be used alone or in combination with other insulation materials as specified in the specification sheet.

1.2 Classification - The wires shall be as described in the applicable military specification sheet.

1.2.1 Part numbers - Part numbers under this specification are coded as in the following example:

M81044/1	-	22	-	9
Applicable specification sheet		Wire size		Insulation color designator or designators

1.2.2 Temperature rating of finished wire - The maximum conductor temperature of the finished wire for continuous use shall be as specified in the applicable military specification sheet (6.1.1).

2. APPLICABLE DOCUMENTS

2.1 Government-furnished documents - The following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein:

FSC 6145

THIS DOCUMENT CONTAINS 38 PAGES.

SPECIFICATIONS

Federal

TT-I-735	Isopropyl Alcohol
UU-T-450	Tissue, Facial

Military

MIL-T-5438	Tester; Abrasion, Electrical Cable
MIL-H-5606	Hydraulic Fluid, Petroleum Base; Aircraft, Missile, and Ordnance
MIL-T-5624	Turbine Fuel, Aviation, Grades JP-4 and JP-5
MIL-P-7254	Propellant, Nitric Acid
MIL-C-12000	Cable, Cord, and Wire, Electric; Packaging of
MIL-L-23699	Lubricating Oil, Aircraft Turbine Engine, Synthetic Base
MIL-P-26536	Propellant, Hydrazine
MIL-P-26539	Propellant, Nitrogen Tetroxide
MIL-D-26937	Detergent, Synthetic, Anionic (Alkyl Benzene Sulfonate)
MIL-P-27402	Propellant, Hydrazine - uns-Dimethylhydrazine (50% N_2H_4 - 50% UDMH)

STANDARDS

Federal

FED-STD-228	Cable and Wire, Insulated; Methods of Testing

Military

MIL-STD-104	Limits for Electrical Insulation Color
MIL-STD-105	Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-109	Quality Assurance Terms and Definitions

STANDARDS (Cont'd)

Military

MIL-STD-129	Marking for Shipment and Storage
MIL-STD-681	Identification Coding and Application of Hookup and Lead Wire

SUPPLEMENT

See Supplement 1 for list of applicable military specification sheets.

PUBLICATIONS

Defense Logistics Services Center

H4-1	Federal Supply Code for Manufacturers Part 1, Name to Code
H4-2	Federal Supply Code for Manufacturers Part 2, Code to Name

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications - The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply:

American Society for Testing and Materials

B33-71	Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes
B298-70a	Standard Specification for Silver-Coated Soft or Annealed Copper Wire
B355-69	Standard Specification for Nickel-Coated Soft or Annealed Copper Wire

(Copies of ASTM publications may be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.)

3. REQUIREMENTS

3.1 Specification sheets - The requirements for the individual wires under this specification shall be as specified herein and in accordance with the applicable military specification sheets. In the event of discrepancy between this specification and the requirements of the applicable military specification sheet, the requirements of the military specification sheet shall govern.

3.2 Classification of requirements - The applicable requirements are classified herein as follows:

Requirement	Paragraph
Qualification	3.3
Materials	3.4
Construction	3.5
Finished Wire	3.6

3.3 Qualification - The wire furnished under this specification shall be a product which is qualified for listing on the applicable qualified products list at the time set for opening of bids (see 4.3 and 6.3). The provisions of 4.6 for retention of qualification are included in this requirement.

3.4 Materials -

3.4.1 Conductor material - All strands used in the manufacture of the conductors shall be tin-coated, silver-coated, or nickel-coated soft annealed copper conforming to ASTM B33-71, B298-70a, or B355-69, as applicable, or shall be silver-coated or nickel-coated high strength copper alloy. Strands shall be free from lumps, kinks, splits, scraped or corroded surfaces and skin impurities. In addition, the strands shall conform to the following requirements as applicable.

3.4.1.1 Tin-coated copper strands - No additional requirements. The tin coating shall be as specified in ASTM B33-71.

3.4.1.2 Silver-coated copper strands - The strands shall have a coating thickness of not less than 40 micro-inches of silver when tested in accordance with ASTM B298-70a.

3.4.1.3 Nickel-coated copper strands - The strands shall have a coating thickness of not less than 50 micro-inches of nickel when tested in accordance with ASTM B355-69. Adhesion of the nickel coating shall be such that, after subjection to the procedures of 4.7.2.1, the strands shall still pass the continuity of coating test in ASTM B355-69.

3.4.1.4 High strength copper alloy - The strands shall be of the applicable AWG gage specified in Table I and of such tensile properties that the conductor from the finished wire conforms to the requirements of 3.5.1.3.2 for elongation and tensile strength. The strands shall be silver-coated or nickel-coated in accordance with 3.4.1.2 or 3.4.1.3 as applicable.

* 3.4.2 Insulating material - All primary insulation shall be crosslinked polyalkene, crosslinked alkane-imide polymer, or polyarylene, as specified in the applicable specification sheet. Insulation coatings or jackets, if present, shall also be of the material specified in the specification sheet. All insulating materials, including primary insulation and coating or jacket, shall be certified virgin material (3.4.2.1) containing no additives except those required as pigmentation for colors, lubricants used in extrusion and stabilizers. The physical properties of the materials shall be such that, when tested in accordance with 4.7.5.7 after extrusion on the finished wire, the insulation will meet the elongation and tensile strength requirements set forth in the specification sheet.

3.4.2.1 Virgin material - For purposes of this specification, virgin material shall be 100 percent new material which has been through only the processes essential to its manufacture and its application to the wire and has been through these essential processes one time only. Any material which has previously been processed in any other manner is considered nonvirgin material. This requirement shall apply to the manufacture of all ingredients and components used.

3.5 Construction - Construction of the wire shall be as specified herein and in the applicable military specification sheet.

3.5.1 Conductor -

3.5.1.1 Stranding -

3.5.1.1.1 Concentric lay stranding - The conductors of wire sizes 30 through 10 shall be concentric-lay conductors constructed as specified in Table I. Concentric lay shall be interpreted to be a central strand surrounded by one or more layers of helically wound strands. It is optional for the direction of lay of the successive layers to be alternately reversed (true concentric lay) or to be in the same direction (unidirectional lay). The strands shall be assembled in a geometric arrangement of concentric layers, so as to produce a smooth and uniform conductor, circular in cross-section and free of any crossovers, high strands, or other irregularities. The direction of lay of the individual strands in the outer layer of the concentrically stranded conductors of finished wire shall be left hand. The length of lay of the outer layer shall not be less than 8 nor more than 16 times the maximum conductor diameter as specified in the applicable military specification sheet.

3.5.1.1.2 Rope lay stranding - The conductors of wire sizes 8 through 0000 shall be rope-lay as specified in Table I and in (a) and (b) below.

(a) Rope-lay stranded conductors shall be laid up concentrically with a central member surrounded by one or more layers of helically wound members. It is optional for the direction of lay of successive layers to be alternately reversed (true concentric lay), or to be in the same direction (unidirectional lay). The length of lay of the outer layer of rope-lay stranded members forming the conductor shall not be less than 10 or more than 14 times the outside diameter of the completed conductor. The direction of lay of the outside layer shall be either left or right hand.

(b) Members of rope-lay stranded conductors: The length of lay of the wires composing the stranded members shall be not greater than 16 times the outside diameter of the member. Stranding of the individual members may be either concentric or bunch.

* 3.5.1.2 Splices - Splices in individual strands or members shall be butt brazed. There shall not be more than one strand-splice in any two lay lengths of a stranded concentric-lay conductor or in any two lay lengths of any member in a rope lay conductor; except that not more than one splice of an entire member shall be permitted in any two lay lengths of a rope lay conductor. Splices in members of a rope lay construction shall be so finished that the conductor diameter is not increased at the point of brazing. In no case shall the whole conductor be spliced at one point.

3.5.1.3 Elongation and tensile strength of conductor -

* 3.5.1.3.1 Soft or annealed copper - The individual strands removed from finished wires with soft or annealed copper conductors, wire sizes 20 and larger, or the whole soft or annealed copper conductor removed from finished wire, sizes 22 and smaller, shall have the following minimum elongation when tested in accordance with 4.7.5.6.1:

Sizes 24 and smaller - 6 percent (minimum)
Sizes 22 and larger - 10 percent (minimum)

There shall be no tensile strength requirements for soft or annealed copper conductors.

* 3.5.1.3.2 High strength copper alloy - The whole conductor removed from finished wires with high strength copper alloy conductors shall exhibit

TABLE I

DETAILS OF CONDUCTORS

Size Designation	Nominal Conductor Area (Cir. Mils) 1/	Stranding (No. of Strands x AWG Gage of Strands)	Allowable No. of Missing Strands (Max)	Nominal Dia of Individual Strands (inch) 1/	Diameter of Stranded Conductor: Min. (inch)	Diameter of Stranded Conductor: Max (Inch), General Purpose, Silver Coated	Max (Inch), General Purpose, Nickel or Tin Coated	Max (Inch), Small Dia (Cu), Silver Coated	Max (Inch), Small Dia (Cu), Nickel or Tin Coated	Max (Inch), Small Dia (Alloy), Silver Coated	Max (Inch), Small Dia (Alloy), Nickel Coated	Maximum Resistance of Finished Wire (Ohms/1,000 Ft. at 20°C): Soft or Annealed Copper, Silver Coated	Soft or Annealed Copper, Nickel Coated	Soft or Annealed Copper, Tin Coated	High Str Cu Alloy, Silver Coated	High Str Cu Alloy, Nickel Coated	Breaking Strength, Alloy Conductor (lbs) (min)
30	112	7 x 38	0	0.0040	0.011	0.012	0.013	0.012	0.013	0.012	0.013	100.7	110.7	108.4	117.4	129.6	5.17
28	175	7 x 36	0	0.0050	0.014	0.015	0.016	0.015	0.016	0.015	0.016	63.8	67.9	68.6	74.4	79.0	8.16
26	304	19 x 38	0	0.0040	0.018	0.020	0.021	0.019	0.020	0.020	0.020	38.4	42.2	41.3	44.8	49.4	14.2
24	475	19 x 36	0	0.0050	0.023	0.025	0.026	0.024	0.024	0.024	0.025	24.3	25.9	26.2	28.4	30.1	22.4
22	754	19 x 34	0	0.0063	0.029	0.032	0.033	0.030	0.031	0.031	0.031	15.1	16.0	16.2	17.5	18.6	35.8
20	1,216	19 x 32	0	0.0080	0.037	0.040	0.041	0.038	0.039	0.039	0.040	9.19	9.77	9.88	10.7	11.4	58.1
18	1,900	19 x 30	0	0.0100	0.046	0.050	0.051	0.048	0.049	-	-	5.79	6.10	6.23			
16	2,426	19 x 29	0	0.0113	0.052	0.057	0.058	0.054	0.055	-	-	4.52	4.76	4.81			
14	3,831	19 x 27	0	0.0142	0.065	0.072	0.073	0.068	0.069	-	-	2.88	3.00	3.06			
12	5,874	37 x 28	0	0.0126	0.084	0.089	0.090	0.087	0.089	-	-	1.90	1.98	2.02			
10	9,354	37 x 26	0	0.0159	0.106	0.112	0.114	0.110	0.112	-	-	1.19	1.24	1.26			
8	16,983	133 x 29	0	0.0113	0.158	0.169	0.173	0.166	0.169	-	-	0.658	0.694	0.701			
6	26,818	133 x 27	0	0.0142	0.198	0.213	0.217	0.208	0.212	-	-	0.418	0.436	0.445			
4	42,615	133 x 25	0	0.0179	0.250	0.268	0.274	0.263	0.268	-	-	0.264	0.275	0.280			
2	66,500	665 x 30	2	0.0100	0.320	0.340	0.340	-	-	-	-	0.170	0.177	0.183			
1	81,700	817 x 30	2	0.0100	0.360	0.380	0.380	-	-	-	-	0.139	0.144	0.149			
0	104,500	1,045 x 30	3	0.0100	0.405	0.425	0.425	-	-	-	-	0.108	0.113	0.116			
00	133,000	1,330 x 30	3	0.0100	0.450	0.475	0.475	-	-	-	-	0.085	0.089	0.091			
000	166,500	1,665 x 30	4	0.0100	0.515	0.540	0.540	-	-	-	-	0.068	0.071	0.071			
0000	210,900	2,109 x 30	5	0.0100	0.580	0.605	0.605	-	-	-	-	0.054	0.056	0.056			

