Rec'd 9-30-80 P

PUB48007

PRELIMINARY

Bell System Voice Communications TECHNICAL REFERENCE

Inside Wiring Cable

(3 to 125 Pair Sizes)

June 1980

DIRECTOR—TERMINAL SYSTEMS PERFORMANCE AND SUPPORT

326-974

PRELIMINARY

NOTICE

This technical Reference is specifically intended for the developers, designers, manufacturers, consultants, suppliers, and users of Inside Wiring Cable intended for Bell System application. American Telephone and Telegraph Company reserves the right to revise this Technical Reference for any reason, including, but not limited to, conformity with Federal Communications Commission (FCC) Regulations, and standards promulgated by the American National Standards Institute (ANSI), the Electronic Industries Association (EIA), the International Telegraph and Telephone Consultive Committee (CCITT), or other standards of other organizations and agencies; utilization of new advances in the state of the technical arts; or to reflect changes in the design of equipment or services described therein. The limits of responsibility and liability of the Bell System with respect to use of customer-provided systems or equipment are set forth in the appropriate tariff regulations.

If further information is required, please write:

Director - Terminal Systems Performance and Support
American Telephone and Telegraph Company
295 North Maple Avenue
Basking Ridge, New Jersey 07920

PRELIMINARY

TECHNICAL REFERENCE

INSIDE WIRING CABLE

TABLE OF CONTENTS

TABLE OF CONTENTS

1. INTRODUCTION AND SCOPE

This Technical Reference presents technical criteria for Inside Wiring Cable. Such cable is herein defined to consist of 24 AWG cylindrical, solid copper conductors individually insulated with poly (vinyl chloride), twisted into pairs, formed into a cylindrical cable core and covered by a poly (vinyl chloride) jacket. Any product using different materials or geometric configuration is beyond the scope of this document.

The criteria in this document are the minimum necessary to determine if a given product is technically suitable to be considered for standardization by the American Telephone and Telegraph Company for usage by the Bell System Operating Companies. These criteria are subdivided into two levels: mandatory (identified by use of the word "shall") and objective (identified by use of the word "desirable"). Mandatory criteria are generally concerned with product safety and protection, signaling compatibility, and absolute minimum acceptable performance levels in areas such as transmission, environmental, durability, and long term reliability. Product candidates are required to meet all mandatory requirements to be considered technically suitable for standardization, except under extreme or unusual circumstances. For example, an unusual circumstance would be one in which a product is shown to comply with the intent of a particular mandatory criterion but does not meet the letter of that criterion. Objective criteria either represent goals whose attainment enhances the general performance of the product in all its Bell System applications or specific techniques for achieving compliance with a mandatory requirement. Objective criteria are used in technical comparisons of two or more product candidates being considered for standardization.

This publication on wiring standards can also be referenced by manufacturers in demonstrating compliance with Section 68.215 (e) (7), Part 68 of the FCC Rules and Regulations. Section 68.215 specifies controls on the installation of other than "fully-protected" premises wiring (wiring used in a system not providing a barrier to both longitudinal imbalances and hazardous voltages) in registered Bell or customer-provided PBX or key telephone systems.

Test procedures have been specified for many of the requirements. This has been done by including the test procedures in the text itself, by referencing Appendices, by citing an ASTM designation, or by combinations of these methods.

This Technical Reference address only those technical requirements which relate directly to product operation and field performance. It does not address technical requirements which are administrative rather than operational in nature, e.g., documentation, design change classification and control, advice and assistance, engineering complaint procedures, and quality assurance. It should be noted that all of these considerations, in addition to market needs and economics, will play a role in the standardization decision.

In particular, quality assurance, although not addressed in this Technical Reference, is considered a mandatory requirement in the standardization procedure. Quality assurance is addressed in Technical Reference PUB53250 - Quality Program Evaluation. PUB53250 contains the guidelines utilized by the Bell System in evaluating programs of potential suppliers of telecommunications products offered for sale to the Bell System.

2. RULES FOR APPLICATION OF CRITERIA

Unless otherwise stated, all criteria specified in this document apply to completed cable (conductor plus insulation plus jacket). In addition, test temperatures are $23 \pm 2^{\circ}C$ ($73.4 \pm 3.6^{\circ}F$) unless otherwise specified.

Whenever reference is made to American Society for Testing and Materials (ASTM) designations, the issue listed in the latest ASTM Index of Standards apply unless otherwise specified. Observational Standards (OS) which are referenced can be obtained for a nominal fee by writing to:

Director - Terminal Systems Performance and Support
American Telephone and Telegraph Company
295 North Maple Avenue
Basking Ridge, New Jersey 07920

All measured and computed values are rounded-off to the number of places and figures given in the corresponding requirements. All rounding off must be done in accordance with Rounding-Off Method per ASTM E29.

Some of the test procedures specified in this document are potentially hazardous to personnel because of the high voltages involved. Because of this, proper safety precautions are mandatory for the prevention of injury to those who operate test equipment.

3. GENERAL PRODUCT CRITERIA

Inside Wiring Cable shall consist of No. 24 AWG solid annealed copper conductors (tinned or untinned as required) individually insulated with distinctively colored poly (vinyl chloride) which is marked at regular intervals with a colored ink or an extruded longitudinal stripe. The colored insulation, in combination with ink marks or longitudinal stripes, provide tip, ring and pair identification. The insulated conductors shall be twisted together to form pairs which shall then be grouped together to form the cable core and covered with a light olive gray or ivory colored poly (vinyl chloride) jacket. A slitting cord shall be laid between the core and jacket. The cable is intended for conventional station wiring, prewiring of houses during construction, and for use in making connector cable. The standard cable sizes presently used in the Bell System are 3, 4, 6, 12, 16, 21, 25, 40, 50, 75, 100 and 125 pair sizes and with the option of a weatherized outdoor or an indoor type poly (vinyl chloride) jacket and insulation. The 3 pair size is used extensively for prewiring of houses.

4. DIMENSIONAL REQUIREMENTS

4.1 Conductors

Conductor size and shape are indirectly and to a large extent constrained by requirements contained in later sections. Furthermore, operating experience has dictated additional constraints.

Each conductor shall be No. 24 AWG. The desired average bare wire conductor diameter is .020 inch, and the minimum bare wire conductor diameter shall be .019 inch.

4.2 Insulation

Dimensional requirements are placed on the insulation in order to assure that the insulated conductor will work reliably with insulation piercing terminals, withstand the forces encountered during handling and installation, and withstand the anticipated environment(s). Hence, the desired average thickness of the insulation is .008 inch for the outdoor material and .006 inch for the indoor material. In addition, the minimum thickness shall be .006 inch for the outdoor material and .004 inch for the indoor material.

4.3 Insulated Conductors

Dimensional requirements are placed on the insulated conductors to assure that they will work reliably with insulation piercing terminals and withstand the forces encountered during handling and installation. Hence, the diameter of the insulated conductors shall be a minimum of .033 inch for the outdoor material and .030 inch for the indoor material. In addition, the diameter shall be a maximum of .038 inch for the outdoor material and .034 inch for the indoor material.

4.4 Jacket

Dimensional requirements are placed on the jacket so that it can withstand the forces encountered during handling and installation such as abrasion, tear, and cut-through. Hence, the desired average thickness of the jacket is as follows:

3 pair cable: .015 inch
4, 6, 12, 16 and 21 pair cable: .025 inch
25 pair cable: .030 inch
40, 50, 75, 100 and 125 pair cable: .035 inch

The average thickness shall be determined from four readings made at any right section along radial lines from the approximate center of the completed cable. The readings shall be taken 90° apart circumferentially. In addition, the minimum jacket thickness at any point shall be as follows:

3 pair cable: .010 inch
4, 6, 12, 16 and 21 pair cable: .020 inch
25 pair cable: .021 inch
40, 50, 75, 100 and 125 pair cable: .026 inch

4.5 Completed Cable

Dimensional requirements are placed on the completed cable to conform with its associated attachment apparatus and so that desired raceway (conduit) fills are achieved. Hence, the completed cable shall have the following maximum diameters and, if it is to be used as connector cable, the following minimum diameter requirements are desirable:

Cable Size (Pairs)	Maximum Diameter (inches)	Minimum Diameter (inches)
3	0.165	0.135
4	0.23	0.19
6	0.25	0.21
12	0.32	0.28
16	0.35	0.31
21	0.38	0.34
25	0.40	0.36
40	0.52	0.46
50	0.58	0.50
75	0.67	0.59
100	0.75	0.67
125	0.83	0.70

The measurements shall be made in such a manner that the insulation or jacket is not deformed.

5. MATERIAL AND MECHANICAL REQUIREMENTS

5.1 Conductors

5.1.1 Material and General Physical Attributes

To insure reliable handling, terminating and transmission characteristics, the conductor must have adequate ductility, the proper shape, mechanical strength and electrical continuity. In addition, tin plating is required under certain conditions to facilitate soldering to connectors, and to help ensure long term reliability at solderless wrap terminations. Therefore, each conductor shall be annealed copper wire (tinned or untinned as required), cylindrical in form, free from kinks, scales, or other flaws, and continuous throughout its length. If the conductors are tinned they shall comply with the requirements of section 5.1.5.

5.1.2 Breaking Strength

To help eliminate serious conductor surface flaws and inclusions and to assure adequate wire strength during installation, a breaking strength requirement has been established. The breaking strength of each conductor shall be a minimum of 9 pounds.

5.1.3 Elongation

A conductor elongation requirement has been established to assure that excessive work hardening has not occurred during processing. Such hardening can adversely affect conductor handling and terminating characteristics. The elongation shall be 14 percent minimum when tested in accordance with the ASTM specification for Soft or Annealed Copper Wire B3. The testing machine shall be adjusted so that the speed of the moving head will not exceed 3 inches per minute under "No Load" conditions. For routine inspection a higher rate of travel up to 10 inches per minute may be used. In the event of failure at the higher rate a retest shall be made at 3 inches per minute.

5.1.4 Factory Joints

Joints in a conductor are permitted provided the jointing method is one of two specified below which have proven their long term reliability. In addition, size and surface finish restrictions are needed against insulation damage (by joints) during processing into finished wire. A minimum break strength requirement is a further check on the joint quality. The following requirements result:

A. Joints shall be made by butt brazing or butt welding.
B. The diameter of the conductor at the joined section shall not be increased by more than 0.005 inch.
C. The surface of the joint shall be smooth and free of sharp edges.
D. Any length of conductor containing a factory joint shall have a breaking strength of 9 pounds minimum.

If a joint is made in an insulated conductor, refer to section 5.2.9 for information on insulation patching.

5.1.5 Tin Plating

Tin plating of conductors is required under certain conditions to facilitate soldering to connectors and to provide long term reliability at solderless wrap terminations. Such plating must cover an adequate portion of the conductor surface in a sufficiently continuous manner. It must also be provided in sufficient amounts to ensure a strong, reliable bond. Hence, where tin coating of the conductors is required, the following requirements shall apply:

A. Tin Continuity - In completed cable, continuity of tin coating at any cross-section shall be a minimum of 90% of the periphery. This shall be determined by examination under 80 power magnification.

