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QUALITY REQUIREMENTS FOR SOLDERLESS WRAPPED CONNECTIONS

MAY 28, 1965

BY

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SUBTASK B.4.3.14.25
CONTRACT NASw-410

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GENERAL ELECTRIC COMPANY
DAYTONA BEACH, FLORIDA

DRAFT

N70-75766
(ACCESSION NUMBER)
20
(PAGES)
CR-113080
(NASA CR OR TMX OR AD NUMBER)
(THRU)
none
(CODE)
(CATEGORY)
FACILITY FORM 602

Summary

A study has been made of the solderless wire wrapping process and its applicability to the Apollo Program.

Solderless wire wrapping (wrapping a wire, under tension, around a terminal for a given number of turns) is one of the four principal means of terminating electrical connections -- the other three are soldering, crimping, and welding. The major features of the wire wrapping process are its extremely high reliability, the fact that it can be automated, and that high density of terminations are possible. The process is relatively simple, operators can easily be trained, and process controls are simple and effective.

The primary development work on solderless wire wrapping was done by the Bell Telephone Laboratories. Their criteria for a 40 year life may partially account for the extremely high reliability that the process has experienced these past 10-12 years. That is, there have been no known failures of equipment caused by a defective solderless wrapped connection. Estimates are that over 100 billion have been made.

Wire wrapping is the most extensively used termination method in the computer and data processing fields, and its advantages are rapidly causing it to be used even more widely. The largest users, the telephone and computer industries, make millions of terminations each day. On Apollo the process is being used in ground support equipment but not, at present, in the vehicle itself. Evaluations are being made that will determine its suitability for the rigors of flights into outer space.

There are several specifications on solderless wrapping. Two were prepared by NASA Centers, KSC-W-151 and MSFC-SPEC-390, and although they are basically good specifications, they are a potential source of difficulty. High costs and utter chaos would result if a contractor had to implement both specifications concurrently in

the same shop. Since many contractors furnish equipment to more than one Center, this confusion is a very real possibility.

Our recommendation is that there should be a single NASA solderless wrap standard utilizing the best positions of the others. With a common standard as a foundation, each Center could, if necessary, issue supplemental specifications to cover applications common only to their products. Coordination on the present Center specifications would not be difficult since, for all intentional purposes, the specifications are very nearly the same.

The tremendous economy of automated solderless wrapped connection will bring a continual expanded use of this method of termination. There will be a decided advantage to the Apollo Program in having a single, workable, coordinated standard suitable for all to use.

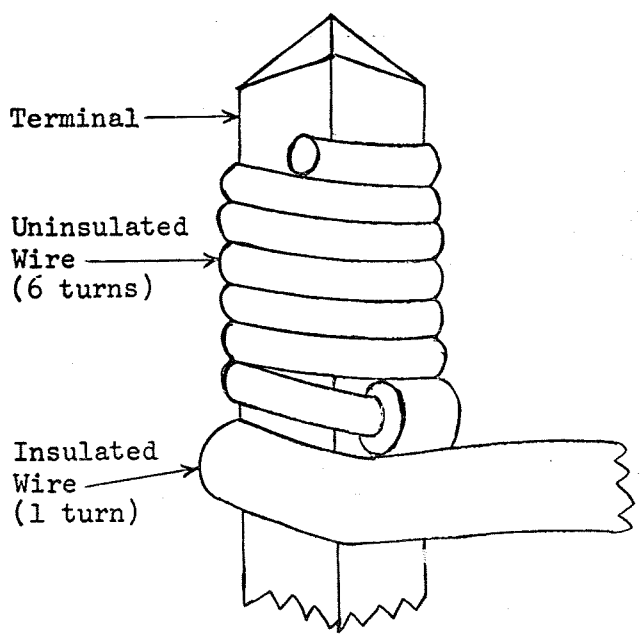

FIGURE 1

An example of a solderless wrapped connection containing one turn of insulated wire and six turns of uninsulated wire.