1/ Nominal values are for information only. Nominal values are not requirements.

elongation of 6 percent, minimum, and a tensile breaking strength conforming with Table I, when tested in accordance with 4.7.5.6.2.

* 3.5.1.4 Conductor diameter - The diameter of the conductor shall be as specified in Table I. Applicability of the "general purpose" or of the "small diameter" Table I requirements for maximum conductor diameter shall be as indicated in the military specification sheet.

3.5.2 Insulation - The insulation shall be constructed as specified in the applicable specification sheet. All insulation shall be readily removable by conventional wire stripping devices without damage to the conductor.

* 3.5.3 Flaws test of primary insulation - One hundred percent of the wire shall be inspected for dielectric flaws after application of the primary insulation and prior to the application of any other material to the wire. This inspection shall be made by either the chain electrode spark test of 4.7.4 or the impulse dielectric test of 4.7.5.1, at the option of the supplier, using the test voltages specified for primary insulation in the applicable specification sheet.

3.6 Finished wire - The finished wire shall conform to the requirements of Table II and those of the applicable military specification sheet. The requirements of 3.6.1 through 3.6.9 also apply.

* 3.6.1 Impulse dielectric test - One hundred percent of the finished wire shall pass the impulse dielectric test of 4.7.5.1, which test shall be made during the final winding of the wire on shipment spools or reels.

* 3.6.2 Color - The color of the finished wire shall be as specified in the procurement contract or order in accordance with this paragraph. The preferred colors are as indicated in the individual specification sheets. All solid colors and the colors of all striping or banding shall be in accordance with MIL-STD-104, Class 1. Striping or banding, if used, shall conform to MIL-STD-681, except that the background insulation color and the colors of the stripes or bands shall be as indicated in the part number of the wire and not necessarily in accordance with the preferred colors specified in MIL-STD-681. Striping or banding shall be capable of withstanding the striping durability test of 4.7.5.3 for the number of strokes and with the weight specified in the applicable specification sheet. This test shall not be required if the striping or banding is under a clear jacket.

* 3.6.3 Identification of product - Except as otherwise specified in the procurement contract or in the applicable specification sheet, the finished wire shall be identified by a printed marking applied to the outer surface of the wire or visible through the outer surface. When the wire is to be used in an end item for the Government, omission of the identification of product shall be permissible only when so stated in the specification sheet for the wire or the Government contract for the end item. The

TABLE II

PROPERTIES OF FINISHED WIRE

EXAMINATION OR TEST	REQUIREMENT	METHOD
Conductor stranding	Table I and 3.5.1.1	4.7.1
Conductor diameter	Table I and 3.5.1.4	4.7.1
Finished wire diameter	Specification sheet	4.7.1
* Construction of insulation	Specification sheet	4.7.1
Removability of insulation	3.5.2	4.7.1
* Impulse dielectric test	3.6.1	4.7.5.1
Insulation resistance	Specification sheet	4.7.5.2
Color	3.6.2	4.7.1
Color striping or banding durability	3.6.2	4.7.5.3
Identification of product	3.6.3	4.7.1
Durability of identification	3.6.3.1	4.7.5.3
Finished wire weight	Specification sheet	4.7.5.4
Conductor resistance	Table I	4.7.5.5
Conductor elongation and tensile strength	3.5.1.3	4.7.5.6
Insulation elongation and tensile strength	Specification sheet	4.7.5.7
* Wrap test (as applicable)		
"Wrap back" test	3.6.4.1	4.7.5.8.1
Mandrel wrap test	3.6.4.2	4.7.5.8.2
* Insulation thickness	Specification sheet (also 3.6.5)	4.7.5.9
Concentricity	70 percent (min) (also 3.6.6)	4.7.5.10

TABLE II (Continued)

EXAMINATION OR TEST	REQUIREMENT	METHOD
Blocking	3.6.7	4.7.5.11
Workmanship	3.6.8	4.7.1
Polyimide cure test (Modified imide polymer coated constructions, sizes 10 and smaller)	No cracking	4.7.5.12
Shrinkage	Specification sheet	4.7.5.13
Wicking	Specification sheet	4.7.5.14
Abrasion resistance, initial	Specification sheet	4.7.5.15
Low temperature (cold bend)	No cracking; no dielectric breakdown	4.7.5.16
Thermal shock resistance	Specification sheet	4.7.5.17
Flammability	Specification sheet	4.7.5.18
* Life cycle	No cracking in bend test No dielectric breakdown No pitting of conductor	4.7.5.19.2 4.7.5.19.3 4.7.5.19.1
Accelerated aging	No cracking in bend test No dielectric breakdown No pitting of conductor Product identification shall remain legible	4.7.5.20
Immersion tests	Diameter increase, 5 percent max No cracking on bending No dielectric breakdown Meet initial abrasion requirements after immersion	4.7.5.21

TABLE II (Continued)

EXAMINATION OR TEST	REQUIREMENT	METHOD
Humidity resistance	Specification sheet	4.7.5.22
Surface resistance	Specification sheet	4.7.5.23
Smoke test	Specification sheet	4.7.5.24
Propellant resistance (When required in specification sheet)	No dielectric breakdown	4.7.5.25
* Continuous lengths	3.6.9	4.7.5.26

printed identification shall consist of the following, at intervals of 9 inches to 60 inches, as measured from the beginning of one complete marking to the beginning of the succeeding complete marking.

Specification sheet part number
Manufacturer's code designation in accordance with publications H4-1 and H4-2

The printing shall be green in color in accordance with MIL-STD-104, Class 1, except that when the wire is solid green or any other solid color against which green is difficult to distinguish, the printing shall be white. Identification printing shall be applied with the vertical axes of the printed characters lengthwise of the wire when the nominal diameter of the finished wire is 0.050 inch or smaller. The vertical axes of the printed characters may be either crosswise or lengthwise of the wire when the nominal diameter of the wire exceeds 0.050 inch. All printed characters shall be complete and legible.

3.6.3.1 Durability and resistance to accelerated aging of identification - Identification printing, when applied to the outer surface of the finished wire, shall be capable of withstanding the durability test specified in 4.7.5.3 for the number of cycles and with the weight specified in the applicable specification sheet. This test shall not be required when the identification marking is under a clear jacket. The identification marking shall also be legible after the accelerated aging of 4.7.5.20.

3.6.4 Wrap test -

3.6.4.1 "Wrap back" test - Wire sizes 10 and smaller of this specification with insulation comprising an extruded primary of crosslinked alkane-imide polymer and an insulation coating of modified imide polymer shall show no cracking of the insulation when tested in accordance with 4.7.5.8.1.

* 3.6.4.2 Mandrel wrap test - Wire of this specification with insulation comprising an extruded crosslinked polyalkene primary and an extruded polyvinylidene fluoride jacket or with insulation composed entirely of polyarylene shall show no cracking of insulation and no dielectric breakdown when tested in accordance with 4.7.5.8.2. This requirement shall also be applicable to wire, sizes 8 and larger, with insulation comprising an extruded primary of crosslinked alkane-imide polymer and an insulation coating of modified imide polymer.

* 3.6.5 Insulation thickness - The requirement for thickness of insulation shall apply to the total insulation wall when the specification sheet specifies a value for this characteristic and shall also apply to any part of the total insulation (e.g., primary insulation, insulation coating, or jacket) for which the specification sheet specifies a value.

3.6.6 Concentricity - The concentricity requirement shall apply to both the primary insulation and the finished wire.

* 3.6.7 Blocking - Adjacent turns or layers of the wire shall not stick to one another when tested as specified in 4.7.5.11 at the temperature specified in the applicable specification sheet.

3.6.8 Workmanship - All details of workmanship shall be in accordance with high grade aircraft wire manufacturing practice. The insulation shall be free of cracks, splits, irregularities, and imbedded foreign material.

* 3.6.9 Continuous lengths - Unless otherwise specified in the contract or order, the individual continuous lengths of wire in each inspection lot shall be of such footage that the inspection lot shall conform to Table III when examined in accordance with 4.7.5.26. Unless otherwise specified in the contract or order, the footage of the individual continuous lengths in each spool or reel shall be marked on the spool or reel in the sequence in which the lengths will be unwound by the user.

TABLE III

MINIMUM CONTINUOUS WIRE LENGTHS

WIRE SIZE (RANGE)	REQUIRED MINIMUM PERCENTAGE OF THE TOTAL INSPECTION LOT FOOTAGE IN CONTINUOUS LENGTHS GREATER THAN		
	1000 feet	500 feet	100 feet
30 - 16	50%	80%	100%
14 - 10	30%	50%	100%
8 - 4	-	50%	100%
2 - 0000	-	-	100%

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection - Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure that supplies and services conform to prescribed requirements.