B. Solderability - In completed cable the tinned conductors shall meet the solderability requirement of Appendix A.

C. Tin Thickness - Free tin shall be determined with a "Grower Test Set" and the requirement shall apply only to wire tested immediately following the insulating operation. Total tin is determined by the atomic absorption method or other suitable means and the requirement applies to all completed wire. Free tin coverage shall be a minimum of 2.0 milligrams per square inch and total tin coverage shall be a minimum of 2.3 milligrams per square inch.

5.2 Insulation

5.2.1 Raw Material

The use of an acceptable raw material formulation for the insulation is critical, not only to comply with the mechanical and electrical specifications set forth herein for newly manufactured product, but also to insure that the material has long term stability, thereby promoting long term product safety and reliability.

Collectively, the raw material requirements specified in Table I bound the range of acceptable formulations so the desired long term stability is assured to a very large extent, while permitting maximum design flexibility on the part of the formulator. These requirements may at some time be augmented or replaced by tests designed to assure long term product safety and reliability. Absent such changes, the insulation shall be a semi-rigid poly (vinyl chloride) compound. Such compound shall be designated either an outdoor or indoor type and shall comply with all of the applicable requirements in Table I. All insulation in any single length of completed cable shall be of the same type.

5.2.2 Porosity

A requirement on porosity is established to guard against loss of mechanical strength of the insulation, to maintain a uniform effective dielectric constant, and to limit long term moisture problems. There shall be no porosity in the PVC insulation when samples are examined under 5X magnification.

5.2.3 Compression Resistance

Compression resistance is a measure of the insulation's ability to withstand the compressive forces which may be encountered during installation or as a result of abuse (e.g., heavy furniture placed on the wire). It is a readily measured property which indicates that the insulation has been properly extruded. It is also a signature that the specified insulation material has been employed. Specimens of single insulated conductors shall be tested in accordance with procedures specified in Appendix B. A steel mandrel not more than .002 inches smaller in diameter than the copper conductor shall be inserted in the insulation in place of the conductor. The sample shall be conditioned at the specified test temperature for at least 1 hour immediately prior to the test.

5.2.4 Shrink-Back

Excessive insulation shrink-back can cause shorts or crosses in high density terminating fields. Therefore, specimens of single insulated conductors are tested in accordance with test procedures specified in Appendix C. The total shrinkage shall not exceed 1/4 inch.

5.2.5 Elongation

Elongation is a measure of the insulation's ability to withstand the bending stresses which may be encountered during installation. It is a readily measured property which signifies that the insulation has been properly extruded and cooled. Any section of poly (vinyl chloride) insulation removed from a conductor shall have an elongation at break of at least 175 percent when tested in accordance with the physical test procedures of ASTM Specification D470, except that the test temperature shall be 23±2°C (73.4±3.6°F). The standard rate of travel shall be 2±1 inches per minute. For routine inspection, a higher rate of travel, up to 40 inches per minute, may be used. In the event of failure at the higher rate, a retest shall be made at 2 inches per minute.

5.2.6 Wrap Test After Aging

A wrap test after aging requirement has been established to gauge the relative performance of the insulation plasticizer with the passage of time. Any length of insulated conductor approximately 12 inches long shall be placed in an air oven maintained at 121±1.2°C (249.8±2.2°F) for a continuous period of 48 hours. The oven shall conform to ASTM Specification D573 or an approved equivalent. After removal from the oven the specimen shall be allowed to cool to 23±2°C (73.4±3.6°F) and shall then be wound tightly for 6 close turns around a steel mandrel having a diameter of 0.038 inch maximum. The insulation shall be examined for cracking, using a lens having 5X magnification. There shall be no cracks in the insulation at the outside surface or at the surface next to the conductor. For inspecting the latter, the insulated conductor shall be straightened, one side of the tube of insulation sliced off with a knife or razor blade, and the conductor removed to permit examination of the inner surface.

5.2.7 Cold Temperature Handling (Outdoor Insulation Only)

To assure that low temperature handling properties have not been compromised either through errors in insulation formulation or in the extrusion process, a cold wrap test has been established. This test and requirement applies only to outdoor type insulation.

Any length of single insulated conductor with a 3 pound minimum load affixed at one end shall be wrapped for 5 consecutive turns in a close helix about a cylindrical steel mandrel having a maximum diameter of 0.040 inches. When examined at 5X magnification, not more than 20 percent of any lot of test specimens shall have cracks in the insulation. When performing the test, the insulated conductor shall be wrapped at a rate of approximately 60 turns per minute. Sharp bends and twisting shall be avoided in bringing the conductor upon the mandrel for test. The test temperature shall be (minus) -17.8±2.8°C (0 ± 5°F). The test specimen and mandrel shall be maintained at this temperature for at least 4 hours immediately prior to and during testing.

5.2.8 Adhesion

If the insulation adhesion at the conductor/insulation interface is too great, excessive force might be required when stripping wire and this could result in conductor damage. Therefore, a requirement is placed on adhesion as follows:

The adhesion of the insulation to the conductor shall be such that a force of 2 pounds maximum, and 3/4 pounds average, applied parallel to the axis of the conductor, is required to strip a 1-1/4 inch length of insulation from the conductor. The sample used in making this test shall have the insulation removed from the conductor for several inches of its length and the 1-1/4 inch length of insulation to be tested shall be at one end of the sample. The stripped conductor shall be passed through a die having an aperture of 0.022 inch to 0.025 inch and the tension shall be applied between the conductor and the die. The speed of the moving head of the testing machine under "No Load" condition shall be constant at 6 ± 1 inch per minute.

5.2.9 Patching

Discontinuities in the conductor insulation due to splices or injuries may be repaired, but all lengths of insulated conductor containing such repaired sections shall conform to the electrical requirements of this specification. The repairs shall be made using a poly (vinyl chloride) compound of the same grade as the insulation and shall be molded in place by the application of heat to insure thorough bonding of the patching compound to the insulation. Other approved methods may be used. In any case, the diameter of the patched section shall not be greater than twice that of an adjacent section.

5.2.10 Flammability - Insulation

To assure that the poly (vinyl chloride) compound does not readily support combustion, any sample of insulated conductor from a completed cable shall be capable of conforming to the following flammability requirement: Ten specimens shall be tested during the process. A maximum of two of the ten specimens may burn at 28% O_2 when tested in accordance with ASTM D2863.

5.3 Jacket Slitting Cord

A jacket slitting cord is a relatively inexpensive aid for jacket removal in those cases where its presence will not detract from appearance. It must be strong enough and flexible enough to perform its function in a reliable manner. Therefore, all cables, except for those less than 30 feet long used as connector cable, shall have a jacket slitting cord. The jacket slitting cord shall be 840 denier - 2 ply nylon or equivalent, and shall have a breaking strength of at least 28 pounds and an elongation of 7 to 14 percent at 10 pounds pull. These tests shall be made at $23 \pm 2^{o}C$ ($73.4 \pm 3.6^{o}F$) and $50 \pm 2\%$ relative humidity. Furthermore, the cord shall be laid longitudinally between the outer surface of the cable core and jacket and shall be continuous throughout any length of completed cable.

5.4 Jacket

Three pair cable is used extensively in pre-wiring. Therefore, the jacket for 3-pair cable shall be of the outdoor type. Cables with twelve or more pairs are used indoors exclusively, therefore, these cables shall utilize an indoor type jacket. Cables with 4 or 6 pairs may utilize either an outdoor or indoor type jacket as required.

5.4.1 Raw Material

The use of an acceptable raw material formulation for the jacket is critical, not only in assuring compliance with the mechanical and electrical specifications set forth herein for newly manufactured product, but also in assuring that the material has good long term stability, thereby contributing to long term product safety and reliability.

The raw material requirements in Table II collectively bound the range of acceptable formulations such that the desired long term stability is to a very large extent assured, while permitting maximum design flexibility on the part of the formulator. These requirements may at some time be augmented or replaced by tests designed to provide long term product safety and reliability. Absent such changes, the insulated conductors and slitting cord shall be enclosed in a continuous jacket of plasticized poly (vinyl chloride) compound. Either a weatherized (ultraviolet light resistant) outdoor type or non-weatherized indoor type shall be used, as required. In either case, the compound shall comply with all of the relevent requirements specified in Table II.

5.4.2 Porosity

A requirement on jacket porosity is established to help assure against deterioriation of the mechanical and electrical properties of the jacket. Hence, there shall be no porosity within the PVC jacket when samples are examined under 5X magnification.

5.4.3 Elongation

Elongation is a measure of the jacket's ability to withstand bending stresses which may be encountered during installation. It is a readily measured property which helps assure that the jacket has been properly extruded and cooled. Thus, any length of jacket from a sample of completed wire, after removal of the insulated conductors and slitting cord, shall be capable of conforming to the following elongation requirement: The elongation at break shall be at least 200 percent when tested in accordance with the physical test procedures of ASTM Specification D470, except that the test temperature shall be $23 \pm 2^{o}C$ ($73.4 \pm 3.6^{o}F$).

5.4.4 Elongation After Aging

An elongation after aging requirement has been established to assure the relative performance of the jacket plasticizer with the passage of time. Hence, any similarly prepared length of jacket from the same sample as that discussed in 5.4.3 shall be capable of conforming to the following elongation requirement after the accelerated aging hereinafter specified. The elongation at break shall be at least 150 percent when measured according to ASTM D470 with a test temperature of 23±2°C (73.4±3.6°F). The aging period shall be 48 hours at a temperature of 100°C (212°F) in an oven conforming to the requirements of the ASTM Specification D573, or an approved equivalent.

5.4.5 Adhesion

Excessive adhesion of the jacket to the core of insulated conductors can result in damage to the insulation during jacket removal. This problem is of particular concern when the same class of materials is used for both the insulation and the jacket. Therefore, the core to jacket adhesion of any length of cable shall be not greater than that exhibited in the following test (the test temperature shall be 18°C (64.4°F) minimum and 35°C (95°F) maximum): Hang a 4-foot length of cable vertically such that the cable is accessible for stripping from the floor and is free hanging. Butt trim the upper end of cable with a suitable tool, slit the jacket from top to bottom, and roll the upper edge down. Attach a 3-pound weight to the upper edge and opposite the slit. The adhesion shall be such that 3 feet of jacket falls off in not more than 30 seconds with no external force other than that of the attached weight.

5.4.6 Cold Temperature Handling (Outdoor Cable Only)

So that low temperature handling properties have not been compromised either through errors in jacket or insulation formulation or in the extrusion process, a cold wrap test for completed cable shall be met. This test and requirement applies only to outdoor type cable (usually 3 pair).

Any length of completed cable with a 9 pound minimum load affixed at one end is wrapped for 5 consecutive turns in a close helix about a cylindrical steel mandrel. The mandrel size is as follows:

3 pair cable - .165 inch maximum diameter
4 and 6 pair cables - .29 inch maximum diameter

The cable shall be wrapped at a rate of approximately 60 turns per minute. Sharp bends and twisting shall be avoided in bringing the cable upon the mandrel for test. The test temperature shall be (minus) -17.8±2.8°C (0±5°F). The test specimen and mandrel shall be maintained at this temperature for at least 4 hours immediately prior to and during the test. There shall be no cracks in the jacket when examined at 5X magnification after testing.