Description

One of the newer methods of terminating electrical connections is the solderless wrapped connection. By this method a copper conductor is tightly wrapped around a terminal with sharp edges. The indentations made in the wire and terminal hold the connection securely, even with the relaxation in the hoop stresses that eventually occurs in the wire over a period of years.

Extensive tests were made by the Bell Telephone Laboratories to verify the adequacy of this connection. One of the major criteria was a life of 40 years. Investigations showed that the connection was both mechanically and electrically sound. Exposure to corrosive atmosphere had no effect, and even wrapping corroded terminals had no effect since the wrapping action wiped off a clean spot at the point of contact. Based on most standards, the number of turns specified gives a gas tight area, as the area of contact is called, that is 2 - 4 times greater than the cross sectional area of the conductor.

Although there is some relaxation of the conductor with time, there is also a molecular diffusion between the terminal and the conductor. This more than offsets the relaxation in conductor tensile strength. Bell found that the bonding forces holding the wire to the terminal, after accelerated life tests simulating 40 years, were actually 20% greater than at the time the bond was made.

Often the wrap includes a half or more turns of insulated wire around the terminal. This is called a modified wrap and its purpose is to cushion the beginning of the wrap from failure because of severe shock or vibration at the point of highest stress -- the first corner wrapped on the terminal.

Process Control

The strip force test is the only significant test that is necessary to control the wire wrapping process. This test determines the force necessary to remove the

wire from the terminal. If the minimum is met, there is assurance that the wrap is mechanically and electrically sound and gas tight. An unwrapping test is often used also to assure that the wrap is not so tight to have stretched the conductor beyond its elastic limit. If this occurs, the wire breaks when unwrapped.

Suitable equipment is available today to easily wrap terminals with wire. Very little skill is needed as the process is mostly mechanical and an operator can be trained in a few hours.

Advantages

Though the solderless wrap process is barely fifteen years old, it is already the predominant termination method in the telephone and computer industries. The principal advantages of this process over soldering, crimping and welding are:

1. High reliability
2. Ability to be automated
3. High density of terminations

Reliability

Actual reliability figures for solderless wrapping have shown an upward trend in recent years, as more confidence is gained. Where the failure rate for soldered connections in some military projects was predicted at one in 10,000, solderless wrapped connections were predicted at one in 100,000. IBM has assigned a confidence figure of one substandard wrap in 200,000 during assembly. Proponents of the solderless wrap point with pride to the fact that there is not one proven case of failure of equipment caused by a defective solderless connection. Estimates are that in excess of 100 billion have been made. Regardless of the figures used, there is no doubt that the simplicity of the wrapped connection, the ease by which it can be controlled, and the lack of operator influence on a connection, have materially contributed to its outstanding reliability.

Automation

Probably the most compelling factor causing engineers and management to consider solderless wire wrapping is the economy of the process. A solderer can make an average of approximately 150 terminations per day. An operator using hand wire wrapping equipment can make nearly 900 terminations per day. An automatic wire wrapping machine (programmed by tape or card that automatically positions, routes, strips the wire and wraps the terminal) can make upwards of 8000 terminations per shift. These figures are based on actual experience at the Apollo Support Department of the General Electric Company.

Terminal Density

The tool bit that wraps the wire around the terminals is relatively small. As a result, terminals wrapped with 24 gage wire, for example, can be spaced as little as 0.200" apart. With terminals on which three wraps can be placed, over 100 terminations can be made in an area of 1 square inch. Welding, especially for microminiature application, is the only process that can provide termination densities greater than that of the wrapped wire design. To obtain the full advantage of density, equipment should be designed for the solderless wrapping process.

Limitations

The solderless wrapped connection is not, however, a panacea for all termination problems. It is presently being used primarily on wire gage sizes 18 through 30. Since only solid wire is used, sizes 16 and below become difficult to work because of stiffness. As previously mentioned, welding is best suited for microminiaturization and soldering will probably continue to be used for simultaneous connection of multiple circuits on printed circuit boards.