4.2 Classification of inspections - The examinations and tests of wires under this specification shall be divided into the following classifications:

Classification	Paragraph
Qualification inspection	4.3
Quality conformance inspection	4.4
Process control inspection	4.5
Periodic qualification re-evaluation	4.6

4.3 Qualification inspection - Qualification inspection shall consist of all the tests of this specification.

* 4.3.1 Sampling for qualification inspection - Except as provided in 4.3.1.1, a finished wire sample of the required length shall be submitted for each range of wire sizes for which qualification is desired. The sample may be any size wire within the specified size range. Ten linear feet of the coated conductor strand used in the manufacture of the finished wire sample shall be submitted with the finished wire sample.

WIRE SIZE RANGE	REQUIRED LENGTH OF SAMPLE (FEET)
30 through 26	150
24 through 16	150
14 through 10	150
8 through 6	100
4 through 0000	100

* 4.3.1.1 Optional qualification samples - In cases where two or more specification sheets cover wires identical in materials and construction except for conductor (i.e., the specified conductor may be silver coated copper, nickel coated copper, tin coated copper, silver coated alloy, or nickel coated alloy in the different specification sheets), the finished wire sample and conductor strand sample in accordance with 4.3.1 may be submitted for any one of the specification sheets for which

qualification is desired. In addition, 10-foot samples of conductor strand only, applicable to the same wire size range or ranges as the finished wire sample, may be submitted for any of the other specification sheets which differ from the finished sample only in conductor. Approval of the finished wire qualification sample shall also qualify the same wire size range or ranges in each of the other specification sheets for which conductor strand samples have been submitted and approved. (Note: For purposes of determining identity of construction in specification sheets under this provision, small differences in specified finished wire diameter or weight which are obviously due to differences in the specified conductor shall not be considered as constituting differences in construction of the wires.)

4.3.2 Forwarding of qualification samples - Samples and the manufacturer's certified test reports shall be forwarded to the testing laboratory designated in the letter of authorization from the activity responsible for qualification (see 6.3), plainly identified by securely attached, durable tags marked with the following information:

Sample for qualification test
WIRE, ELECTRIC, CROSSLINKED POLYALKENE INSULATED,* COPPER**
Specification sheet part number
Manufacturer's name and code number (Publications H4-1 and H4-2)
Manufacturer's part number
Comprehensive description and prime manufacturer's name and formulation number of the base materials from which the product is made. (This information will not be divulged by the Government.)
Place and date of manufacture of sample
Submitted by (name) (date) for qualification tests in accordance with the requirements of MIL-W-81044B under authorization (reference authorizing letter).

* or "CROSSLINKED ALKANE-IMIDE POLYMER INSULATED" or "POLYARYLENE INSULATED", as applicable
** or "COPPER ALLOY", as applicable

4.4 Quality conformance inspection - Quality conformance inspection shall consist of the examinations and tests listed in Table IV and described under "Test Methods" (4.7). Quality conformance inspection shall be performed on every lot of wire procured under this specification.

TABLE IV

QUALITY CONFORMANCE INSPECTION

EXAMINATION OR TEST	REQUIREMENT	METHOD
Group I Characteristics		
Conductor stranding	Table I and 3.5.1.1	4.7.1
Conductor diameter	Table I and 3.5.1.4	4.7.1
Finished wire diameter	Specification sheet	4.7.1
* Construction of insulation	Specification sheet	4.7.1
Removability of insulation	3.5.2	4.7.1
* Insulation resistance	Specification sheet	4.7.5.2
Color	3.6.2	4.7.1
Color striping or banding durability	3.6.2	4.7.5.3
Identification of product	3.6.3	4.7.1
Durability of identification	3.6.3.1	4.7.5.3
Workmanship	3.6.8	4.7.1
Finished wire weight	Specification sheet	4.7.5.4
Conductor resistance	Table I	4.7.5.5
Conductor elongation and tensile strength	3.5.1.3	4.7.5.6
Insulation elongation and tensile strength	Specification sheet	4.7.5.7
Group II Characteristics		
* Wrap test (as applicable)		
"Wrap back" test	3.6.4.1	4.7.5.8.1
Mandrel wrap test	3.6.4.2	4.7.5.8.2

TABLE IV (Continued)

	EXAMINATION OR TEST	REQUIREMENT	METHOD
	Group II Characteristics (Continued)		
*	Insulation thickness	Specification sheet (also 3.6.5)	4.7.5.9
	Concentricity	70 percent (min) (also 3.6.6)	4.7.5.10
	Polyimide cure test (Modified imide polymer coated constructions, sizes 10 and smaller)	No cracking	4.7.5.12
	Shrinkage	Specification sheet	4.7.5.13
	Wicking	Specification sheet	4.7.5.14
	Abrasion resistance, initial	Specification sheet	4.7.5.15
	Low temperature (cold bend)	No cracking; no dielectric breakdown	4.7.5.16
	Thermal shock resistance	Specification sheet	4.7.5.17
	Flammability	Specification sheet	4.7.5.18
	Accelerated aging	Table II	4.7.5.20
*	Group III Characteristic		
	Impulse dielectric test	3.6.1	4.7.5.1
*	Group IV Characteristic		
	Continuous lengths	3.6.9	4.7.5.26

4.4.1 Sampling for quality conformance inspection - MIL-STD-109 shall apply for definitions of inspection terms used herein. For purposes of this specification, the following shall apply:

* 4.4.1.1 Lot - The inspection lot shall include all wire of one part number subjected to inspection at one time.

4.4.1.2 Unit of product - The unit of product for determining lot size for sampling shall be one continuous length of wire as offered for inspection.

4.4.1.3 Sample unit (Groups I and II tests) - The sample unit for Groups I and II tests, except for the Group I insulation resistance test, shall consist of a single piece of finished wire chosen at random from the inspection lot and of sufficient length to permit all applicable examinations and tests. Unless otherwise specified, the length of the sample unit for Group I tests of Table IV, other than insulation resistance, shall be 20 feet and the length of the sample unit for Group II tests shall be 25 feet. Not more than one sample unit for each group of tests shall be taken from a single unit of product.

* 4.4.1.3.1 Sample unit for insulation resistance test (Group I) - The sample unit for the Group I insulation resistance test shall be a specimen at least 26 feet in length selected at random from finished wire which has passed the Group III impulse dielectric test. It is optional whether the specimen is tested on the reel or removed from the reel for the test, provided the length of the specimen can be determined.

4.4.1.4 Inspection levels and acceptable quality levels (AQL) (Groups I and II tests) - For Group I characteristics, including the insulation resistance test, the inspection level shall be S-2 and the AQL shall be 6.5 percent defective units in accordance with MIL-STD-105. For Group II characteristics, the inspection level shall be S-3 and the AQL shall be 1.5 percent defective units.

* 4.4.1.5 Sampling and acceptance for the Group III (impulse dielectric) test - The sample for the Group III impulse dielectric test shall be 100 percent of the finished wire and every length of the wire shall be subjected fully to the test. Insulation breakdowns resulting from the test and ends or portions not subjected to the test shall be marked or cut out of the finished wire (4.7.5.1.3).

* 4.4.1.6 Sampling and acceptability levels for Group IV (continuous lengths) examination - The inspection level and acceptable quality level for this examination shall be as required for the applicable procedure of 4.7.5.26.

4.4.2 Nonconforming inspection lots - Disposition of inspection lots found unacceptable under initial quality conformance inspection shall be in accordance with MIL-STD-105.

4.5 Process control inspection - This inspection comprises tests and examinations of such a nature that they cannot be performed on the finished wire as submitted for inspection and therefore must be conducted at the most appropriate stage of the manufacturing operations. The process control tests shall consist of the tests listed in Table V. Process control inspection shall be performed on every lot of wire procured under this specification.

4.5.1 Sampling for process control inspection -

4.5.1.1 Conductor material - From each weeks's production of individual coated strands or from every 1000 pounds of such strands, whichever is less, three ten-foot lengths of strand shall be selected in such a manner as to be representative of the material to be used in the finished wire.

* 4.5.1.2 Insulation material - If process control tests of the insulating material are required (4.7.3), three wire lengths, adequate for testing and representative of the insulating material to be used in each lot of wire, shall be selected after extrusion of the insulation on the wire.

TABLE V

PROCESS CONTROL INSPECTION

EXAMINATION OR TEST	REQUIREMENT	METHOD
Conductor material 1/	3.4.1	4.7.2
Insulating material	3.4.2	4.7.3, 4.7.5.7
Conductor splices	3.5.1.2	4.7.1
Flaws test of primary insulation (as applicable)		
Spark test	3.5.3	4.7.4
Impulse dielectric test	3.5.3	4.7.5.1

1/ Except adhesion of nickel coating. See Table VI.

4.5.1.3 Conductor splices - The manufacturer's method of splicing individual strands and entire members shall be observed at the discretion of the Government representative.

* 4.5.1.4 Flaws test of primary insulation - The sample for this test (3.5.3) shall be one hundred percent of the wire after application of the primary insulation and prior to the application of any other material. One hundred percent of the wire shall be subjected to either the spark test or the dielectric impulse test at this stage in production. Portions showing dielectric breakdown shall be cut out or removed and testing of the balance of production shall be resumed.

4.5.2 Rejection and retest in process control inspection - When a sample selected from a production run fails to meet the specified tests (except flaws test of primary insulation, see 4.5.1.4), no items still on hand or later produced shall be accepted until the extent and cause of the failure have been determined. After investigation, the contractor shall advise the Government of the action taken and, after corrections have been made, shall repeat all the process control tests. Rejection after corrective action will require that the contractor advise the procuring activity of the details surrounding the retest and cause for rejection. Nonconformities of primary insulation in the flaws test shall be handled as provided in 4.5.1.4.

4.5.2.1 Effect of process control failure on quality conformance testing - Quality conformance testing may be continued during the investigation of the failure of a process control sample, but final acceptance of the material shall not be made until it is determined that the lot meets all the process control requirements and quality conformance requirements of the specification.

4.6 Retention of qualification - Periodic qualification re-evaluations shall be made at two-year intervals after the date of the letter of notification of the product's acceptability for qualification. Materials from current production shall be evaluated against the requirements of Table VI in addition to the quality conformance requirements and process control requirements of Table IV and Table V.