5.4.7 Dynamic Thermal Stability

Any sample of jacket from completed cable shall be capable of conforming to the following dynamic thermal stability requirement: The processing time shall be 30 minutes minimum when tested in accordance with Appendix G; using a speed of 100 rpm, a temperature of 205°C, a Type 5 roller head and a sample weight in grams equal to 45X specific gravity. The jacket material shall be fed from the hopper section of the roller head.

5.4.8 Flammability - Jacket

To assure that the poly (vinyl chloride) compound does not readily support combustion, any sample of jacket from completed cable $\leq$25 pair size shall be capable of conforming to the following flammability requirement: A maximum of two of ten specimens may burn at 29% O_2 when tested in accordance with ASTM 2863. The jacket specimens shall be in tube form for cables $\leq$ 6 pair size and die punched to 0.25 inch width for cables 6 up to 25 pair size. Ten specimens shall be tested during the process.

5.4.9 Absorption Coefficient (Outdoor Jacket Only)

To affirm adequate resistance against sunlight degradation of the poly (vinyl chloride) compound, any sample of jacket from completed cable shall be capable of conforming to the following light absorption requirement: The absorption coefficient shall be 170 minimum when tested in accordance with ASTM D3349 at a wavelength of 375 nanometers.

5.5 Completed Cable

5.5.1 Flame Spread

To assure that installed cables do not constitute a serious threat to fire safety, any sample of completed cable $\leq$ 25 pair size shall be capable of conforming to the following flame spread requirement: The flame spread shall be 19 ft. maximum when tested in accordance with Underwriters Laboratories Inc. "Outline of Proposed Test Method for Cables With Respect to Fire and Smoke Considerations," Subject 910, October 1979.

6. COLOR CODING AND PRODUCT IDENTIFICATION REQUIREMENTS

6.1 Insulation

6.1.1 Color Coding

Insulation color coding is required so that conductor pairs can be properly identified since it is often impractical to check both ends of the cable after installation. Therefore, color coding shall be accomplished by use of colored insulation in combination with either a) single marks of a colored ink, or b) an extruded colored stripe. The color coding sequence shall be as follows for the first 25 pairs in a cable, each pair being twisted together as specified in section 7.1:

Pair No.	Ring Conductor: Color of Insulation	Ring Conductor: Color of Mark of Stripe	Tip Conductor: Color of Insulation	Tip Conductor: Color of Mark or Stripe
1	Blue	White	White	Blue
2	Orange	White	White	Orange
3	Green	White	White	Green
4	Brown	White	White	Brown
5	Slate	White	White	Slate
6	Blue	Red	Red	Blue
7	Orange	Red	Red	Orange
8	Green	Red	Red	Green
9	Brown	Red	Red	Brown
10	Slate	Red	Red	Slate
11	Blue	Black	Black	Blue
12	Orange	Black	Black	Orange
13	Green	Black	Black	Green
14	Brown	Black	Black	Brown
15	Slate	Black	Black	Slate
16	Blue	Yellow	Yellow	Blue
17	Orange	Yellow	Yellow	Orange
18	Green	Yellow	Yellow	Green
19	Brown	Yellow	Yellow	Brown
20	Slate	Yellow	Yellow	Slate
21	Blue	Violet	Violet	Blue
22	Orange	Violet	Violet	Orange
23	Green	Violet	Violet	Green
24	Brown	Violet	Violet	Brown
25	Slate	Violet	Violet	Slate

Cables containing more than 25 pairs shall be color coded by repeating the sequence given above for each of the groupings or units of 25 (or fewer) pairs contained in the cable and by binding each of these units using color coded binders. The color coding sequence for the binders shall be as follows:

Cable Pair Size	Unit(s)	Pair Numbers	Unit Binders
3	1	1 to 3	-
4	1	1 to 4	-
6	1	1 to 6	-
12	1	1 to 12	-
16	1	1 to 16	-
21	1	1 to 21	-
25	1	1 to 25	-
40	1	1 to 25	Blue-White
	2	1 to 15	Orange-White
50	1	1 to 25	Blue-White
	2	1 to 25	Orange-White

Cable Pair Size	Unit(s)	Pair Numbers	Unit Binders
75	1	1 to 25	Blue-White
	2	1 to 25	Orange-White
	3	1 to 25	Green-White
100	1	1 to 25	Blue-White
	2	1 to 25	Orange-White
	3	1 to 25	Green-White
	4	1 to 25	Brown-White
125	1	1 to 25	Blue-White
	2	1 to 25	Orange-White
	3	1 to 25	Green-White
	4	1 to 25	Brown-White
	5	1 to 25	Slate-White

6.1.2 Color Variation

Color limits are required to guard against color variation that could cause pair identification difficulties. Hence, the insulation colors, including the extruded stripes (if stripes are used), shall match the following standards when examined under the equivalent of north sky daylight having a correlated color temperature of 7400° Kelvin:

Color	Munsell Designation		
	Light Limit	Centroid	Dark Limit
Blue	2.5 PB 6.5/10	2.5 PB 5.5/10	2.5 PB 4.5/10
Orange	10 R 6/12	9.8 R 5.25/13.5	-
Green	2.5 G 5.5/12	2.5 G 5/12	2.5 G 4.5/12
Brown	2.5 YR 4/6	2.5 YR 3.5/6	2.5 YR 3/6
Slate	N 5.5/	-	N 5/
White	N 9.4/	-	N 9/
Red	2.5 R 4.5/12	2.5 R 4/12	2.5 R 3.5/12
Black	N 2/	N 1.5/	N 1/
Yellow	-	5 Y 8.5/12	5 Y 8/12
Violet	2.5 P 4.5/10	2.5 P 4/10	2.5 P 3.5/10

If colored ink markings are used, the color of the ink markings, after application, shall match their respective Munsell Designation given below as closely as commercially practicable.

Color	Munsell Designation	Color	Munsell Designation
Blue	2.5 PB 4.5/10	Red	7.5 R 4/14
Orange	8.7 R 5/14	Black	N 1/
Green	2.5 G 5/12	Yellow	2.5 Y 8/12
Brown	7.5 YR 4/4	Violet	2.5 P 4.5/10
Slate	5 PB 6/2		
White	N 9/		

6.1.3 Color Permanency

6.1.3.1 Ink Marks

If colored ink markings are used, the ink and the dying process must gaurantee a long term reliable marking in the anticipated environment. Thus, the ink used for marking shall be non-conductive and permanent and shall employ pigments or dyes least affected by light, by the plasticizer incorporated in the insulation, and by temperatures up to 90°C (194°F). On the finished conductor markings shall remain fast when specimens are immersed for 15 minutes in tap water, mineral spirits, and turpentine; one specimen to be immersed in each fluid. To test for fastness, the specimen shall be removed from the fluid and drawn once through a wiper consisting of four thicknesses of bleached Grade A cheesecloth which is held between the forefinger and the ball of the thumb with a force of about two pounds. There shall be no more than a slight transfer of color to the cloth and there shall be no more than a slight smearing of the ink on the wire.

6.1.3.2 Colored Stripes

Adequate color permanency and easy pair identification shall be provided by extruding (in the insulation) longitudinal color coded stripes using the same raw material formulation as that specified for the insulation (section 5.2.1) and by designing the stripe to form an integral wedge-shaped section of the insulation which shall extend around the circumference of the insulated conductor for $120 \pm 30^{\circ}$.

6.1.4 Size and Location of Ink Marks

The following dimensional requirements represent one satisfactory approach to ink marking which achieves the primary objective of easy pair identification. Other acceptable approaches may exist and will be considered provided they shall comply with the above stated primary objective. Thus, the following requirements are desirable objectives:

A. An individual code mark should consist of a single ink mark applied to one side of the insulated wire. A complete code mark should consist of the single ink mark on one side of the wire and its corresponding mark on the opposite side of the insulated wire. The individual code markings should be spaced center to center 0.63 inch minimum, 0.75 inch maximum, along the wire. The length along the insulated wire of each individual code mark should be 0.13 inch minimum, 0.25 inch maximum with an average length of 0.19 inch.

B. All markings should be applied in such a manner that for each mark on one side of the insulated wire there should be a corresponding mark approximately 180° around the circumference. Each ink marking on each side of the insulated wire should extend around its circumference a minimum of 120°.

C. An individual code mark should be considered defective if it cannot be identified from the specified color coding when looking at the code mark from the direction of application. In any 40 consecutive marks, there should be no more than 5 defective individual code marks on each side of the insulated conductor, and 2 defective marks should not occur consecutively. If a sample fails to meet this requirement, but the two adjacent lengths on both sides of the sample conform, the coding is considered acceptable.

6.2 Jacket Color

A jacket color requirement has been established to provide compatibility with the great variety of customer decors. Thus, the jacket compound shall be light olive gray per OS-10808 or ivory per Munsell 2.1Y8.45/1.85, whichever applies as specified below. The colors shall match these standards as close as is commercially practicable when examined under the equivalent of north sky daylight having a correlated color temperature of 7400° Kelvin. The jacket type and color shall be as follows:

Cable Size	Jacket Type	Jacket Color
3, 4 and 6 pair	Outdoor	Ivory Only
4 and 6 pair	Indoor	Ivory or Light Olive Gray
12, 16, 21, 25 40, 50, 75, 100, and 125 pair	Indoor	Light Olive Gray Only

6.3 Product Indentification

In order to properly track the field performance of products made by different manufacturers and to identify a product as being supplied by the Bell System, it is necessary to uniquely identify each product. Therefore, inside wiring cable shall carry a marker laid longitudinally between the core and the jacket. The marker shall be the manufacturer's identifying marker and shall consist of nylon or rayon yarn not coarser than No. 20/1 ply or equivalent. The yarn shall be continuous in any length of wire.

Each manufacturer's marker shall consist of two strands of yarn. The colors shall be assigned by the American Telephone and Telegraph Company from among the following eight:

Blue	Slate
Orange	Yellow
Green	Red
Brown	Black

The colors shall approximate the centroid shown in the "Munsell Color Charts for color coding, EIA Standard RS-359, 1969".

7. ASSEMBLY REQUIREMENTS

7.1 Insulated Conductor Twisting

In order to limit interpair crosstalk, a number of variables must be controlled. Three of these variables relate to assembly, namely; type of twist, direction of twist, and length of twist. Hence, the following requirements are imposed:

A. The insulated conductors shall be twisted together as twisted pairs and marked for identification as specified in section 6.1.1.

B. The insulated conductors of each pair shall be twisted together with a left-hand twist; a left-hand twist being defined as a counterclockwise twist away from the observer.

C. The length of twist shall be defined as the length in inches found by dividing 120 (the length of the required test sample in inches) by the number of turns (twists) in the sample. The twisting operation shall be such as to produce a length of twist not more than 5.5 inches. For individually twisted pairs, the twist lengths selected shall not include odd or even multiples of one another nor a multiple of 1.5.