Stranded wire is not used for wrapping since it does not provide enough rigidity to remain secured. Interface with other equipment utilizing stranded wire is

possible, however, by soldering the stranded wire to the solderless wrap terminal.

Applications

All present applications of solderless wrapping on Apollo are in ground support equipment. None of the contractors are using the process in any portion of the flight vehicle, although some have the process under evaluation. Many environmental tests have been run on wrapped connections -- vibration, thermal and physical shock, exposures to heat and cold, etc. Many tests are still underway evaluating its full flight capabilities for space, so, published results of its chances for success or failure are limited. The data between some reports is conflicting, which indicates that the overall equipment design may affect environmental limitation. There is no doubt, however, that these connections can withstand more severe applications than encountered in ground support equipment.

Specifications

Several specifications were reviewed but the actual comparisons shown in appendix are of four select, primary specifications:

EIA-RS-280	Solderless Wrapped Electrical Connections (Electronic Industries Association, Aug. 1963)
NAVORD OS 11120	Description and Requirements for Solderless Wrapped Connections Process (Bureau of Weapons, Navy Dept., April 1963)
MSFC-SPEC-390	Electrical Wire Wrapped Connections (Marshall Space Flight Center, February 1965)
KSC-W-151A (DP)	Solderless Wrap Process, Electrical Connections (John F. Kennedy Space Center, April 1964)

These are the only specifications that have general distribution. Several companies have their own internal specifications and the military has one drafted but not issued.

Except for EIA-RS-280, each of these specifications are project oriented. That is, they are intended for a certain project and are restrictive in some design

features. MSFC-SPEC-390 and KSC-W-151A, by definition, are intended for ground support applications. NAVORD OS 11120 differentiates between shore based and shipboard applications. Only EIA-RS-280 describes the physical, electrical, and mechanical features of the wrap alone; design features such as wrap post material, conductor insulation, etc., are determined by user for each application.

The full economic benefits of the solderless wrap method come with the step from the use of hand wrap guns to the use of automatic wire wrapping machines. The automatic machines are not as flexible as the hand wrap guns, however, and small differences in specifications could actually negate the economic benefits of automatic equipment. For example, to change an automatic machine designed to wrap #24 gage wire to wrap #30 gage wire would cost approximately $15,000. A change in the number of turns alone would cause a redesign costing $5,000, and this does not include secondary costs that may result, such as the need for a non-standard terminal (for longer length). Automatic wrapping machines cost around $200,000.

Specification Differences

The points of differences in the specifications cause two major problems. One is that the effectiveness of economy through automation is reduced and the second is that confusion and misunderstanding develop where contractors concurrently work to different specifications. Since the products of each Center must often interface with one another, it would be advantageous to have one solderless wrapping standard that is suitable for all. The standard should be confined to the wrap alone, that is, to those items that would remain constant regardless of application. Examples of these items are the number of turns, strip force, gas tight area, space between turns, wrapper resistance (electrical), etc. Design features would not be a part of the standard since these would be determined for each application. Each

Center could still issue specifications as necessary to control these items. Examples of design features are wrap post material, insulation, conductor finish, environmental requirements, etc.

Solderless Wrap Differences

Some of the differences in the Center specifications on the solderless wrapping itself that lead to confusion are:

1. End tails
2. Number of turns of insulated wire
3. Magnification for visual inspection
4. Gas tight area

The specification comparison chart in the appendix clearly shows the details of these differences. None of these four are of major significance as for the quality of the wrap. However, the first difference means retraining of operators and inspectors, the second means new wrap tool bits and the third means new inspection equipment.

The controversial subject of magnification for visual inspection is one on which most experienced contractors have reached firm conclusions. The specification chart shows that the magnifications required run from 0 to 8 power.

To inspect a panel of solderless wrap terminals under a magnifying glass is much slower than with the eye unaided. It would be virtually impossible to inspect the wraps with the higher magnifications since the terminals are longer than the focal distances of the magnifying glasses. Some advocate magnified inspection for production samples only, but not for the production itself. Many have stated that substandard wraps of any consequence can be seen with the eye alone and that a magnification of a few powers is only beneficial in solving borderline cases.