TABLE VI

TESTS APPLICABLE ONLY TO QUALIFICATION INSPECTION AND QUALIFICATION RE-EVALUATION

TEST	REQUIREMENT	METHOD
Adhesion of nickel coating	3.4.1.3	4.7.2.1
Blocking	3.6.7	4.7.5.11
Life cycle	Table II	4.7.5.19
Immersion tests	Table II	4.7.5.21
Humidity resistance	Specification sheet	4.7.5.22
Surface resistance	Specification sheet	4.7.5.23
Smoke test	Specification sheet	4.7.5.24
Propellant resistance (When required in specification sheet)	No dielectric breakdown	4.7.5.25

4.6.1 Re-evaluation procedure - It shall be the responsibility of the qualified supplier to furnish to the Government, at two-year intervals, the data necessary to establish the continued conformity of the product to all qualification requirements. These data should preferably be complete test results of a sample representative of current production, tested against all the requirements of the specification. At the discretion of the qualifying activity, test records from current production may be accepted for the re-evaluation to the extent they are available and samples from current production need be subjected to only the tests for which no production test records are available. The qualifying activity shall be notified of the test results. If a failure occurs, no wire represented by the sample nor any other wire manufactured with the same materials and processes, which has not already been submitted for quality conformance inspection, shall be offered for acceptance until the cause for failure has been determined and concurred in by the qualifying activity as not affecting the ability of the wire to pass qualification inspection requirements. In the event the date for re-evaluation has passed and no current production materials or data are available for re-evaluation, the supplier shall still be eligible for contract award, but final acceptance of material from such a supplier is contingent upon his material meeting all the qualifying requirements of the specification.

4.7 Test methods -

4.7.1 Examination of product - All samples shall be examined carefully to determine conformance to this specification and to the applicable specification sheets with regard to requirements not covered by specific test methods.

4.7.2 Conductor material - Conductor strands, prior to use in the conductor, shall be tested for conformity to ASTM Standards B33-71, B298-70a, or B355-69, as applicable. Thickness of silver or nickel coating shall also be determined by the methods of ASTM Standards B298-70a and B355-69.

4.7.2.1 Adhesion of nickel coating - Two 6-inch specimens shall be cut from the sample of nickel-coated strand. One specimen shall be wrapped over its own diameter for eight close turns. The second specimen shall remain in its straight form. Both specimens shall then be subjected to ten continuous cycles of temperature change. Each cycle of temperature change shall consist of 4 hours at 250 ± 3°C (482 ± 5.4°F) followed by 4 hours at room temperature. Upon completion of the thermal cycling, the straight specimen shall be wrapped over its own diameter for eight close turns in a manner identical to that of the first specimen. Both wrapped specimens shall then be tested for continuity of coating in accordance with the procedure given in ASTM Standard B355-69.

* 4.7.3 Insulation material - Unless otherwise specified in the procurement contract or order (6.2), certification of conformity by the wire supplier shall be acceptable in lieu of process control tests of the insulation material. Such certification, however, shall not relieve the supplier's product from the necessity of passing all tests required of the finished wire including those relative to insulation. If the contract or order requires process control tests of the insulation material, samples selected in accordance with 4.5.1.2 shall be tested as specified in 4.7.5.7.

4.7.4 Spark test of primary insulation (when applicable, 3.5.3) - The wire, after application of the primary insulation and prior to the application of any other material, shall be passed through a chain electrode spark test device using the voltage and frequency specified in the applicable specification sheet. The electrode shall be of a suitable bead chain or fine mesh construction that will give intimate metallic contact with practically all the wire insulation surface. Electrode length and speed of wire movement shall be such that the insulation is subjected to the test voltage for a minimum of 0.2 second. Any portion showing insulation breakdown shall be cut out of the wire including at least 2 inches of wire on each side of the failure.

4.7.5 Finished wire - Methods of test of the finished wire (and of unfinished wire also, when so specified) shall be as follows:

* 4.7.5.1 Impulse dielectric test -

4.7.5.1.1 Test equipment - The electrode head through which the wire is passed in the impulse dielectric test shall be of a suitable bead chain construction such that the electrode will give intimate metallic contact with practically all of the wire insulation surface. The characteristics of the test impulse and of the equipment auxiliary to the electrode head shall be as follows:

(a) Test impulse - The wave form of the voltage supplied to the electrode head shall consist of a negative pulse, the peak magnitude of which shall be as specified in the applicable specification sheet, followed by a damped oscillation. The rise time of the negative impulse wave front from zero magnitude to 90 percent of the specified peak voltage shall be not more than 75 microseconds. The peak value of the first positive overshoot and each of the subsequent damped oscillations shall be smaller than the initial negative pulse. The time during which each pulse and accompanying damped oscillation (positive and negative) remains at an absolute potential of 80 percent or greater of the specified peak voltage shall be 20 to 100 microseconds. The pulse repetition rate shall be 200 to 250 pulses per second, inclusive. Except for the final peak voltage adjustment (4.7.5.1.3), conformity to these test impulse parameters shall be determined with no capacitive load impressed upon the electrode.

(b) Capacitive tolerance - The tolerance of the equipment to change in capacitive load shall be such that the peak output voltage shall not be reduced by more than 12 percent in the event of an increase of capacitive load, between electrode and ground, from an initial load of 12.5 picofarads per inch to 25 picofarads per inch of electrode length.

(c) Instrument voltmeter - Connected to the electrode head, there shall be a peak reading voltmeter indicating continually the potential of the electrode. The voltmeter shall show full deflection at a potential not exceeding 15 kilovolts and shall have a minimum accuracy of ± 4 percent at the specified test impulse potential.

(d) Failure detection circuit. There shall be a failure detection circuit to give a visible or audible indication of insulation failure, automatically deenergize the electrode head, and stop progress of the wire through the electrode. The detecting circuit shall be sufficiently sensitive to indicate a fault at 75 percent of the specified test voltage when the electrode is arced to ground through a 20 kilohm resistor and shall be capable of detecting a fault which lasts for the duration of only one impulse.

4.7.5.1.2 Calibration of equipment - The instrument voltmeter shall be calibrated by comparison with an external standard voltmeter capable of detecting the peak potential at the electrode head with or without auxiliary circuitry. In performing the calibration, the standard voltmeter shall be connected to one of the electrode beads directly or through a calibrated attenuator circuit. The impulse generator shall be energized and the voltage control of the impulse generator shall be adjusted until the reading on the standard voltmeter is the specified potential, at which point the reading on the instrument voltmeter shall be observed and recorded. This calibration shall be repeated for each peak potential at which it is intended to operate the equipment. An alternative procedure is by means of a calibrated oscilloscope connected to the bead electrode through a suitable attenuator. The peak magnitude of the negative pulse can then be read directly from the waveform display. An oscilloscope connected to the electrode head at suitable test points shall also be used to verify conformance to the other waveform parameters specified in 4.7.5.1.1(a).

4.7.5.1.3 Test procedure - The finished wire or unfinished wire (3.5.3), as applicable, shall be threaded through the electrode head and the conductor shall be grounded at one or both ends. The electrode shall be energized to the specified peak potential and, after final adjustment of the voltage with wire in the electrode head, the wire shall be passed from the pay-off spool through the electrode and onto the take-up spool. The speed of passage of the wire through the electrode shall be such that the wire is subjected to not less than 3 nor more than 100 pulses at any given point. Any dielectric failures which occur shall be cut out or marked for later removal along with at least 2 inches of wire on each side of the failure. During all parts of the test, including string-up of new lengths, every effort shall be made to test the entire length, including ends of the wire, in accordance with this procedure. All ends or other portions of the wire not so tested shall be removed subsequent to the test. When specified in contract or order (6.2), in tests of finished wire, the dielectric failures, untested portions of wire, or portions which have been exposed to fewer or more than the specified number of pulses may be marked by stripping the insulation or by other suitable method of marking as specified in the contract in lieu of being cut out of the wire.

4.7.5.2 Insulation resistance - The ends of a wire specimen at least 26 feet in length shall be connected electrically to a DC terminal. The specimen shall be immersed in a water bath, at 25 $\pm$5°C (77 $\pm$9°F), containing 0.5 to 1.0 percent of an anionic wetting agent, except that the electrical contacts and approximately six inches of insulated wire at each end of the specimen shall protrude above the surface of the water. After 4 hours minimum of immersion, the specimen shall be subjected to a potential of 250 to 500 volts applied between the conductor and the water bath, which serves as the second electrode. The insulation resistance of the specimen shall be determined after one minute of electrification at this potential and shall be calculated to megohms for 1000 feet as follows:

$$\text{Megohms for 1000 feet} = \frac{\text{Specimen resistance (megohms) x immersed length (feet)}}{1000}$$

4.7.5.3 Durability of color markings - The durability of product identification or color markings applied to the wire for coding shall be evaluated at 20 to 25°C (68 to 77°F) as follows:

4.7.5.3.1 Durability testing apparatus - The markings durability tester shall be designed to hold a short specimen of finished wire firmly clamped in a horizontal position with the upper longitudinal surface of the specimen fully exposed. The instrument shall be capable of rubbing a small cylindrical steel mandrel (usually a needle), 0.025 inch in diameter, repeatedly over the upper surface of the wire, in such position that the longitudinal axes of the mandrel and the specimen are at right angles to each other with cylindrical surfaces in contact. A weight affixed to a jig above the mandrel shall control the thrust exerted normal to the surface of the insulation. A motor driven, reciprocating cam mechanism and counter shall be used to deliver an accurate number of abrading strokes in a direction parallel to the axis of the specimen. The length of the stroke shall be 3/8 inch and the frequency shall be 120 strokes (60 stroking cycles) per minute.

4.7.5.3.2 Durability testing procedure - In performing the test, a specimen of wire shall be mounted in the specimen clamp and the weight specified in the applicable specification sheet shall be applied through the abrading mandrel to the marked surface. The counter shall be set at zero and the drive motor started. The specimen shall be observed throughout the progress of the test and, as soon as the mandrel has developed a continuous line of erasure or obliteration through all applicable markings contacted in its strokes, the number of abrading cycles shall be recorded. Three specimens from each sample unit shall be tested and the results averaged.

4.7.5.4 Wire weight - The weight of each lot of finished wire shall be determined by Procedure I (4.7.5.4.1). Lots failing to meet the wire weight requirement of the applicable specification sheet when tested in accordance with Procedure I shall be subjected to Procedure II (4.7.5.4.2). All reels or spools failing to meet the requirements of the specification sheet when tested by Procedure II shall be rejected. The sampling plans of 4.4.1 are not applicable in Procedure II.

4.7.5.4.1 Procedure I - The length and weight of a specimen at least 10 feet long shall be accurately measured and the resultant measurements converted to pounds per 1000 feet.

4.7.5.4.2 Procedure II - The net weight of the finished wire on each reel or spool shall be obtained by subtracting the tare weight of the reel or spool from the gross weight of the reel or spool containing the finished wire. The net weight of wire on each reel or spool shall be divided by the accurately determined length of finished wire on that reel or spool and the resultant figure shall be converted to pounds per 1000 feet. When wood or other moisture absorbent materials are used for reel or spool construction, tare weight and gross weight shall be determined under substantially the same conditions of relative humidity.

* 4.7.5.5 Conductor resistance - The DC resistance of the conductor shall be measured in accordance with Method 6021 of FED-STD-228 except that the wire shall be tested dry without immersion.