7.2 Cable Core Construction

To minimize cable stiffness and to facilitate handling and installation, cables with more than 6 pairs shall use a stranded lay structure. The twisted pairs shall be formed into units consisting of one or more circular layers (this improves crosstalk characteristics). Each unit shall consist of Pair No. 1 (26, 51, etc.) plus the remaining required pairs in numerically ascending order up to Pair No. 25 (50, 75, etc.). All of the pairs in each unit shall be stranded together (for cables over 6 pairs) using a right hand stranding lay and the length of lay shall be 15 ± 1 inches. A right hand lay shall be defined as a clockwise twist away from the observer. The length of lay shall be measured as the average length of five consecutive twists in the cable when taken without distortion from the shipping reel and with the ends held to prevent changes of lay length resulting from residual stresses. Cables larger than 25 pairs shall be formed by laying all pairs of each unit parallel prior to final cabling and binding each unit with a unit binder. The units shall then be stranded together with a right hand lay of 15 ± 1 inches in length. The cable construction shall be as follows:

Cable Pair Size	Unit(s)	Pair Numbers	Unit Binders
3	1	1 to 3	-
4	1	1 to 4	-
6	1	1 to 6	-
12	1	1 to 12	-
16	1	1 to 16	-
21	1	1 to 21	-
25	1	1 to 25	-
40	1	1 to 25	Blue-White
	2	1 to 15	Orange-White
50	1	1 to 25	Blue-White
	2	1 to 25	Orange-White
75	1	1 to 25	Blue-White
	2	1 to 25	Orange-White
	3	1 to 25	Green-White
100	1	1 to 25	Blue-White
	2	1 to 25	Orange-White
	3	1 to 25	Green-White
	4	1 to 25	Brown-White
125	1	1 to 25	Blue-White
	2	1 to 25	Orange-White
	3	1 to 25	Green-White
	4	1 to 25	Brown-White
	5	1 to 25	Slate-White

7.3 Binders

7.3.1 Unit Binders

Each unit of the 40 to 125 pair sizes shall be bound with two strips of 3/16 inch minimum width colored polyolefin tape. One strip of each specified color shall be used (see Section 7.2). The colors shall match the standards previously specified for insulation (section 6.1.2). The binders shall be applied, right hand twisted, with a 5 inch maximum twist length. The binder shall have a 50% retention of tensile strength at break after forced air oven aging for six hours minimum at 160°C (320°F). The binder tension shall be controlled so as to avoid impressions in the conductor insulation.

7.3.2 Core Binders

It is permissible to bind the cable core as a processing aid. If this is done, it shall be done direction left, with one or more binder servings of natural or synthetic textile yarn or a polyolefin tape. In addition, the binder tension shall be controlled so as to avoid impressions in the conductor insulation.

7.4 Jacket

In order to obtain an acceptable surface appearance, to provide compatibility with cable attachment fixtures, and to facilitate easy installation and adequate raceway fill, the jacket shall be fit as tightly on the cable core (including jacket slitting cord) as is consistent with good commercial practice and shall be free from openings and other defects.

8. ELECTRICAL REQUIREMENTS

8.1 Continuity and Shorts

Absolute minimum requirements for the wire to perform as a reliable transmission medium are that it be electrically continuous and free from shorts. Hence, all completed cable shall be free from opens and from short circuits between conductors. The minimum voltage for determining the absence of these conditions shall be 48 volts D.C.

8.2 Insulation Imperfections

Conductive inclusions and/or physical damage to the insulation, if not limited, can degrade transmission quality. Spark testing is a convenient and economical means for detecting such imperfections. Therefore, all single insulated conductors shall be spark tested in accordance with Appendix D prior to twisting. (Either alternating current or direct current testing shall be used.) The insulated conductor shall show not more than an average of one fault per 3000 feet in any reel length of insulated conductor. There shall be no faults in which more than a 1-inch length of conductor is exposed.

8.3 Conductor Resistance

Conductor resistance must be limited to keep voiceband transmission and supervisory signaling losses at an acceptably low level. A resistance test on completed cable helps confirm that the proper type and size conductor has been used without excessive draw-down. Thus, the direct current resistance of any conductor of the completed cable shall be no greater than 28.6 ohms per 1000 feet at a temperature of 20^{o}C (68^{o}F).

8.4 Insulation Resistance

Conductor insulation resistance must be sufficiently high so as not to degrade either voiceband transmission or supervisory signaling. Thus, before jacketing, any 50 foot or greater length of insulated conductor shall conform to the following insulation resistance requirements while immersed in water under conditions that insure complete wetting of the surface of the wire, and having been so immersed for a period of at least 12 hours immediately prior to testing: The insulation resistance from the conductor to the water shall be at least 300 megohms /1000 feet at or corrected to a temperature of 23°C (73.4°F). The insulation resistance for any length shall be corrected to a 1000 ft. basis by multiplying the insulation resistance value by n/1000 where n equals the length of the test sample. The measurement is made using a General Radio Corp. Model 1862 Megohmmeter or an approved equivalent. The voltage used for testing shall be a minimum of 100 volts D.C. and maximum of 500 volts D.C. and one pole shall be grounded. The test voltage shall be applied for 60±5 seconds before reading the insulation resistance values. Corrections for measurements made on lengths of cable of less than 1,000 feet are made by computing insulation resistance from the following equation:

$$\text{Insulation Resistance} = \text{Measured Insulation Resistance} \times \frac{n}{1{,}000}$$

where n is the actual length of cable used in the measurement.

The insulation resistance shall be corrected to the reference temperature of 23°C (73.4°F) by multiplying the measured value of insulation resistance by the coefficient specified below corresponding to the temperature of the water at the time the measurement was made. Temperature readings shall be accurate to within ±.1°C (± .2°F). The coefficients are as follows:

Temperature Correction Coefficients

°F	Coeff.	°F	Coeff.	°F	Coeff.
60	.21	70	.67	78	1.53
62	.27	72	.85	80	1.78
64	.34	73.4	1.00	82	2.12
66	.43	74	1.07	84	2.71
68	.54	76	1.30	86	3.76

Any required interpolation between values on this chart shall be linear.

8.5 Coaxial Capacitance

The coaxial capacitance of the insulated conductors must be sufficiently low so as not to degrade voice band transmission. This capacitance can be degraded during processing by an increase in the insulation dielectric constant or via excessive conductor/insulation eccentricity. Therefore, before jacketing, any 50 foot or greater length of insulated conductor shall conform to the following coaxial capacitance requirements while immersed in water under conditions that insure complete wetting of the surface of the wire, and having been so immersed for a period of at least 12 hours immediately prior to testing: The coaxial capacitance from conductor to water of the insulated conductor shall be no more than .15 microfarads per 1000 feet when measured at a frequency of 1.0 kilohertz and a temperature of 23 ± 2°C (73.4 ± 3.6°F).

8.6 Capacitance Unbalance

Crosstalk can occur if the capacitive coupling between pairs is not sufficiently balanced. Therefore, the pair to pair capacitance unbalance of any pair combination in any sample of completed cable 100 feet in length shall not be greater than 70 picofarads when measured at a frequency of 1.0 kilohertz. The unbalance may be measured on longer lengths and converted to a 100 feet basis in which case the measured unbalance shall be multiplied by $\sqrt{100/n}$ where n equals the length measured. The average pair-to-pair capacitance unbalance of all possible intra unit combinations of any unit shall not be greater than 45% of the maximum value for that unit. Additionally, in multi-unit cables the average pair-to-pair capacitance unbalance of all possible inter-unit combinations between the outer layer of one unit and the outer layer of all other units shall not be greater than 45% of the maximum value for that cable. The Siemens capacitance unbalance bridge type REL 3R 313 is a suitable measuring device for these measurements. In any case, capacitance unbalance shall be computed as shown in Appendix E.

8.7 Longitudinal Balance

Longitudinal balance requirements shall be provided at a later date.

8.8 Voltage Breakdown

The insulation of the completed cable shall form an adequate dielectric barrier to potential power crosses when the jacket has been removed, thereby protecting telephone company equipment and craftpersons who might be working on the line at the time of a cross or shortly thereafter. To confirm that the insulation is free from mechanical damage or dielectric defects which could reduce the wire's ability to withstand such crosses, the following requirement is established. Any length of completed wire, not less than 150 feet in length, shall be capable of withstanding at least one of the following: a) potential of 2000 volts A.C. (RMS) or b) a potential of 2800 volts D.C. In either case, the voltage shall be applied for a least 1 second between each conductor individually and all other conductors tied together and to ground.

8.9 Federal Communications Commission (FCC) Requirements

A. Any length of completed cable shall be capable of conforming to the requirements of FCC Rules and Regulations, Part 68, Section 68.215.

B. In particular, insulated conductors shall have a jacket or sheath with a 1500 volt rms minimum breakdown rating, except where located in an equipment enclosure or an equipment room with restricted access. This rating shall be established by covering the jacket or sheath with at least six inches (measured linearly on the cable) of conductive foil, and establishing a potential difference between the foil and all of the individual conductors connected together, such potential difference gradually increased over a 30 second time period to 1500 volts rms, 60 Hz, then applied continuously for one minute. At no time during this 90 second time interval shall the current between these points exceed 10 milliamperes peak.

9. PACKAGING REQUIREMENTS

The primary objective in specifying packing requirements is to provide an economical, conveniently sized package which permits tangle free distribution of cable from an unattended dispenser. Therefore, the majority of the following requirements are desirable objectives which, taken as a whole, specify one acceptable design which has proven effective. Other methods of packaging will be considered, provided they shall comply with the above stated primary objective.

It is desirable that the cable be packaged, depending on size, in one of the following preferred manners:

Cable Size	Acceptable Packaging
3 pair	disposable spools or disposable dispensing cartons
4 pair	disposable spools
6,12,16,21,25, 40,50,75,100, and 125 pair	large wooden reels or coils laid in shipping containers

Each wooden reel, coil, disposable spool, dispensing carton, or other approved package shall be marked in a suitable manner with the following information:

- Manufacturer's name or trademark
- Cable type
- Length in feet
- Date of manufacture
- Gauge of conductors
- Jacket color
- Any auxiliary information which aids the wire dispensing function or inventory management.

9.1 Dispensing Cartons

This type of packaging is intended for 3-pair cable used for the wiring of fully completed buildings (as opposed to prewiring unfinished buildings).

The cable shall be furnished in coils individually packed in cartons. The wire in each coil shall be in one continuous length. Of the following requirements, A through D are desirables and E is mandatory:

A. The coiling process should produce a coil approximately 400 feet in length. The length of cable in each nominal 400 foot coil should not be less than 385 feet. Exceptions may be granted for a small percentage of coils (perhaps 1 or 2 percent) to reduce waste. However, the minimum allowable length of any coil should be 100 feet. The cable should be evenly and compactly coiled. Each coil should be wound with an eye diameter of approximately 8 inches. The mean outside diameter of the completed coil should not be more than 12-1/4 inches.