Our conclusion is that the use of magnification for visual inspection should be optional. During training periods and with production samples on the smaller wire diameters, it may be of some limited benefit. It should not, however, be required for all conditions.

Design Differences

The differences in design criteria of each Center specification are listed below. These are significant because both are intended for ground support equipment. The differences are:

1. Wrap post (terminal) material and finish
2. Conductor plating
3. Wrapper resistance and contact potential test
4. Physical shock
5. Thermal shock
6. Quality assurance provisions

A further example of the chaos that would result from a contractor working concurrently to two specifications is with the process control sample. This sample is daily submitted to strip force and unwrap tests. The sample sizes for hand wrapping are as follows:

Period	Size of Sample	
	MSFC	KSC
At start of shift	9	10
At middle of shift	2	3
At end of shift	0	3

It is fairly easy to imagine the confusion to two operators, sitting side by side, and each working to a different specification, or, a single operator working to one specification one day, and a different one the next day. In fact, administration

of two different specifications simultaneously would be virtually impossible.

Conclusion

The solderless wrapping method should be encouraged because of its high reliability and low cost, wherever it is most advantageous to Apollo.

To realize the utmost economy and to prevent confusion and chaos among contractors, it is strongly recommended that NASA develop a single standard.

A standard, once properly developed, will not need revision. Design criteria to meet individual applications could be developed by the Centers as necessary.

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With two exceptions, only those documents dated after 1960 have been listed. In addition, test results and specifications from several contractors were reviewed, and interviews and conversations were held with many authorities on solderless wrapping. Especially helpful was A. I. Pranikoff, of the General Electric Company, who is Chairman of the Electronic Industries Association's Committee P7.5, "Solderless Wrapped Connections."

COMPARISON OF SOLDERLESS WIRE WRAPPING SPEC

ITEM	ELECTRONIC INDUSTRIES ASSOCIATION RS-280		NAVORD OS 11120	MSFC-SPEC-3
Title	Solderless Wrapped Electrical Connections		Requirements For Solderless Wrapped Connections Process	Wire Wrapped Elec Connections Speci tion
Scope	Requirements given for mechanical and electrical stable connection made of solid, round wire.		Mechanical and electrical joints for shipboard and shorebase environs.	Ground Support Eq ment (not for hig temperature or ex vibration).
Number of Turns, Uninsulated Wire (Minimum) AWG	Copper, Nickel, Brass	Nickel Iron, Copper Clad Steels	Ship and Shore	
26	6	5	6 +1 -0	6
24	5	4	5	6
22	4	4	5	5
20	4	4	4	5
18	4	3	4	
16	3	3		
Number of Turns, Insulated Wire (Minimum)	1/2 or 2 corners, if specified (for vibration).		1/2 on all shipboard applications.	1/2 turn.
Space Between Turns (Maximum)	1/2 uninsulated wire diameter.		1/2 bare wire diameter.	1/2 uninsulated wi diameter.
End Tails	As specified by user.		Less than 1 bare wire diameter from post.	Maximum of 1 bare diameter past last ner locked on post
Wrap Post (Terminal)	As specified by user, provided wrap will meet EIA standard. May be plated.		Suitable copper alloy Rc 25-40 preferred, .045 x .045, radii .003 maximum, burrs .0015 maximum 10 rewraps permitted.	Copper alloy, Rc 2 .045 x .045, gold (per MIL-G-45204, I Type II - .00005 imum hard gold) 10 rewraps permitted.
Length of Wrap Post (Minimum)			Shipboard	
			1 Wrap / 2 Wraps / 3 Wraps	1 Wrap / 2 Wraps
			0.23 / 0.43 / 0.64	0.23 / 0.43
			.24 / .45 / .67	.24 / .45
			.29 / .54 / .82	.29 / .54
			.31 / .59 / .88	.31 / .59