4.7.5.6 Conductor elongation and tensile strength -

* 4.7.5.6.1 Soft or annealed copper - Elongation tests of soft or annealed copper conductors shall be performed in accordance with Method 3211 of FED-STD-228. For wire sizes 20 and larger, the tests shall be performed upon individual strands taken from the conductor of the finished wire. For sizes 22 and smaller, the tests shall be performed upon the whole conductor removed from the finished wire and the elongation shall be measured when the first strand of the conductor breaks. For wire sizes 20

and larger, only the values obtained with individual strands shall be considered and, for wire sizes 22 and smaller, only the values obtained with the whole conductor shall be considered, in determining the conformance of soft or annealed copper conductors to elongation requirements of this specification.

* 4.7.5.6.2 High strength copper alloy - Elongation and tensile strength tests of high strength alloy conductors shall be performed in accordance with Method 3211 of FED-STD-228, except that the rate of travel of the power-actuated grip shall be 2 ±1/2 inches per minute and that the tensile strength shall be reported as the tensile breaking strength of the conductor rather than in pounds per square inch. The tests shall be performed upon the whole conductor removed from the finished wire. Conductor elongation shall be measured when the first strand of the conductor breaks, and the total tensile force indicated by the testing machine at break of that strand shall be regarded as the breaking strength of the conductor. Only the values thus obtained with the whole conductor shall be considered in determining the conformity of high strength alloy conductors to the elongation and tensile strength requirements of this specification.

* 4.7.5.7 Insulation elongation and tensile strength - When the specification sheet specifies test of the primary insulation alone, specimens of the finished wire shall have the jacket or coating, if present, carefully removed from the primary insulation. When the specification sheet specifies test of the entire insulation, there shall be no removal of jacket or coating from the specimens. The primary insulation or entire insulation, as applicable, shall then be carefully removed from the conductor and tested for elongation and tensile strength by Methods 3031 and 3021, respectively, of FED-STD-228, utilizing one inch bench marks and one inch initial jaw separation. The rate of travel of the power-actuated jaw of the test instrument shall be in accordance with the applicable method of FED-STD-228 unless otherwise specified in the specification sheet.

4.7.5.8 Wrap test -

4.7.5.8.1 "Wrap back" test (see 3.6.4.1 for applicability) - A 12-inch specimen of finished wire shall be bent back on itself at the mid-portion, on a radius not less than the radius of the wire, and one end of the specimen shall be wound tightly around the other end as a mandrel for a total of four close turns. The specimen shall then be examined visually, without the aid of magnification, for cracks.

4.7.5.8.2 Mandrel wrap test (see 3.6.4.2 for applicability) - A specimen of finished wire, with a length of 12 inches plus the additional length required for winding on the mandrel, shall be wound tightly for two close turns around a mandrel of the diameter specified in the applicable specification sheet. The winding may be accomplished manually and shall be in the middle portion of the specimen so that 6 inches of each end shall remain straight. The specimen shall then be removed from the mandrel, examined for cracks visually without aid of magnification, and subjected to the dielectric test of 4.7.5.19.3.

* 4.7.5.9 Insulation thickness - All insulation thickness measurements shall be made on cross sections of the wire at suitable magnification. A wall thickness of the primary insulation or of the finished wire shall be the shortest distance, at the point of measurement, between the outer rim of the primary insulation or finished wire, as applicable, and the outer rim of the outermost strand of the conductor. For the coating or jacket, the thickness shall be the shortest distance, at the point of measurement, between the inner and outer surfaces of the coating or jacket. When a minimum thickness is specified in the specification sheet, the specimen shall be considered as meeting the requirement, if the smallest thickness measurement present in the cross section equals or exceeds the specified minimum. If a thickness range is specified in the specification sheet, the specimen shall be considered as meeting the requirement if both the smallest individual thickness measurement and the largest individual thickness measurement present in the cross section fall within the specified thickness range.

4.7.5.10 Concentricity - The concentricity of the primary insulation and of the finished wire shall be determined in accordance with the procedures of 4.7.5.10.1 and 4.7.5.10.2 as applicable. All wall thickness measurements shall be made on cross sections of the wire under suitable magnification. A wall thickness shall be the shortest distance between the outer rim of the primary insulation or finished wire, as applicable, and the outer rim of the outermost strand of the conductor.

4.7.5.10.1 Concentric-lay wires - The concentricity of the primary insulation or of the finished wire shall be determined by first locating and recording the minimum wall thickness measured on a cross section of the primary insulation or finished wire. The maximum wall thickness of this same cross section of the primary insulation or finished wire shall also be located and recorded. For concentric-lay wires, 100 times the ratio of the minimum wall thickness to the maximum wall thickness shall define the percent concentricity.

4.7.5.10.2 Rope-lay wires - The concentricity of the primary insulation or of the finished wire shall be determined by first locating and recording the minimum wall thickness measured on a cross section of the primary insulation or of the finished wire. From this point on the outer rim of the primary insulation or finished wire at which the minimum wall thickness was measured, three more reference points 90 degrees apart on the outside rim of the primary insulation or finished wire shall be established. At each of these three reference points the nearest member of the rope-lay conductor shall be selected and the minimum wall thickness between that member and the outer rim of the primary insulation or finished wire shall be measured. The average of the four readings shall be considered to be the average wall thickness. For rope-lay wires, 100 times the ratio of the minimum wall thickness to the average wall thickness shall define the percent concentricity.

4.7.5.11 Blocking - One end of a piece of finished wire, of sufficient length to perform the test, shall be affixed to a metal spool of the barrel diameter specified for the applicable wire size in Table VII. The wire shall then be wound helically on the spool for at least three turns, with the succeeding turns in close contact with one another. The tension for winding shall be equal to the test load specified for the cold bend test of the same size wire in the applicable specification sheet. The winding shall be continued until there are at least three closely-wound layers of such helical turns on the spool. The free end of the wire shall then be affixed to the spool or shall continue to be weighted with the winding tension load so as to prevent unwinding or loosening of the turns or layers and the spool and wire shall be placed for 24 hours in an air oven at the temperature specified on the applicable specification sheet. At the end of the 24-hour period, the spool and wire shall be removed from the oven and allowed to cool to room temperature. After cooling, the wire shall be unwound manually, meanwhile being examined for evidence of adhesion (blocking) of adjacent turns or layers.

4.7.5.12 Polyimide cure test - Two hundred milliliters of distilled water together with a few boiling chips or beads shall be placed in a 1 liter Erlenmeyer flask and the flask shall be closed by a rubber stopper fitted with a water cooled reflux condenser. The flask shall be heated by hot plate or heating mantle until the water is boiling and condensate is returning from the reflux condenser. One end of an approximately 12 inch length of the wire to be tested shall be inserted into the flask by passing it between the rubber stopper and the side of the flask or through a snugly fitting hole in the stopper, so that 5 inches of the wire length extends into the vapor phase inside the flask. The portion of the wire inside the flask shall be essentially straight and shall not be in contact with the glass sides of the flask or condenser, the layer of liquid water in the bottom of the flask, or the liquid condensate returning from the condenser. Heating of the flask shall be resumed, with stopper and reflux condenser again in place. The portion of wire inside the flask shall be exposed to the vapor phase above the boiling water for 1 hour ±5 minutes and shall then be removed from the flask. A 4 inch specimen shall be cut from the vapor-exposed portion of the wire, avoiding the one inch which was nearest the rubber stopper during vapor exposure. The 4 inch specimen shall be allowed to cool at room temperature for a minimum of fifteen minutes, after which it shall be wrapped in a tight spiral for six turns or the full length of the specimen, whichever is lesser, around a mandrel which for wire sizes 18 and smaller shall be the specified maximum diameter of the wire and for wire sizes 16 and larger shall be three times the specified maximum diameter of the wire. The specimen shall then be inspected visually for cracks without the aid of magnification.

* 4.7.5.13 Shrinkage - A 12-inch specimen of the finished wire shall be cut so that the insulation and conductor are flush at both ends. The specimen shall be placed in an air-circulating oven and maintained for a period of 6 hours at the temperature specified in the applicable specification

sheet. The velocity of air past the specimen location in the oven shall be between 100 and 200 feet per minute as determined at room temperature. At the end of the 6-hour period, the specimen shall be removed from the oven and allowed to return to room temperature. Shrinkage of the insulation shall be measured as the greatest distance which any layer of the insulation, including jacket if present, has receded from either end of the conductor; that is, the measurement obtained at the end showing the greater shrinkage shall be considered the shrinkage of the specimen.

* 4.7.5.14 Wicking - A specimen of each finished wire size to be tested shall be cut 6 ± 1/16 inches with square ends. The specimen shall be vertically immersed for two inches of its length in a fluorescent dye solution contained in an open test tube and shall be conditioned thus for 24 hours at room temperature in a draft-free room. The fluorescent dye solution shall be prepared by dissolving 0.02 gram of Rhodamine B dye in 30 mls of ethyl alcohol and diluting with 2 liters of distilled water containing 3 mls of an anionic wetting agent, Specification MIL-D-26937. After this conditioning, the specimen shall be removed from the fluorescent dye solution and excess solution on the surface shall be removed immediately from the two inches immersed by wiping gently with a clean, dry, lint-free cloth. The jacket shall be removed from the specimen and the outside of the primary insulation and the inside of the jacket shall be examined under ultraviolet illumination for evidence of fluorescent dye. The distance that the dye has traveled, between jacket and primary insulation, from the end of the specimen shall be recorded as the distance of wicking.

4.7.5.15 Abrasion - Abrasion resistance shall be determined by Procedure I or II as specified in the applicable specification sheet.

4.7.5.15.1 Procedure I - The test shall be conducted on an abrasion testing machine conforming to MIL-T-5438, except that the machine shall be modified or supplemented by a device to determine the lengthwise tension of the wire specimen when it is being clamped into the machine. The abrasive tape shall be as specified in MIL-T-5438. The insulation of the wire sample shall be free of surface contaminants such as oil or moisture and, for referee tests, atmospheric conditions shall be standard as defined in FED-STD-228. In making the test, an inch of the insulation shall be removed from one end of a 30-inch specimen of the finished wire and this end shall be connected to the detection circuit of the tester. The specimen shall be clamped into the tester, using the lengthwise tensile load, the weight support bracket and the vertical weight specified in the applicable specification sheet. The specimen shall then be abraded. At the start of each measurement the center of a conducting stripe shall be at the point of contact with the wire. The reading of each measurement shall be the length of abrasion tape in inches to come in contact with the wire insulation to the point where the machine stops. After each reading, the specimen shall be moved forward 2 inches and rotated clockwise 90 degrees. Eight readings shall be obtained for each specimen. An average shall be obtained by calculating the arithmetic mean of all the readings which are individually less than the arithmetic mean of all the eight readings per specimen. This average shall define the abrasion resistance of the specimen under test.