B. Each coil should be packed individually in a carton one side of which should have a knockout 7 inches in diameter centrally located and capable of easy removal. On the same side of the carton, a knockout 1-1/2 inches in diameter should be provided. The small knockout should be located so that, when removed, the amount of cable remaining on the coil can be estimated. The opposite side of the carton should have a small knockout which, when removed, will provide an opening through which the fingers or a strap may be passed to facilitate carrying the packaged coil.

C. Each coil should be placed in the carton so that the inner end of the coil will pay out in a counterclockwise direction through the hole provided by the removal of the circular knockout. A suitable insert should be included to insure that the cable will pay out of an unattended carton without developing excessive tangles. The inner end of each coil should be secured in a lock strip cut into the panel of the carton opposite the 7 inch knockout.

D. The words "TO OPEN REMOVE THIS KNOCKOUT" should be marked on the circular knockout and the words "REPLACE WIRE IN SLOT AFTER CUTTING" and "DO NOT REMOVE INSERT" should appear outside the periphery of this knockout. The words "OPEN FOR FIELD INSPECTION" should be marked on the small knockout. the words "OPEN OTHER SIDE" should appear on the opposite side of the carton.

E. Any coil of cable shall be capable of pay out from its dispensing carton without incurring more than one knot or kink at any point throughout the entire coil length. The knot or kink shall not prevent the free pay out of all remaining convolutions of cable.

9.2 <u>Disposable Spools</u>

This type of packaging is intended for 3 and 4 pair cable used in prewiring buildings. Thus, it is essential to have long and continuous pieces of cable to reduce the need for splicing.

The cable shall be furnished as one continuous length of not less than 1000 feet on small disposable spools of sufficient strength to withstand normal handling in transportation and storage. Each spool shall be packaged in fiberboard shipping containers constructed in accordance with Rule 41 of the Uniform Freight Classification and meet the following requirements:

A. It is desirable that the dimensions of the spools be: overall width, 8-3/8 ± 1/8 inches; diameter of spool heads, 10 ± 1/4 inches; and arbor hole, 2-3/4 + 0-1/8 inches.

B. To enable dispensing of the cable, it is desirable that the shipping container contain suitable knockout holes in which a 3/4 inch diameter mandrel may be inserted.

9.3 Coils Laid in Shipping Containers

This type of packaging is intended for short pieces of cable which are by-products of longer cable packaging discussed in Section 9.4. It applies only to cables of 6 or more pairs.

The cable shall be furnished in coils of one continuous length. Several coils may be packed in corrugated fiberboard shipping containers, constructed in accordance with Rule 41 of the Uniform Freight Classification, and which meet the following requirements:

A. It is desirable that the length of each coil be at least 50 feet minimum or no more than 150 feet maximum.

B. It is desirable that the eye diameter of the coil be 9 inches minimum.

C. It is desirable that each coil be bound securely with strong twine or tape in three places spaced equally around the circumference of the coil.

9.4 Large Wooden Reels

This type of packaging is for cables having 6 or more pairs.

The cable shall be furnished on large reels of sufficient strength to withstand normal handling in transportation and storage. The cable shall be supplied in one continuous length. Exceptions may be granted for a small percentage of coils (perhaps 1 or 2 percent) in order to reduce waste.

The following requirements A through D are desirable:

A. The dimensions of the reel should be: overall width, 20 inches miximum; diameter of the reel heads, 36±1/2 inches; and arbor hole 2-3/4±1/16 inches. Each reel should be lagged with a fiberboard reel mat dimensioned to fit snugly between the reel heads and completely cover the outer turns of cable. The reel mat should protect the cable during normal handling and storage and should be secured by tensioned flat or round steel banding.

B. The cable should be supplied in one continuous piece not less than 1,000 feet in length. Exceptions may be granted for a small percentage of coils (perhaps 1 or 2 percent), however, each reel may contain not more than five pieces of cable of the same pair size and color, and not more than one piece shall be less than 150 feet in length.

C. On each reel containing more than one piece of cable, the innermost cable should be designated "Number 1" and the succeeding pieces should be numbered consecutively. A durable tag with the marking information previously specified should be securely fastened to the outer end of each piece on the reel.

D. The outer end of each piece of cable should be securely fastened to the inside of the reel head or secured by a strong twine tie by fastening one end of the tie to the outer end of the piece of cable and passing the free end of the tie once around the reel over the turns of cable and tying securely to the same end of the piece of cable.

PRELIMINARY

TABLE I

RAW MATERIAL REQUIREMENTS

CHEMICAL, PHYSICAL AND ELECTRICAL CHARACTERISTICS OF OUTDOOR (LOW TEMP.) AND INDOOR POLY (VINYL CHLORIDE) PLASTIC (CONDUCTOR INSULATION)

Property	Requirements		Test Procedure
	Outdoor Compound	Indoor Compound	
Heat Distortion	15% max.	15% max.	ASTM D2633, 2000 g load, 121° C.
Low Temperature Brittleness	-15°C, 2/10 failures max.	N. A.	ASTM D746, Test 10 specimens. Failures are complete breaks.
Flammability (Oxygen Index)	31% oxygen min.	31% oxygen min.	ASTM D2863, except thickness is 0.075" ± .010"
Tensile Strength	3000 psi min.	3000 psi min.	ASTM D412, use Die C and 20"/min. speed
Ultimate Elongation			
Original	200% min.	200% min.	ASTM D412, use Die C and 20"/min. speed,
Aged	80% of original	80% of original	and ASTM D753, 7 days aging at 100° C
Shear Strength	1450 lb f min.	2000 lb f min.	Appendix B
Volatile Loss	1.0% max.	1.0% max.	ASTM D1203, Method A, 105°C, 24 hours
Plasticizer Compatibility	0 grade max.	0 grade max.	ASTM D3291
Thermal Stability	16 minutes min.	16 minutes min.	Appendix G, 205° C, 45.5 cc, 100 rpm
Volume Resistivity			
Dry	$5X10^{13}$ ohm-cm min.	$5X10^{13}$ ohm-cm min.	ASTM D257, 500 V. wet; after two days
Wet	$1X10^{13}$ ohm-cm min.	$1X10^{13}$ ohm-cm min.	immersion in tap water at 23°C
Dielectric Strength	500V/mil min.	500V/mil min.	ASTM D149 (1000 V/sec), 0.025" ± .005" thick test sheet
Dielectric Constant	4.2 min., 4.6 max.	3.5 min., 3.7 max.	Appendix F

PRELIMINARY

TABLE II

RAW MATERIAL REQUIREMENTS

CHEMICAL, PHYSICAL AND ELECTRICAL CHARACTERISTICS
OF
WEATHERIZED OUTDOOR AND INDOOR POLY (VINYL CHLORIDE) PLASTIC
(CABLE JACKET)

Property	Requirements: Outdoor Compound	Requirements: Indoor Compound	Test Procedure
Heat Distortion	30% max.	25% max.	ASTM D2633, 2000 g load, 121°C.
Low Temperature Brittleness	-45°C, 2/10 failures max.	-23°C, 2/10 failures max.	ASTM D746 Test 10 specimens. Failures are complete breaks.
Flammability (Oxygen Index)	29% oxygen min.	31% oxygen min.	ASTM D2863, except thickness is 0.075" ± .010".
Light Absorption	170 min.	N. A.	ASTM D3349
Color (Munsell)			
Ivory	2.1Y8.45/1.85	2.1Y8.45/1.85	ASTM D1535
Light Olive Gray	N. A.	6.4Y5.5/1.2	
Tensile Strength	2500 psi min.	2500 psi min.	ASTM D412, use Die C and 20"/min. speed
Ultimate Elongation	200% min.	200% min.	ASTM D412, use Die C and 20"/min. speed
Tear Resistance	300 lb f/in min.	450 lb f/in min.	ASTM D624, use Die B and 20"/min. speed
Shear Strength	500 lb f min.	650 lb f min.	Appendix B
Coefficient of friction	1.5 max.	0.9 max.	Appendix H
Plasticizer Compatibility	0 grade max.	0 grade max.	ASTM D3291
Volatile Loss	2.0% max.	2.0% max.	ASTM D1203, Method A, 105° C, 24 hrs.

PRELIMINARY

TABLE II (Continued)

Property	Requirements: Outdoor Compound	Requirements: Indoor Compound	Test Procedure
Thermal Stability	30 minutes min.	30 minutes min.	Appendix G, 205° C, 45.5 cc, 100 rpm
Volume Resistivity			
Dry	$5X10^{12}$ ohm-cm min.	$5X10^{12}$ ohm-cm min.	ASTM D257, 500 V. Wet; after two days immersion in tap water at 23°C.
Wet	$1X10^{12}$ ohm-cm min.	$1X10^{12}$ ohm-cm min.	
Dielectric Strength	300 V/mil min.	300 V/mil min.	ASTM D149 (1000 V/sec.), 0.025" ± .005" thick test sheet

APPENDIX A

SOLDERABILITY TEST

1. OUTLINE OF METHOD

The method determines the solderability of wire to be joined to terminals and other components by a soldering operation employing rosin flux and immersion in molten solder or by use of a soldering iron. Flux is applied to the surface to be tested, the surface is immersed in molten solder, and the coating is examined.

2. APPARATUS

2.1 Solder Bath

An electrically heated, thermostatically controlled solder pot of sufficient size containing at least 2 pounds of the required solder shall be used. The temperature control shall be capable of maintaining the solder at a temperature of 232 $\pm 6^{\circ}C$ (450 $\pm 10^{\circ}F$).

3. MATERIALS

3.1 Solder

The solder shall meet the requirements of Alloy Grade 60B per ASTM B 32 - nominal composition 60 tin and 40 lead.

3.2 Flux

The flux shall be 25 percent by weight of Grade WW rosin per ASTM D 509 and 75 percent by weight of 99 percent isopropyl alcohol.

4. PROCEDURE

4.1 Solder Bath

The solder bath is prepared as outlined in section 2.1 and maintained at 232 $\pm 6^{\circ}C$ (450 $\pm 10^{\circ}F$). The solder is stirred occasionally to maintain a uniform temperature. Dross and burned flux are skimmed from the molten solder surface prior to each test.

4.2 Solderability Test

Dip wire into flux to a depth of 1 to 2 inches. Keep the wire in the flux for at least 5 seconds. Withdraw it from the flux. Dip it immediately into the molten solder to the same depth, at a rate of approximately 1 inch per second. Keep in the molten solder for 2 to 5 seconds. Withdraw it at the rate of about 1 inch per second, and allow the solder to cool in the air.

5. REQUIREMENT

If the soldered surface is generally uniform and free from unwetted or untinned areas the wire shall be considered solderable and shall meet this requirement.

APPENDIX B

COMPRESSION TEST

1. OUTLINE OF METHOD

A specimen is placed between the parallel jaws of a compression-testing machine, and the force necessary to rupture the insulation is measured. If sheet insulation is to be tested, the upper jaw of the machine is replaced with a wedge. The testing machine produces an autographic record of the variation in thickness versus increase in load; it also registers the breaking load. Stress-strain relationships are read from the record chart. The test may be made in either of two types of apparatus (A or B).