COMPARISON OF SOLDERLESS WIRE WRAPPING SPECIFICATIONS

NAVORD OS 11120	MSFC-SPEC-390	KSC-W-151A (DP)	REMARKS
Requirements For Solderless Wrapped Connections Process	Wire Wrapped Electrical Connections Specification	Solderless Wrap Process Specification	
Mechanical and electrical joints for shipboard and shorebase environs.	Ground Support Equipment (not for high temperature or extreme vibration).	Mechanical and electrical stable solderless wrapped connections (intended for ground support).	
Ship and Shore 6 +1 -0 5 5 4 4	6 6 5 5	6 6 5 5	Differences can be significant.
1/2 on all shipboard applications.	1/2 turn.	1 turn.	Affects length of wrap post.
1/2 bare wire diameter.	1/2 uninsulated wire diameter.	1/2 uninsulated wire diameter.	
Less than 1 bare wire diameter from post.	Maximum of 1 bare wire diameter past last corner locked on post.	Not more than 2 times uninsulated wire diameter.	Wrap post spacing mainly determines this.
Suitable copper alloy Rc 25-40 preferred, .045 x .045, radii .003 maximum, burrs .0015 maximum 10 rewraps permitted.	Copper alloy, Rc 25-40, .045 x .045, gold plate (per MIL-G-45204, Class I Type II - .000050 minimum hard gold) 10 rewraps permitted.	Beryllium copper, Rc 25-40, .045 x .045 (.060 x .030 allowable) Radii .003 maximum, burrs .002 maximum. Durability to be rewrapped at least 10 times.	Environment and interconnection design are significant.
Shipboard			
1 Wrap / 2 Wraps / 3 Wraps	1 Wrap / 2 Wraps / 3 Wraps	1 Wrap / 2 Wraps	Nonstandard lengths may require special wrap posts.
0.23 / 0.43 / 0.64	0.23 / 0.43 / 0.64	0.25 / 0.46	
.24 / .45 / .67	.24 / .45 / .67	.26 / .49	
.29 / .54 / .82	.29 / .54 / .82	.32 / .59	
.31 / .59 / .88	.31 / .59 / .88	.34 / .64	

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COMPARISON OF SOLDERLESS WIRE WRAPPING

ITEM	ELECTRONIC INDUSTRIES ASSOCIATION RS-280	NAVORD OS 11120	MSFC-SPEC-
Wrap Post Spacing		.200" minimum (AWG 20 to 26).	
Wire	As specified by user. .0015 maximum thickness of tin-lead alloy finish if used. Per cent elongation, for 10" of copper: AWG 26 & 24 = 15% AWG 22 - 18 = 20%	Solid, copper wire, tin-coated, per WS 2072. Per cent elongation same as EIA specifications.	AWG 20 - 26 solid per, nickel plate Minimum elongatio 10" sample = 15%.
Insulation	As specified by user. For modified wrap, wall thickness should be greater than 40% of wire diameter.	PVC with nylon jacket (per WS 2072).	PVC with nylon jac
Visual Inspections	Without instruments - space between turns, overlaps, end tails, position of connection, damage, rewrapping, number of turns and soldering.	8 power magnifying glass - number of turns, position of wraps on terminal, wrapper ends, dressing, workmanship, etc. (Use of metallic instruments must be approved by GIA).	7 power glass - in tion wrap, spacing, overlap, number of pigtail, overwrap, wrap, wire routing, posts, damage, etc. (nonmetallic instr only).
Stripping Force (Lbs. Minimum) AWG	Lbs.	Lbs.	Lbs.
26	5	6	6
24	6.5	7	7
22	8	8	8
20	8	9	9
18	12	15	
16	15		
Rate of Application of Strip Force	Maximum of 10 inches per minute.	1 to 10 inches per minute.	1 inch per minute.
Unwrapping	No breakage. Unwrap tool optional. For process control, not acceptance or rejection of product.	No breakage. Unwrap tool specified.	No breakage or cra Unwrap tool specif