4.7.5.15.2 Procedure II - The test method shall be in accordance with Procedure I, except that the abradant of the abrasive cloth tape shall be aluminum oxide, grit 400, and the detection cross stripes of conductive silver paint on the tape shall be 1/4 inch wide, spaced 3 inches apart, center to center.

4.7.5.16 Low temperature (cold bend) - One end of a wire specimen 36 inches in length shall be secured to a rotatable mandrel in a cold chamber and the other end to the load weight specified in the applicable specification sheet. The diameter of the mandrel shall be as specified in the specification sheet. Provision shall be made for rotating the mandrel by means of a handle or control located outside the chamber. The specimen of wire and the mandrel shall be conditioned for 4 hours at a temperature of -65 ±2°C (-85 ±3.6°F). At the end of this period and while both mandrel and specimen are still at this low temperature, the specimen shall be wrapped helically, for its entire length or for 20 turns whichever is the lesser number of turns, around the mandrel without opening the chamber. The bending shall be accomplished at a uniform rate of 2 ±1 RPM. At the completion of this test the specimen shall be removed from the cold box and from the mandrel without straightening. The specimen shall be examined for cracks in the insulation. The insulation shall then be removed for a distance of 1 inch from each end of the specimen and the specimen shall be subjected to the dielectric test specified in 4.7.5.19.3 with the bent portion submerged.

4.7.5.17 Thermal shock resistance -

4.7.5.17.1 Preparation of specimen - A specimen of wire, five feet long shall be prepared by carefully removing 1 inch of insulation from each end of the wire. (For purposes of this test, insulation is defined as all layers of non-conducting material covering the electrical conductor, e.g., primary insulation, all tapes and braids, and the jacket.) A razor blade or equivalent, held perpendicular to the axis of the wire, shall be used to cut the insulation for the removal operation. The length of exposed conductor at each end of the specimen shall be measured to the nearest 0.01 inch. The specimen shall be formed into a loose coil not less than 1 foot in diameter and shall be laid on a wire screen for handling throughout the test.

4.7.5.17.2 Test procedure - The specimen shall be placed for 30 minutes in a preheated air circulating oven at the temperature specified in the applicable specification sheet. The specimen shall then be removed from the oven and, within two minutes, placed in a chamber which has been precooled to -55 ±2°C (-67 ±3.6°F). It shall be exposed to this temperature for 30 minutes, after which it shall be removed and allowed a minimum of 30 minutes to return to room temperature, 20 to 25°C (68 to 77°F). At the conclusion of this cycle, the distance from the end of each layer of insulation to the end of the conductor shall be measured to the nearest 0.01 inch. This thermal shock cycle and the measurements shall be repeated for an additional three cycles (a total of four cycles). Any measurement varying from the original measurement by more than the amount specified in the applicable specification sheet shall constitute failure. Any flaring of any layer shall also constitute failure.

4.7.5.18 Flammability -

4.7.5.18.1 Apparatus - The test shall be performed within a test chamber approximately one foot square by two feet in height, open at top and front to provide adequate ventilation for combustion but to prevent drafts. The specimen holder shall be so designed that the lower end of a 24-inch wire specimen is held by a clamp, while the upper end of the specimen passes over a pulley and can be suitably weighted to hold the specimen taut at an angle of 60 degrees with the horizontal, in a plane parallel to and approximately 6 inches from the back of the chamber. The test flame shall originate from a Bunsen type gas burner with a 1/4 inch inlet, a needle valve in the base for gas adjustment, a bore of 3/8 inch nominal, and a barrel length of approximately 4 inches above the air inlets. The burner shall be adjusted to furnish a 3 inch conical flame with an inner cone approximately 1 inch in length and a flame temperature not less than 954°C (1749°F) at its hottest point, as measured with an accurate thermocouple pyrometer. A sheet of facial tissue conforming to UU-T-450 shall be suspended taut and horizontal 9-1/2 inches below the point of application of the flame to the wire specimen and at least 1/2 inch from the chamber floor, so that any material dripping from the wire specimen shall fall upon the tissue.

4.7.5.18.2 Procedure - A 24-inch specimen of wire shall be marked at a distance of 8 inches from its lower end to indicate the point for flame application and shall be placed in the specified 60 degree position in the test chamber. The lower end of the specimen shall be clamped in position in the specimen holder and the upper end shall be passed over the pulley of the holder and weighted with the weight specified for life cycle test of the same wire in the applicable specification sheet. With the burner held perpendicular to the specimen and at an angle of 30 degrees from the vertical plane of the specimen, the hottest portion of the flame shall be applied to the lower side of the wire at the test mark. The period of test flame application shall be 30 seconds for all sizes of wire and the test flame shall be withdrawn immediately at the end of that period. The distance of flame travel upward along the specimen from the test mark and the time of burning after removal of the test flame shall be recorded; also the presence or absence of flame in the facial tissue due to incendiary drip from the specimen. Charred holes or charred spots in the tissue shall be ignored in the absence of actual flame. Breaking of the wire specimens in sizes 24 and smaller shall not be considered as failure provided the requirements for flame travel limits, duration of flame, and absence of incendiary dripping are met.

4.7.5.19 Life cycle -

4.7.5.19.1 Air oven - One inch of the insulation shall be removed from each end of a 24-inch specimen of the finished wire. The central portion of the specimen shall then be bent over a horizontally positioned smooth stainless steel mandrel of the diameter specified in the applicable specification sheet. To prevent sticking of the wire to the mandrel, the mandrel may be coated with polytetrafluoroethylene in the form of either enamel or wrapped tape, provided that the diameter of the mandrel after coating is still in conformity with the specification sheet. Each end of the conductor shall be weighted with the test load specified in the specification sheet, so that the portion of the insulation between the conductor and mandrel is under compression and the conductor is under tension. This specimen so prepared on the mandrel shall be placed in an air-circulating oven and maintained for the period of time and at the temperature specified in the specification sheet. The velocity of air past the specimen location in the oven shall be between 100 and 200 feet per minute as determined at room temperature. After completion of the air oven exposure, the specimen shall be allowed to cool to between 20 and 25°C (68 to 77°F). When cooled, the wire shall be freed from tension, removed from the mandrel, and straightened. The specimen shall then be subjected to the bend test (4.7.5.19.2), followed by dielectric test (4.7.5.19.3). After the dielectric test, the insulation shall be removed from the specimen and the conductor shall be examined for pitting. Darkening of a tin coating caused by normal air oxidation shall not be cause for rejection.

4.7.5.19.2 Bend test - In a temperature maintained between 20 and 25°C (68 to 77°F), one end of the specimen shall be secured to the mandrel and the other end to the load weight specified in the applicable specification sheet. The mandrel shall be rotated until the full length of the specimen is wrapped around the mandrel and is under the specified tension with adjoining coils in contact. The mandrel shall then be rotated in reverse direction until the full length of the wire which was outside during the first wrapping is now next to the mandrel. This procedure shall be repeated until two bends in each direction have been formed in the same section of the wire. The outer surface of the wire shall then be observed for cracking of the insulation.

4.7.5.19.3 Wet dielectric test - The uninsulated ends of the specimen shall be attached to an electric lead. The specimen shall be immersed in a 5 percent, by weight, solution of sodium chloride in water at 20 to 25°C (68 to 77°F), except that the uninsulated ends and 1-1/2 inches of insulated wire at each end of the specimen shall protrude above the surface of the solution. After immersion for 5 hours, the voltage specified in the applicable specification sheet at 60 hertz (cycles per second) shall be applied between the conductor and an electrode in contact with the liquid.

The voltage shall be gradually increased at a uniform rate from zero to the specified voltage in 1/2 minute, maintained at that voltage for a period of 5 minutes, and gradually reduced to zero in 1/2 minute.

4.7.5.20 Accelerated aging - The specimen, apparatus and procedure for this test shall be exactly as specified for the life cycle test in 4.7.5.19 through 4.7.5.19.3, except that the temperature and duration of the oven exposure shall be as specified for accelerated aging in the applicable specification sheet. Also, unless the specification sheet specifies a separate accelerated aging temperature for determining retention of legibility of the product identification (3.6.3.1), the 24-inch accelerated aging specimen shall be selected to include a printed identification marking and shall be examined for legibility of the marking after the oven exposure. When the specification sheet specifies a separate temperature for accelerated aging of the product identification, a separate specimen including an identification marking shall be exposed at the temperature specified for test of the marking and shall be examined thereafter for legibility.

4.7.5.21 Immersion tests - Specimens of wire of sufficient length to perform the subsequent tests shall be gaged to determine their initial diameter and shall then be immersed to within 6 inches of their ends in each of the following fluids (using a separate specimen for each fluid) for 20 hours at a temperature of 48 to 50°C (118.4 to 122°F).

(a) Lubricating oil, aircraft, turbine engines, synthetic base, MIL-L-23699.

(b) Hydraulic fluid, petroleum base, aircraft, missile, and ordnance, MIL-H-5606.

(c) Isopropyl alcohol, TT-I-735.

(d) Turbine fuel, aviation, Grade JP-4, MIL-T-5624.

During the immersion tests, the radius of bend of the wire shall be not less than fourteen times the specified maximum diameter of the wire under test. Upon removal from the liquids, the specimen shall remain for 1 hour in free air at room temperature. The diameter shall be gaged and compared to the initial diameter. The insulation shall be removed for a distance of one inch from each end of a 24-inch length of the specimen and this length shall be subjected to the bend test of 4.7.5.19.2 followed by the dielectric test of 4.7.5.19.3. A sufficient length of each specimen, after immersion, shall also be subjected to the abrasion test of 4.7.5.15 by Procedure I or II as specified in the applicable specification sheet. The specimen shall be wiped free of the immersion fluid and air dried for 24 hours at 25 ± 4°C (77 $\pm$ 7.2°F) prior to abrasion.

4.7.5.22 Humidity resistance - A 52-foot specimen of wire shall be subjected to the following:

4.7.5.22.1 Apparatus - The apparatus shall consist of a test chamber capable of maintaining an internal temperature of 70 ±2°C (158 ±3.6°F) and an internal relative humidity of 95 ±5 percent. The test chamber shall be capable of being so sealed as to retain the total moisture content in the test space. The heat loss from the chamber shall be sufficient to reduce the internal temperature from the above specified operating temperature to not more than 38°C (100.4°F) within a period of 16 hours from the time of removal of the source of heat. Distilled or demineralized water shall be used to obtain the required humidity.