2. APPARATUS

2.1 Type A Compression Tester

This is any suitable mechanical testing machine which applies the compression load through a steel spring (either 0-1000 lbs. or 0-2000 lbs.) at a fixed speed of either 1.5 or 2.25 inches per minute. It shall contain a drive mechanism and a recording indicator that furnishes a plot of specimen deformation versus compression load. The Scott Tester Inc., Model R Compression Tester is satisfactory for this purpose.

2.2 Type B Compression Tester

This is any suitable testing machine of the constant-rate-of-crosshead movement type which comprises a drive mechanism and a recording indicator that furnishes a plot of specimen deformation versus compressive load. The standard speed for the approach of the two crossheads shall be 0.5 cm (0.2 inch) per minute.

2.3 Wedge

This is a wedge shaped jaw suitable for testing sheet material PVC plastic as illustrated in Fig. B1. As shown, a 1 inch wide flat wedge surface is used.

3. PROCEDURE

3.1 Standard Atmosphere

All tests are run in an atmosphere having a temperature of 23 $\pm 1^{o}$C (73.4 $\pm 1.8^{o}$F) and an RH of 50 ± 2 percent.

3.2 Test Specimens

3.2.1 Insulated Wire

The test specimen shall be at least 15 cm (6 inches) long.

3.2.2 Sheet Materials

Sheet specimens shall have a minimum length of 5 cm (2 inches) and a minimum width of 0.64 cm (0.25 inch). If the material to be tested has been removed from a wire or cable, buff the specimen to a uniform thickness before cutting out the test specimen. At least three specimens are needed:

3.3 Testing Procedure

3.3.1 Insulated Wire

3.3.1.1 Rigid steel flats 5 cm by 2.5 cm (2 inches by 1 inch) that are aligned to match when closed are used as the upper and lower jaws. When the crushing load on a specimen in the 5 cm by 2.5 cm (2 inch by 1 inch) flats exceeds the 910 kg (2000 pound) capacity of the testing machine, smaller flats, 2.5 cm by 2.5 cm (1 inch by 1 inch) or 1.25 cm by 2.5 cm (1/2 inch by 1 inch) are used.

3.3.1.2 Place the wire between the jaws of the machine (parallel to the long edge) and start the machine. Determine the break point (the point at which the load produces an abrupt reduction in the jaw separation without a proportionate increase in load) from the stress-strain chart. Record this as the Breaking Load. When the 1.25 cm by 2.5 cm flats are used, position the wire so that a 1.25 cm length of wire is compressed.

3.3.1.3 The 15 cm (6 inch) length permits the making of two tests. Make the first test with one end of the specimen extending approximately 1.3 cm (1/2 inch) beyond the edge of the jaws. After the first test, rotate the sample through a 90 degree angle about the conductor axis; then position it so that the second test will be made about 2.5 cm (1 inch) away from the first test.

3.3.2 Sheet Materials

3.3.2.1 Jaws for Type A Machine: Replace upper steel flat with a wedge; the lower jaw is covered with a 0.16 cm (0.065 inch) thick copper plate to protect the edge of the wedge. A suitable wedge design for testing sheet material PVC plastic is shown in Fig. B1.

3.3.2.2 Jaws for Type B Machine: The upper jaw is the same as for type A machine. The lower jaw is a rigid steel flat covered with an assembly consisting first of a flexible rubber sheet (tire tread stock) 0.6 cm (0.25 inch) thick, followed by a smooth steel plate of the same thickness. This is then covered with a copper plate 0.16 cm (0.065 inch) thick.

3.3.2.3 Place the sheet specimen lengthwise along the bottom jaw of the testing machine so that the apex of the wedge is parallel with the longitudinal central axis of the specimen. Apply the load until failure occurs. Record the Breaking Load.

3.3.2.4 Calculation

The shear strength is the load required for the equivalent of a wedge 2.54 cm (1 inch) in length to cut through the specimen. The magnitude of this load is determined from the load deformation curve as follows:

$$\text{Shear Strength kg (lbs)} = \frac{\text{Breaking Load, kg (lbs)}}{\text{Wedge Length, cm (in.)}}$$

4. CALIBRATION OF COMPRESSION TESTERS

4.1 Type A Compression Tester With Mechanical Recorder (Scott Tester Model R)

4.1.1 Insert a 0.381 cm (0.150 inch) thick test steel gauge between flat jaws; with the pen on the chart, operate the machine. This should mark a line parallel to and on the top line of the chart. Remove the test piece and, with pen on the chart, operate the machine. This should mark a line parallel to and on the bottom line of the chart. If the lines marked are not parallel to chart lines, move the platens until registration is obtained.

4.1.2 Remove upper jaw from machine. Place calibration jaw on the lower jaw. Before tightening the setscrew, make certain that the upper portion of the calibration jaw is centered in, and not rubbing against the machine frame. Place calibration block in position. Remove the two outside right hand bolts from head of machine. Place beam in central position over the jaws and fasten in place with the two long bolts provided. Hang the beam counterweight on the right hand side of the beam. Hang the weight holder on the left hand side of the beam.

4.1.3 The initial load shall be 180 kg (400 pounds) for the 910 kg (2000 pound) spring. The load is increased by increments of 90 kg (200 pounds) for the 910 kg spring until the normal capacity of the spring has been reached. The pan should weigh 4.5 kg (10 pounds), and at the provided ratio of ten to one, will be equivalent, therefore, to a 45 kg (100 pound) load. The effective load of other weights will be in the same ratio.

4.1.4 With the initial load on the beam, operate the machine. If the line drawn on the chart by the recording pen does not coincide with the scale on the chart, adjust the length of the cord which moves the swinging arm carrying the chart by means of the micrometer setscrew until the two lines coincide. When this condition is obtained, calibrate for the various increments. If at any load within the range normally encountered in the use of the machine there is a noticeable departure (4.5 kg or more) from coincidence of the line drawn by the pen and the corresponding chart line, do not use the machine until this condition has been corrected.

4.2 Type A Compression Tester With Compression Load Cell and Recorder

Calibrate the compression load cell in accordance with the instructions of the manufacturer.

4.3 Type B Compression Tester

Calibrate as required in accordance with the instructions of the manufacturer.

PRELIMINARY

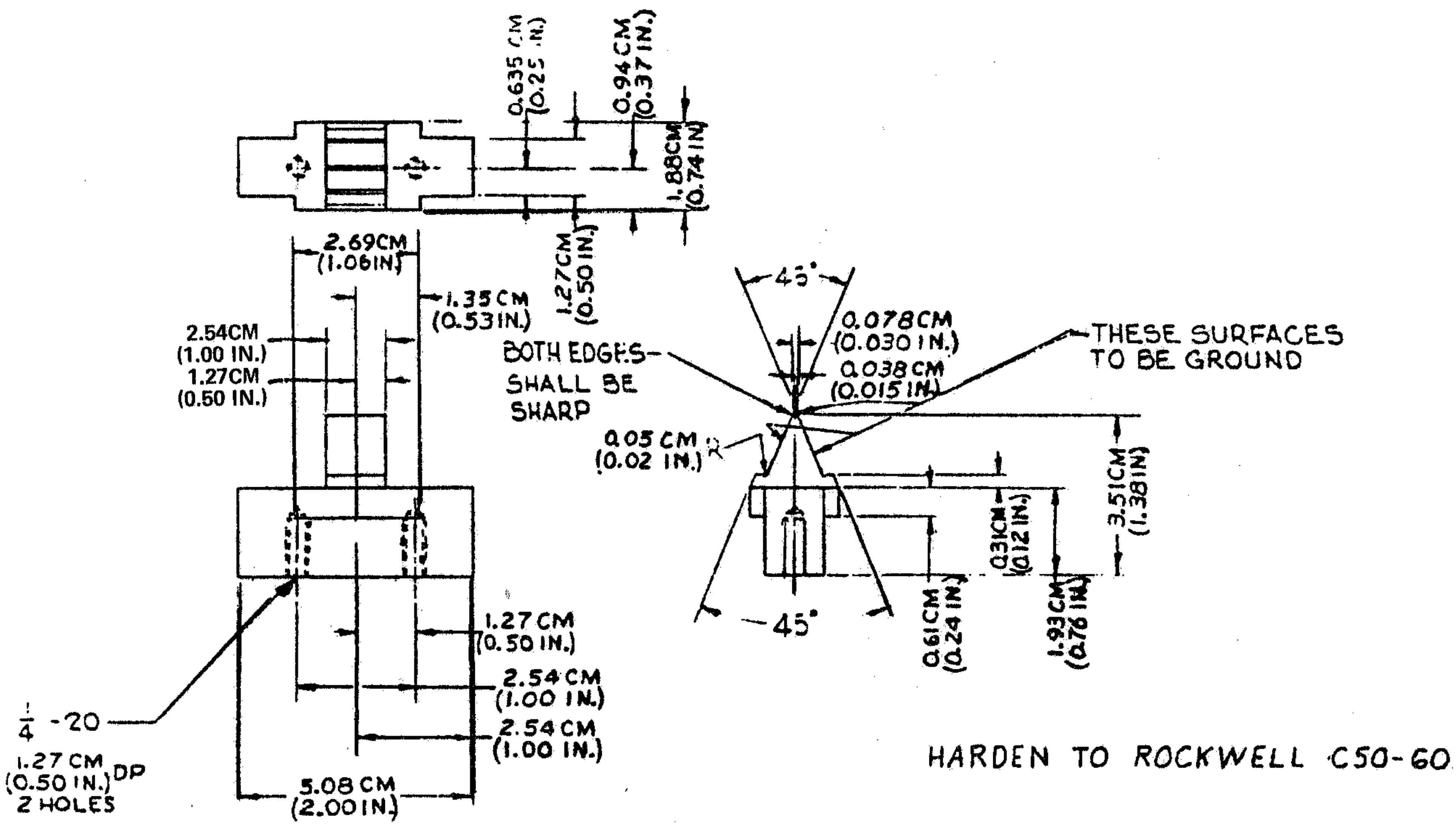


Fig. B1 — Wedge Design for Testing Sheet Material PVC Plastic

APPENDIX C

SHRINK-BACK TEST

1. Care shall be exercised in the preparation of samples.

2. Specimens of single insulated conductor approximately 6 inches long are cut from the center of a 6 foot length of sample with a sharp blade (razor) or fine toothed saw. The insulation and conductor shall be cut in one operation.

2.1 The test specimen is cut immediately prior to test and is placed in an air oven maintained at a temperature of 121 $\pm$ 1.5^{o}C (249.8 $\pm$ 2.7^{o}F) for a period of one hour.

2.2 The air oven conforms to the requirements of the ASTM Method of Test for Accelerated Aging of Vulcanized Rubber by the Oven Method, D573, or an approved equivalent.

2.3 The samples are placed on a piece of felt which has been conditioned for at least one hour at the test temperature. The felt is perforated. The holes are approximately 1 inch in diameter on 2 inch centers.