NAVORD OS 11120	MSFC-SPEC-390	KSC-W-151A (DP)	REMARKS
.200" minimum (AWG 20 to 26).			
Solid, copper wire, tin-coated, per WS 2072. Per cent elongation same as EIA specifications.	AWG 20 - 26 solid copper, nickel plated. Minimum elongation on 10" sample = 15%.	Tin-coated copper, per MIL-W-16878/1 and Type S, Table II of specification QQ-W-343. Minimum elongation same as EIA specifications.	Elongation is significant. Environment is criteria for finish.
PVC with nylon jacket (per WS 2072).	PVC with nylon jacket.	MIL-W-16878/1, with nylon jacket (Type B 105°C, 600V).	Cut through resistance and thin wall are desirable. Environment is also a factor.
8 power magnifying glass - number of turns, position of wraps on terminal, wrapper ends, dressing, workmanship, etc. (Use of metallic instruments must be approved by GIA).	7 power glass - insulation wrap, spacing, overlap, number of turns, pigtail, overwrap, open-wrap, wire routing, bent posts, damage, etc. (nonmetallic instruments only).	5 power glass minimum - number of turns, wrapper spacing, overlap, ends, position of wrap, wire dress, damage, workmanship, etc. (nonmetallic instruments only).	
Lbs. 6 7 8 9 15	Lbs. 6 7 8 9	Lbs. 6 7 8 9	Slight differences are not significant.
1 to 10 inches per minute.	1 inch per minute.	1 inch per minute.	Different stripping forces because of different stripping rates have been reported.
No breakage. Unwrap tool specified.	No breakage or cracks. Unwrap tool specified.	No breakage. Unwrap tool specified.	

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COMPARISON OF SOLDERLESS WIRE WRAPPING SPECIFICATIONS

ITEM	ELECTRONIC INDUSTRIES ASSOCIATION RS-280	NAVORD OS 11120	MSFC-SPEC-390
Gas Tight Area (Minimum)	Equal to cross-sectional area of bare wire.	Equal to cross-sectional area of bare wire.	Equal to cross-sectional area of bare wire.
Wrapper Resistance	Not to exceed R for 1" of wire used.	4.0 millivolt drop, maximum (2.4 amps), all gages of wire.	2.0 millivolt drop, maximum (2.4 amps), all gages of wire.
Resistance Variation	Not to exceed R for 1" of wire used. (Deflection 1/32" per inch of terminal length).		
Contact Potential (Dry Circuit)		Two tests: (a) microvolt test (switch polarity), (b) contact resistance measurement (± 25% variation permitted).	
Current Overload		4.0 millivolt drop maximum, overload 125% for 2 hrs., 150% for 5 min.	2.0 millivolt drop maximum. (Same overload as NAVORD).
Vibration		Per MIL-STD-202, Method 201A, 2 hour cycles. Wrapper resistance to be monitored during vibration.	Per MIL-STD-202, Method 201 except for 4 hour cycles. Must then pass strip, unwrap and wrapper resistance tests
Salt Spray		Per MIL-STD-202, Method 101, Condition B. Must then pass wrapper resistance test.	Per MIL-STD-202, Method 101. Must then pass strip, unwrap and wrapper resistance tests.
Shock			Per MIL-STD-202, Method 202, acceleration = 10g for 30 milliseconds, 3 shocks in 3 axes. Must then pass same tests as after salt spray.