4.7.5.22.2 Procedure - The specimen shall be placed in the test chamber and the temperature and relative humidity raised over a 2-hour period to the values specified in 4.7.5.22.1 and maintained at such for a period of 6 hours. At the end of the 6-hour period the heat shall be shut off. During the following 16-hour period, the temperature must drop to 38°C (100.4°F) or lower. At the end of the 16-hour period, heat shall be again supplied for a 2-hour period to stabilize at 70 ±2°C (158 ±3.6°F). This cycle (2 hours heating, 6 hours at high temperature, 16 hours cooling) shall be repeated a sufficient number of times to extend the total time of the test to 360 hours (fifteen cycles). At the end of the fifteenth cycle, the 50-foot center section of the specimen shall be immersed in a 5 percent, by weight, solution of sodium chloride in water at room temperature. The insulation resistance of the specimen shall be measured with the outer surface of the specimen grounded, through an electrode in the electrolyte, and with a potential of 250 to 500 volts DC applied to the conductor of the specimen after 1 minute of electrification at this potential. The insulation resistance shall be converted to megohms for 1000 feet by the calculation shown in 4.7.5.2.

* 4.7.5.23 Surface resistance - The surface resistance of the finished wire shall be measured in accordance with Method 6041 of FED-STD-228. All specimens, after having been provided with the required electrodes but prior to testing, shall be cleaned by the procedure described in the test method. In positioning the specimens in the test chamber, the specimens shall be so placed that their ends are a minimum of one inch from any wall of the chamber.

4.7.5.24 Smoke - This test shall be conducted in still air at an ambient temperature of 25 ±5°C (77 ±9°F). A specimen approximately 15 feet long of the wire shall be so suspended that at least the central 10-foot section is horizontal and unsupported. One end of the wire shall be suitably weighted in order that no sagging will occur throughout the test. An electric current shall be applied to the wire and the voltage drop shall be measured over the central 10-foot portion. From the current and voltage values, the resistance of the wire shall be calculated. The temperature of the wire conductor shall be determined from the change in resistance. The current shall be so adjusted that the conductor temperature stabilizes at the temperature specified in the applicable specification sheet. This conductor temperature shall be thus maintained for 15 minutes during which time there shall be no indication of visible smoke. A flat-black background shall be used for this test.

4.7.5.25 Propellant resistance - Specimens of finished wire, 24 inches long shall be immersed to within 1-1/2 inches of each end in the following propellants for 30 minutes at normal room temperature, using a separate specimen for each propellant.

(a) Propellant, nitric acid, MIL-P-7254.

(b) Propellant, hydrazine, MIL-P-26536.

(c) Propellant, nitrogen tetroxide, MIL-P-26539.

(d) Propellant, hydrazine - uns-dimethylhydrazine (50% N_2H_4-50% UDMH), MIL-P-27402.

During immersion, the radius of bend of the wire shall be not less than fourteen times the maximum diameter of the wire specified in the applicable specification sheet. Upon removal from the liquids, the specimens shall remain for 1 hour in free air at room temperature. The insulation shall be removed for a distance of one inch from each end of the specimens and the specimens shall be subjected to the dielectric test of 4.7.5.19.3.

* 4.7.5.26 Continuous lengths - Unless otherwise specified in the ordering data (6.2), the inspection requirements for continuous wire lengths shall be satisfied by the supplier's certificate of conformity and the presence of the required piece length markings on the spools or reels (3.6.9). However, the Government reserves the right to examine such certified lots if deemed necessary to assure that the lengths actually conform to requirement. When the ordering data specifies examination of the wire lengths, the Government representative shall examine the wire at his own discretion to determine conformity in this characteristic. In measuring continuous wire lengths where the wire has been marked or stripped of insulation in lieu of being cut to mark insulation failures or identify untested or improperly tested areas (4.7.5.1.3), such marking or stripping shall be considered equivalent to complete severance of the wire at the two ends of each marked or stripped area.

4.8 Examination of preparation for delivery - Preparation for delivery of materials ready for shipment shall be examined to determine conformity to the requirements of Section 5.

5. PREPARATION FOR DELIVERY

5.1 Packaging - Packaging shall be Level A or C. Unless otherwise specified in the order (6.2), Level A shall be applicable.

5.1.1 Level A - Packaging shall be in accordance with the Level A requirements of MIL-C-12000 and as follows:

5.1.1.1 Reels and spools - Wire shall be delivered wound on reels and spools of a nonreturnable type. Each reel or spool shall have an appropriate diameter for the respective wire size. In no case shall the barrel of the reel or spool have a diameter less than that specified in Table VII or less than 3 inches, whichever is greater. Reels and spools shall be suitably finished to prevent corrosion under typical storage and handling conditions. The method of attachment of flanges to barrels on metal reels or spools shall be structurally equivalent to a full circumferential crimp.

TABLE VII

BARREL DIAMETERS OF SPOOLS AND REELS

WIRE SIZE (RANGE)	MINIMUM DIAMETER OF BARREL (AS TIMES NOMINAL DIAMETER OF FINISHED WIRE, EXCEPT SEE 5.1.1.1)
30-16	50X
14-10	40X
8-4	30X
2-0000	20X

* 5.1.1.2 Winding requirements - Unless otherwise specified in the order (6.2), there shall be no restriction on the number of wire lengths per reel or spool, provided the wire length requirements of 3.6.9 are met by the inspection lot.

5.1.2 Level C - Packaging shall be in accordance with the requirements of MIL-C-12000 for Level C packaging.

5.2 Packing - Packing shall be Level A, B, or C in accordance with MIL-C-12000. Unless otherwise specified in the order (6.2), Level C shall be applicable.

* 5.3 Marking - Unless otherwise specified in the contract or order, each reel or spool shall be marked with the footage of the individual

continuous lengths wound thereon, as specified in 3.6.9. In addition, interior packages and exterior shipping containers shall be marked in accordance with MIL-C-12000 and MIL-STD-129. The identification shall be composed of the following information listed in the order shown:

> WIRE, ELECTRIC, CROSSLINKED POLYALKENE INSULATED*, COPPER**
> Specification sheet part No.
> Specification MIL-W-81044B
> Length______________feet
> Size
> Date of manufacture
> Name of manufacturer
> *or "CROSSLINKED ALKANE-IMIDE POLYMER INSULATED," or "POLYARYLENE INSULATED" as applicable
> **or "COPPER ALLOY," as applicable

6. NOTES

6.1 Intended use - The electric wires covered by this specification are intended for use in any application where their performance characteristics are required. The wires are suitable for installation on aerospace electrical systems within the limitations of applicable performance requirements.

* 6.1.1 Temperature rating - Temperature ratings as specified in specification sheets pertaining to this specification represent the maximum permissible operating temperature of the conductor. The maximum ambient temperature should be the rated maximum conductor temperature of the wire diminished by the operating rise in temperature of the conductor.

* 6.1.2 Compatibility note - The insulation systems of polyvinylidene fluoride-jacketed electric wires of this specification may be degraded by contact with hydraulic fluids of phosphate ester type at high temperatures. Wires of this specification with polyvinylidene fluoride jackets are not recommended for applications where they will be in contact with hydraulic fluids of phosphate ester type at temperatures above 50°C (122°F).

6.1.3 Size designations - The conductor sizes and the corresponding size designations of this specification are in accordance with established usage for stranded copper conductors for hookup wire in the electronic and aircraft industries. It should be noted that these sizes and size designations are not identical with American Wire Gage (AWG) sizes for solid wire and strands. The diameters and cross-sectional areas of the stranded conductors of this specification are, in most sizes, only roughly approximate to those of AWG solid conductors of the same numerical size designation.

* 6.2 Ordering data - Procurement documents should specify the following:

(a) Title, number, and date of this specification.

(b) Applicable specification sheet number, title, and date (1.2).

(c) Applicable specification sheet part number (1.2.1).

(d) Color required (3.6.2).

(e) Quantity of wire required.

(f) Levels of packaging and packing required.

(g) Exceptions, if any, to the optional provisions of this specification including:

(1) Exceptions to identification of product requirement (3.6.3), if applicable.

(2) Applicable minimum length requirements, if other than specified in 3.6.9 and Table III.

(3) Responsibility for inspection, if other than specified in 4.1.

(4) Requirement, if applicable, that insulation materials be subjected to process control test rather than accepted on suppliers certification of conformity (4.7.3).

(5) Marking of dielectric test failures by stripping of insulation or by other method specified in the contract in lieu of cutting of the wire, if applicable (4.7.5.1.3).

(6) Special preparation for delivery requirements, if applicable (Section 5).

6.3 Qualification - With respect to products requiring qualification, awards will be made only for such products as have, prior to the time set for opening of bids, been tested and approved for inclusion in the applicable Qualified Products List (QPL) whether or not such products have actually been so listed by that date. The attention of the suppliers is called to this requirement, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. The activity responsible for the Qualified Products List is the Naval Air Systems Command, Washington, D.C. 20361; however, application for qualification of products should be made to the Commanding Officer, Naval Ammunition Depot (70515), Crane, Indiana 47522, who has been designated Naval Air Systems Command agent for establishing this Qualified Products List.

6.3.1 Conformity to qualified sample - It is understood that wire supplied under contract shall be identical in every respect to the qualification sample tested and found satisfactory, except for changes previously approved by the Government. Any unapproved changes from the qualification sample shall constitute cause for rejection.

* 6.4 Patent notice -

6.4.1 Crosslinked polyalkene - The Government has a royalty-free license under Patent No. 3,269,862 for the benefit of manufacturers of electric wire having an insulating covering comprising a crosslinked polyalkene layer and a crosslinked polyvinylidene fluoride layer either for the Government or for use in equipment to be delivered to the Government.

6.4.2 Alkane-imide polymer - The Government has a royalty-free license under Patent Nos. 3,607,387 and 3,551,200 for the benefit of manufacturers of electric wire having an insulating covering comprising a crosslinked alkane-imide polymer layer and a modified imide polymer layer either for the Government or for use in equipment to be delivered to the Government.

6.5 Marginal notations - The margins of this specification are marked with an asterisk to indicate where changes (additions, modifications, corrections, deletions) from the previous issue were made. This was done as a convenience only and the Government assumes no liability whatsoever for any inaccuracies in these notations. Bidders and contractors are cautioned to evaluate the requirements of this document on the entire content as written irrespective of the marginal notations and relationship to the last previous issue.