2.4 After removal from the oven, the samples are allowed to cool to room temperature, and the shrinkage of the insulation at each end is measured.

2.5 The total shrinkage from both ends (added together) is measured.

3. Alternatively, specimens may be prepared by cutting the insulation as specified above with a sharp blade (razor) and scoring the conductor during this process at two places approximately 6 inches apart in the center of a 6 foot length of sample. The conductor is then cut with pliers approximately 3/4 inch outside the score marks and the short lengths of insulation are removed.

3.1 Same as Par. 2.1

3.2 Same as Par. 2.2

3.3 Same as Par. 2.3

3.4 Same as Par. 2.4; the measurements being made from each score mark.

3.5 Same as Par. 2.5

APPENDIX D

SPARK TEST

1. AC Method

1.1 All insulated conductors are passed through a single closely fitting electrode of such length that any point on the product under test remains within the electrode for a period of not less than 0.20 seconds.

1.2 The electrode makes intimate contact with the surface of the product under test and is connected to one terminal of a source of alternating potential having a frequency of not less than 25 Hz. The other terminal of this source of potential and the conductor of the product under test are grounded.

1.3 The peak alternating potential of the electrode is a minimum of 3000 volts as determined with a peak indicating electronic voltmeter or approved equivalent. The meter may be calibrated to read the rms of the sine wave of potential. The required rms value is defined as the required peak value multiplied by 0.71.

1.4 A suitable device which will definitely indicate the arcing between electrode and conductor (faults) is employed.

2. DC Method

2.1 Electrode

All wire under test is passed through one of the following types of electrodes or an approved equivalent.

Type A. A corrosion resistant homogeneous metallic electrode of 1.0 ±1/16 inch length. The inside diameter of the electrode aperture shall not exceed the diameter of the wire under test by more than 20 mils and is circular in cross section.

Type B. A Hipotronics Incorporated electrode consisting of spiral corrosion resistant metal rods forming a conical surface, the cross section of which is a hyperbola. The effective electrode length between the vertices of the hyperbola is 1/2 +1/16 - 0 inch. The inside diameter of the electrode aperture shall not exceed the diameter of the wire under test by more than 20 mils.

Type C. This electrode is a device which makes as intimate a contact as practicable with the surface of the wire being tested. The electrode shall be link or bead chain type in a V-shaped metal enclosure, both of which are composed of corrosion resistant metal. The chains of the electrode shall have a length appreciably greater than the depth of the enclosure, and the width of the trough shall be approximately 1.0 inch greater than the largest size wire which will be tested. If a bead chain type of electrode is used, the beads shall have a nominal diameter of 2/16 +1/16-0 inch, the longitudinal spacing of the chains shall not be more than 1/2 inch and the transverse spacing of the chains shall be more than 3/8 inch, except that the spacing may be 1/2 inch if the transverse rows of chains are staggered. The surface of the wire under test shall be in intimate contact with the V-shaped metal enclosure and the bead chains for a distance of 5 ±1.0 inches.

Type D. A corrosion resistant metallic electrode consisting of two spaced parallel plates. The dimensions of each plate shall be 3/4 ± 1/16 inch X 1.0 ± 1/16 X 1/16 inch minimum. The 1.0 inch dimension shall be parallel to the axis of the wire passing between the plates. The spacing between the electrode plates shall not exceed the diameter of the wire under test by more than 20 mils.

2.2 DC Power Supply

The DC potential applied to the electrode shall be that value computed from the equations in Table D-1 for the appropriate electrode type, except in the case of using a bead chain electrode, in which case 3000 volts shall be used. The D.C. voltage is determined with an electronic voltmeter or approved equivalent. The electrode is connected to one terminal of this source of potential. The other terminal of this source of potential and the conductor of the product under test are grounded. The D.C. power source shall have a maximum current output of 5 millamperes with a maximum ripple of 1%. After a fault, the test voltage shall recover to its specified value within 1 millisecond or less.

2.3 Fault Detector

A fault detector operating with electronic or solid state devices shall be employed to detect a voltage breakdown of the dielectric, which is characterized by arcing between the electrode and conductor under test. A breakdown is defined as a decrease of 25% or more from the test voltage applied between the electrode and the grounded conductor. The fault detector consists essentially of a trigger circuit which has the characteristic of converting an input pulse of short time duration to an output pulse of sufficient magnitude and duration to reliably operate the fault indicating circuit.

3. FAULT COUNTER

The spark test fault counter operating in conjunction with the fault detector shall have a response time such that it will register faults spaced no further than 24.0 inches apart for any combination of wire speed and counter response time. This distance relationship may be expressed as follows:

Distance between faults (in.) =
Wire speed (in/sec) X Counter response time (sec)

The fault counter shall accumulate the faults in numerically increasing sequence and display the accumulated total in digital form.

Table D-1

Electrode Potential

Electrode Type	D. C. Potential
A and B	$E = 350^* \times (D1/2) \times [\ln (D2/D1) + K_1 \ln(D3/D2)]$
C	$E = 500 \times (D1/2) \times [\ln(D2/D1)]$
D	$E = 500 \times [(D1/2) \times \sqrt{(D2/D1 - 1)/(D2/D1 + 1)} \times \ln (D2/D1) + \sqrt{(D2/D1)^2 - 1}]$

D1 = Nominal Diameter of Bare Conductor (mils)

D2 = Nominal Diameter of Insulated Conductor (mils)

D3 = Inside Diameter of Electrode Aperture (mils)

E = D.C. Potential (volts)

K_1 = The 1 Kilohertz dielectric constant of the insulation which extends radially from the conductor.

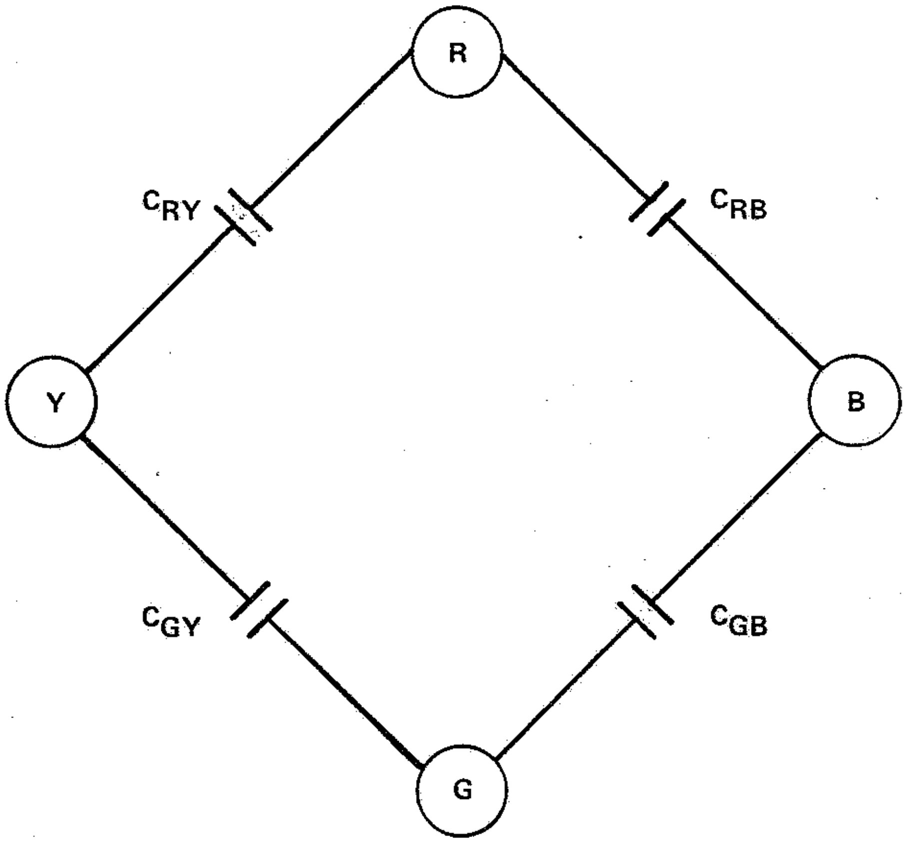
ln = Logarithm to the base e.

* The gradient specified for the type A and B electrodes (350 volts per mil) has been reduced an appropriate amount to compensate for point contact between electrode and insulation. This condition has been considered in the development of the potential equation for the type D electrode.

APPENDIX E

CAPACITANCE UNBALANCE TEST

R = First Conductor Of First Pair
G = Second Conductor Of First Pair
B = First Conductor Of Second Páir
Y = Second Conductor Of Second Pair



Unbalance = $(C_{RB} + C_{GY}) - (C_{RY} + C_{GB})$
C_{RB} Represents The Capacitance From Wire R Of One Pair To Wire B In The Adjacent Pair Only; All Other Conductors Are Left Out Of The Circuit.

APPENDIX F

DIELECTRIC CONSTANT TEST

1. OUTLINE OF METHOD

This specification contains instructions for determining the dielectric constant of PVC material using a capacitance bridge and a liquid displacement cell. The dielectric constant of the test specimen is determined by using a two-terminal, self-shielded test cell filled with silicone liquid. Bridge measurements are made with silicone liquid only and also with test specimens immersed for this determination.

2. APPLICABILITY

This method is intended for use in testing PVC with a dielectric constant between 2 and 5 at a fequency of 10 KHz.

3. APPARATUS AND MATERIAL

3.1 Capacitance Measuring Assembly

This device is obtainable from the General Radio Company, West Concord, Massachusetts, as their type 1620-A Capacitance Measuring Assembly. An approved equivalent may also be used.

3.2 Measuring Cell (See Figure F1)

This is a two-electrode, fixed, parallel-plate, self-shielded, capacitance cell, obtainable from the Balsbaugh Laboratories, Duxbury, Massachusetts, or Bridgewater Engineering Company, Bound Brook Road, Middlesex, New Jersey. The gap spacing (t_a) between the plates shall be 1.47 to 1.57 mm. An approved equivalent may be used.

3.3 Coaxial Cables (Two Required)

A 30 to 60 centimeter coaxial cable (such as RG-58-C/U or equivalent) is required for connecting the capacitance measuring assembly to the measuring cell. A male BNC connector is fitted to one end of each coaxial cable. At the opposite end of each coaxial cable an alligator clip is fitted to the center conductor.

3.4 GR-BNC Connectors (Two Required)

A General Radio Company adapter for a male BNC connector, or equivalent, is needed for attaching coaxial cables to the bridge.

3.5 Thermometer (One Required)

A device meeting ASTM E 1, No. 23C (Engler Viscosity) is required.

3.6 Tweezers

Metal tweezers of any convenient size for use when handling the test specimens to prevent fingerprinting and contamination are required.

3.7 Micrometer Caliper

Either a dead-weight (approximately 1.75 kilograms per square centimeter) dial-gauge or machinist micrometer caliper, with a ratchet, capable of measuring to $\pm$0.002 mm, having spindle surfaces of 6.35 mm in diameter is required.