	NAVORD OS 11120	MSFC-SPEC-390	KSC-W-151A (DP)	REMARKS
l	Equal to cross-sectional area of bare wire.	Equal to cross-sectional area of bare wire.	Equal to twice the cross-sectional area of bare conductor.	
	4.0 millivolt drop, maximum (2.4 amps), all gages of wire.	2.0 millivolt drop, maximum (2.4 amps), all gages of wire.	Two tests: 2.0 millivolt drop, maximum (2.5 amps). Also, contact resistance test (25% variation permitted)	KSC specifies both resistance and voltage drop tests.
				Wrap post is deflected and R is measured while wrap post oscillates.
	Two tests: (a) microvolt test (switch polarity), (b) contact resistance measurement (± 25% variation permitted).		One test - microvolt test (switch polarity).	
	4.0 millivolt drop maximum, overload 125% for 2 hrs., 150% for 5 min.	2.0 millivolt drop maximum. (Same overload as NAVORD).	2.0 millivolt drop. Must pass wrapper resistance and contact potential tests. (Same overload as NAVORD).	
	Per MIL-STD-202, Method 201A, 2 hour cycles. Wrapper resistance to be monitored during vibration.	Per MIL-STD-202, Method 201 except for 4 hour cycles. Must then pass strip, unwrap and wrapper resistance tests.	Per MIL-STD-202, Method 201A except for 4 hour cycles. Must then pass visual, wrapper potential and resistance, strip and unwrap tests.	
	Per MIL-STD-202, Method 101, Condition B. Must then pass wrapper resistance test.	Per MIL-STD-202, Method 101. Must then pass strip, unwrap and wrapper resistance tests.	Per MIL-STD-202, Method 101A, Condition A. Must then pass visual, contact potential and resistance, strip and unwrap tests.	20% salt solution, temperature - 95°F. Condition A = 96 hours. Condition B = 48 hours.
		Per MIL-STD-202, Method 202, acceleration = 10g for 30 milliseconds, 3 shocks in 3 axes. Must then pass same tests as after salt spray.	Per MIL-STD-202, Method 202A, acceleration = 30g, for 10 milliseconds, 3 shocks in 3 axes. Must then pass same tests as after salt spray.	

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COMPARISON OF SOLDERLESS WIRE WRAPPING SPECIFICA

ITEM	ELECTRONIC INDUSTRIES ASSOCIATION RS-280	NAVORD OS 11120	MSFC-SPEC-390
Thermal Shock		+105°C to -55°C, 5 cycles, 30 minutes at each temperature. Must then pass unwrap and wrapper resistance tests.	MIL-STD-202, Method 107 -20°C to +85°C, 5 cycles, 30 minutes at each temperature. Must then pass strip, unwrap and wrapper resistance tests.
Quality Assurance Provisions		Preproduction - if not waived. Each 10,000 Wraps - AQL specified. Strip, unwrap and visual inspection. Each 500,000 Wraps (or 6 months) - all preproduction tests. Equipment - (new or modified) must pass strip test.	Preproduction - only if specified. Quality Assurance - samples from start, middle and end of a programmed operation. For hand operation samples from start and middle of each shift. Must pass all tests. Equipment Certification - Must pass wrap and unwrap tests. To be recertified every 30 days.

NAVORD OS 11120	MSFC-SPEC-390	KSC-W-151A (DP)	REMARKS
+105°C to -55°C, 5 cycles, 30 minutes at each temperature. Must then pass unwrap and wrapper resistance tests.	MIL-STD-202, Method 107. -20°C to +85°C, 5 cycles, 30 minutes at each temperature. Must then pass strip, unwrap and wrapper resistance tests.	MIL-STD-202, Method 102A Test Condition A, +100°C to -20°C, 5 cycles, 30 minutes at each temperature. Must then pass same tests as after salt spray.	Methods 102 and 107 have substantially the same purpose. Method 107 is useful for large components.
Preproduction - if not waived. Each 10,000 Wraps - AQL specified. Strip, unwrap and visual inspection. Each 500,000 Wraps (or 6 months) - all preproduction tests. Equipment - (new or modified) must pass strip test.	Preproduction - only if specified. Quality Assurance - samples from start, middle and end of a programmed operation. For hand operation samples from start and middle of each shift. Must pass all tests. Equipment Certification - Must pass wrap and unwrap tests. To be recertified every 30 days.	Preproduction - Specified. Process Control - samples from start, middle, end of each shift. Perform visual strip and unwrap test. Equipment Recertification - same as process control tests (except for sample sizes). Production Tests - Visual inspection of all wraps made.	Sample sizes vary. (See comments in text).

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