Custodians:
Navy - AS
Army - EL
Air Force - 11

Preparing activity:
Navy - AS
(Project No. 6145-0333)

Review activities:
Navy - EC
Army - AT, AV, MI, MU
Air Force - 80
DSA - IS
NSA

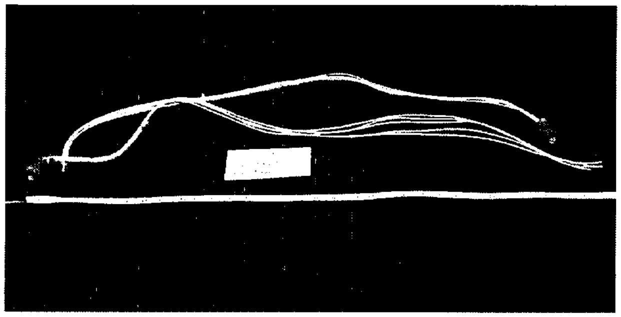
User activities
Navy - MC, OS
Army -
Air Force -

Review/user information is current as of the date of this document. For future coordination of changes in this document, draft circulation should be based on the information in the current Federal Supply Classification Listing of DOD Standardization Documents.

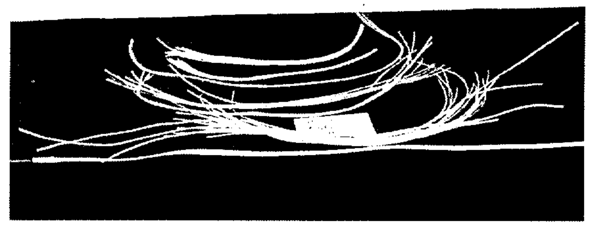
APPENDIX III

Sample Photographs

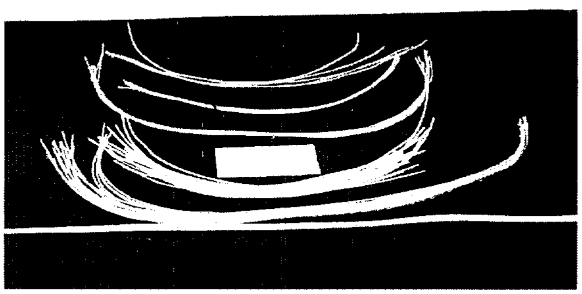
Photograph A1: White 747, Sample 1



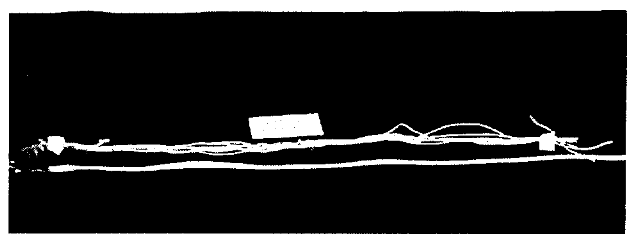
Photograph A2: White 747, Sample 2



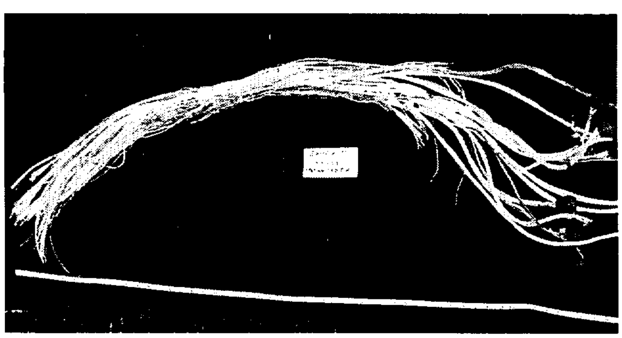
Photograph A3: White 747, Sample 3



Photograph A4: White 747, Sample 4

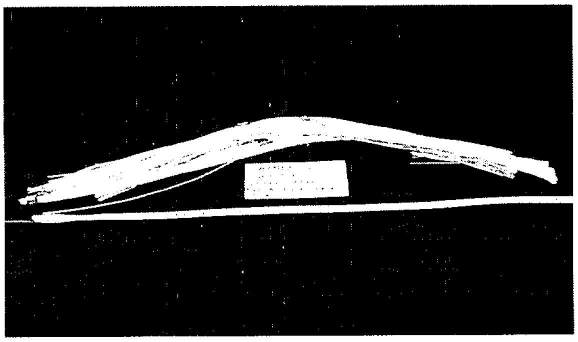


Photograph A5: White 747, Sample 5

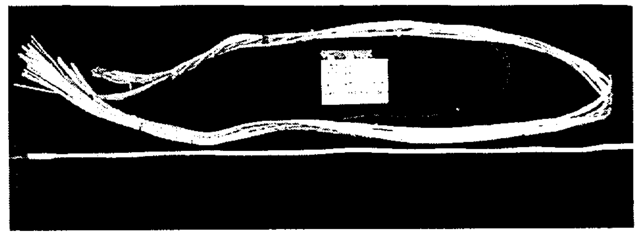


Photograph A6: White 747, Sample 5a

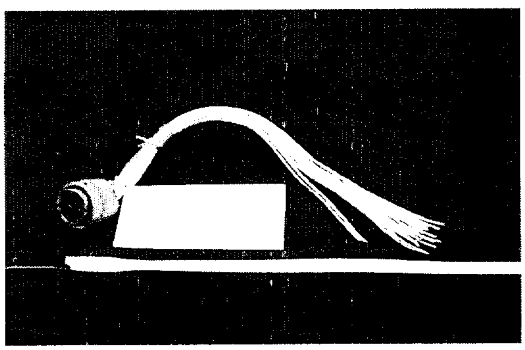
Photograph A7: White 747, Sample 6



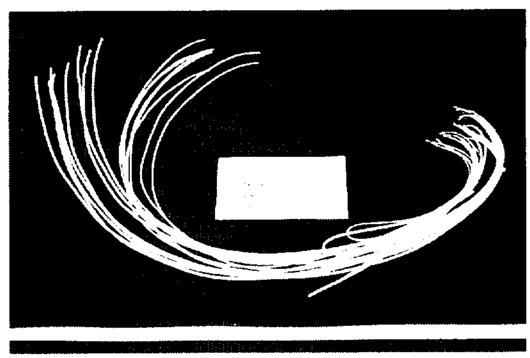
Photograph A8: White 747, Sample 7



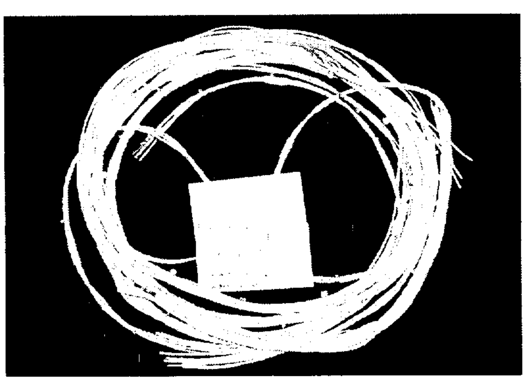
Photograph B1: DC-10, Sample 1



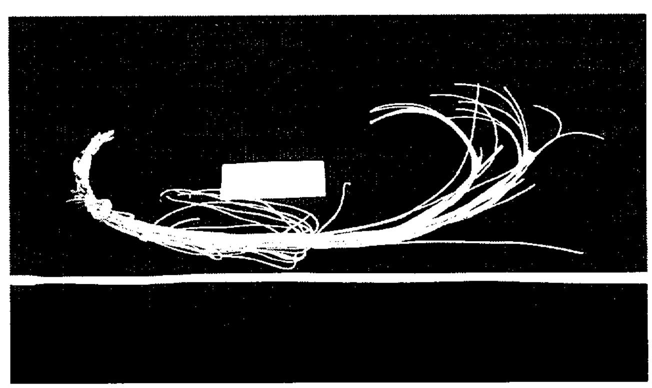
Photograph B2: DC-10, Sample 3



Photograph B3: DC-10, Sample 4

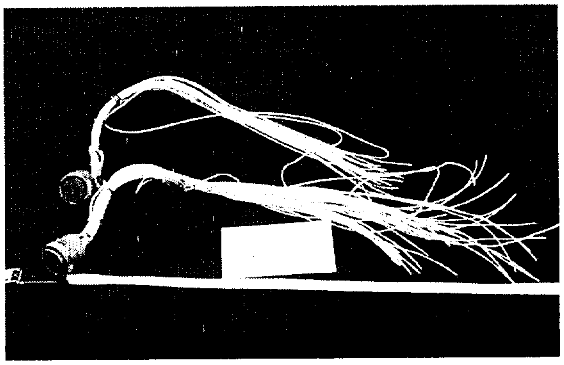


Photograph B4: DC-10, Sample 5

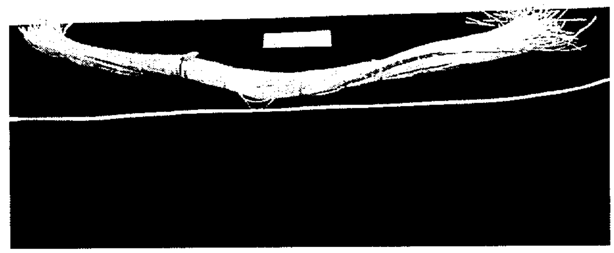


* **No photograph of DC-10, Sample 2 available.**

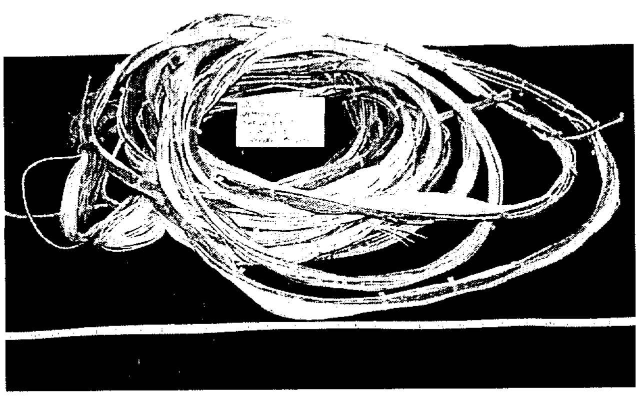
Photograph B5: DC-10, Sample 6



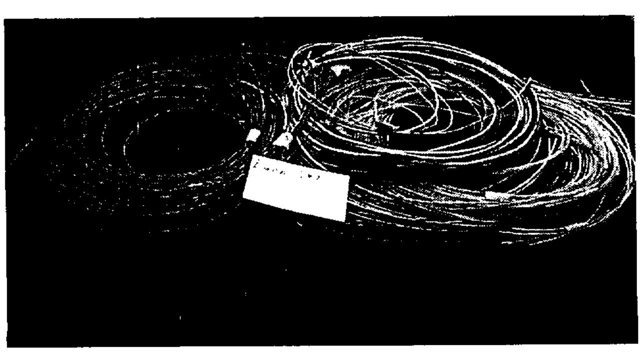
Photograph B6: DC-10, Sample 7



Photograph B7: DC-10, Sample 8



Photograph C1: European 747, Sample 1



APPENDIX IV

Photographs of Sample Problems