3.8 Die or Template and Snippers

These are required for cutting rectangular test specimens of 68.2 by 100.0 mm. A suitable die is obtainable from Fremont Tool and Die Company, 428 Wood Street, Fremont, Ohio, or Thwing-Albert Instrument Company, Philadelphia, Pennsylvania. A suitable template can be made from 0.8 mm thick aluminum. Light metal snippers are convenient to cut 1.27 mm thick plastics.

3.9 Inside Telescoping Gauge

This device shall be capable of measuring 9.4 mm to within $\pm$ 0.002 mm.

3.10 Acetone

This must be ACS grade or better.

3.11 Silicone Liquid

This shall be Dow-Corning DC 200, 1-centistoke viscosity liquid. Store the liquid at the temperature at which the test will be made.

Warning - Combustible: this liquid has a flash point of 38°C (100.4°F.) It should be kept away from heat, sparks, and open flame. Keep the container closed, use it only with adequate ventilation, and avoid prolonged or repeated breathing of the vapor. Although silicones are reputed to be nontoxic, the 1-centistoke, DC 200 liquid is a volatile liquid and as such should be handled with caution.

3.12 Insulating Square

A piece of polytetrafluorethylene, or equivalent, approximately 15 by 15 centimeters for supporting the measuring cell is required.

4. TEST SPECIMENS

4.1 Two sheets of test material are required; each sheet large enough to yield one pair of specimens.

4.2 Using the die or the template and snippers, cut two specimens 68.2 by 100.0 mm from each test sheet which is 1.1 to 1.4 mm thick. Determine the thickness of each specimen by taking the average of five thickness measurements made along the diagonals of the surface, one measurement near the center, and one near each corner, measuring to the nearest 0.002 mm in accordance with ASTM D 374. No measurement shall vary more than ± 0.05 mm from the average of the five measurements. Designate as t_s the average thickness of the two test specimens based on the ten measurements and measured to the nearest 0.002 mm.

4.3 The faces of each test specimen shall be flat, smooth, and free from bubbles, pits, or blemishes. Condition the specimens for a minimum of 24 hours at 23 $\pm$ 1.0°C (73.4 $\pm$ 1.8°F) and a relative humidity of not more than 52 percent.

5. MEASURING CELL

5.1 Determine the average spacing between the inside faces of the ground electrode as follows:

5.5.1 Remove the center electrode and determine the average thickness by taking five measurements along the diagonals of the surface of the electrode plate, one near the center and one near each corner. Use a micrometer and determine to the nearest 0.002 mm.

5.1.2 Determine the average distance between the opposite, inner ground electrode surfaces of the cell by taking five measurements along the diagonals of the surfaces, one near the center, and one near each corner. Use the telescoping gauge and determine to the nearest 0.002 mm.

5.1.3 Subtract the average thickness of the center electrode from the average distance between the two inside surfaces and divide the difference by 2. Record as T_a.

5.2 Determine the area of one face of the center electrode to the nearest 0.01 square centimeter, multiply by 2, and record as A.

5.3 Rinse new cells or infrequently used cells by filling and rinsing the cell at least three times each with:

(1) warm distilled water,
(2) acetone, and when this has all evaporated,
(3) with the standard silicone liquid.

Dry for 1 hour at about 50°C, then store at 23±1.0°C (73.4±1.8°F) and a relative humidity of not more than 52 percent until thermal equilibrium has been reached.

6. MEASURING CELL SETUP

Place the measuring cell to the right of the capacitance measuring assembly on the insulating square. Locate the overflow pipe of the measuring cell to the right, press-fit a few centimeters of polyethylene tubing on the overflow pipe, and locate a catch bottle under the end of the polyethylene tubing. Place the thermometer in the cell.

7. CAPACITANCE MEASURING ASSEMBLY

7.1 Install and set up the capacitance measuring assembly in accordance with the manufacturer's recommended instructions.

7.2 Set the generator and detector to 10 KHz.

7.3 Set on the capacitance bridge of the assmebly;

(1) MULTIPLY EXT STANDARD BY switch to zero.
(2) D/G range selector to D MAX 0.01.
(3) C range selector to C MAX 1000 pf.
(4) Terminal selector to UNKNOWN 3 TERM (coaxial position).

7.4 Connect bridge UNKNOWN L terminal to the ground (outside) electrode and the UNKNOWN H terminal to the high (center) electrode of the measuring cell, using the two coaxial cables and the two GR-BNC connectors. Make the outer conductors of the coaxial cables extend as near to the measuring cell as is possible without shorting to the cell.

7.5 Ground the bridge.

8. MEASUREMENT PROCEDURE

8.1 Make all measurements at 23$\pm$1.0°C (73.4$\pm$1.8°F) and a relative humidity of not more than 52 percent.

8.2 Turn on the generator and detector of the capacitance measuring assembly.

8.3 Fill the measuring cell slowly with the silicone liquid, either directly from the original bottle or from a chemically-clean glass container equipped with a small glass tube. Fill the cell until a small quantity flows out of the overflow tube into the catch bottle.

8.4 Balance the bridge (test circuit) and record the total cell capacitance with the silicone liquid as C_1.

8.5 Carefully insert one pair of specimens between the plates of the measuring cell, using clean metal tweezers.

8.6 Rebalance the bridge, and record the total cell capacitance with silicone liquid and test specimens as C_2, and the temperature at which measurement is made as T.

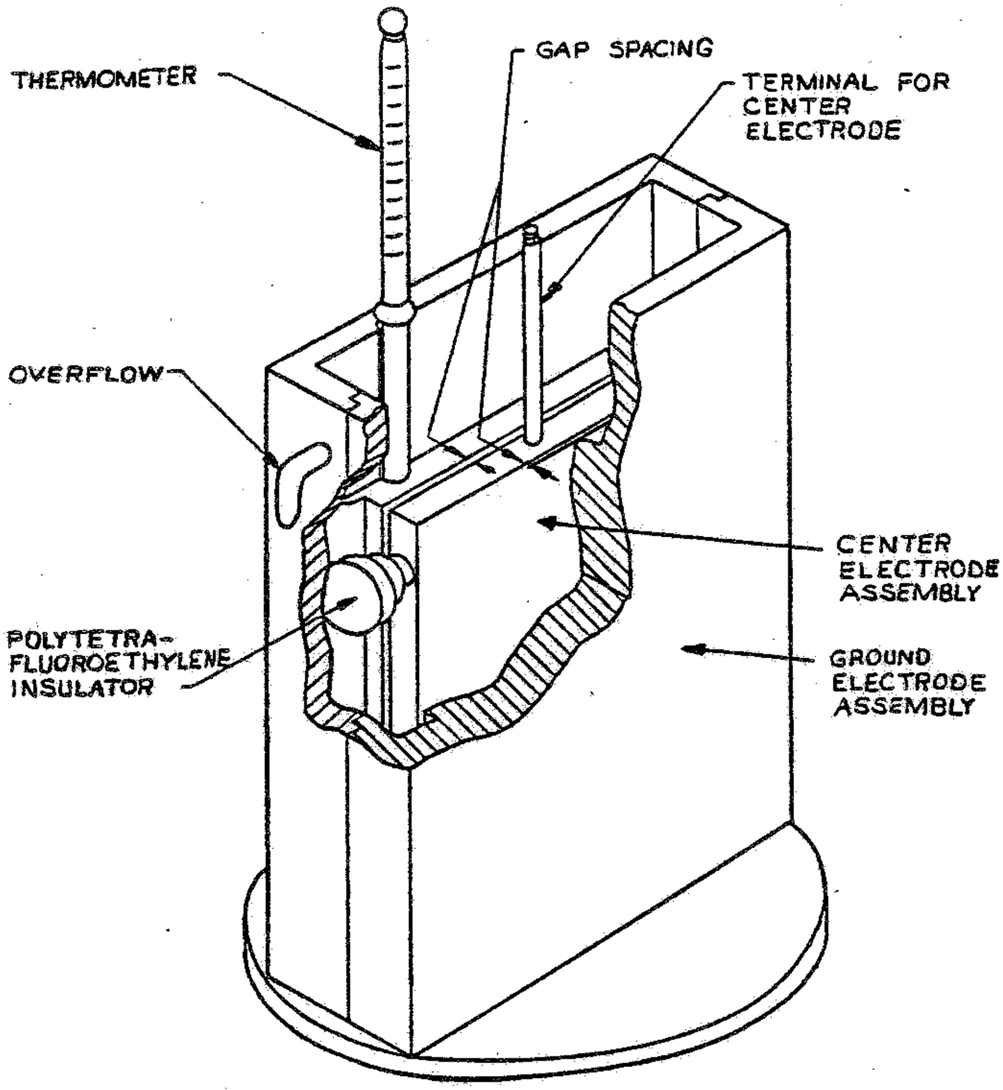
8.7 Remove the pair of specimens.

8.8 Repeat 8.3 through 8.7 for the second pair of specimens.

8.9 Calculate the dielectric constant of the test specimens $K_s(T)$ according to equations No. 1 and 2 (see section 9) for each pair of specimens.

9. DEFINITIONS AND CALCULATIONS

Equation No.	Symbol	Unit	Equation and Definition
	A	sq cm	Effective area of the center electrode (two times the area of one face).
	C_1	pf	Total cell capacitance with silicone liquid only.
	C_2	pf	Total cell capacitance with silicone liquid and specimen.
	ΔC	pf	$C_2 - C_1$ = Change in capacitance after specimens have been introduced.
	C_v	pf	$\frac{0.08854A}{t_a}$ = Calculated interelectrode vacuum capacitance of cell
1	$K_\ell(T)$		Dielectric constant of silicone liquid at test temperature (T) = $2.300 - 0.003 \times (T - 23.0^oC)$
2	$K_s(T)$		Dielectric constant of test specimen at test temperature (T) = $\dfrac{K_\ell(T)}{1 - \left(\dfrac{\Delta C}{K_\ell(T)C_v + \Delta C}\right)\left(\dfrac{ta}{t_s}\right)}$
	t_a	cm	Average gap spacing of the cell. Must be measured to the nearest 0.002 mm and the largest variation in gap spacing shall not exceed 0.025 mm. (Approximately 1.47 to 1.57 mm.)
	t_s	cm	Average thickness of test specimen based on 10 measurements and measured to the nearest 0.002 mm.
	T	degrees C	Temperature at which measurement is made.



Notes

1. All metal parts are brass, gold-plated.
2. The center electrode shall be a sliding fit in the ground electrode assembly. If necessary, the polytetrafluoroethylene insulators may be modified very slightly to accomplish this.

Fig. F1 — Measuring Cell

APPENDIX G

TORQUE RHEOMETER TEST FOR PLASTICS

1.0 OUTLINE OF METHOD

The time required to break down poly (vinyl chloride) plastic under specified conditions of temperature and shear is a way of measuring thermal stabilizer efficiency and content. The torque rheometer is a convenient way of determining this quantity.

2.0 APPLICABILITY

This specification applies to flexible and semirigid vinyl chloride plastics.

3.0 APPARATUS

3.1 Torque Rheometer

Such as Brabender Plasti-Corder manufactured by C. W. Brabender Instruments, Inc., South Hackensack, N.J.; see Fig. G1. This apparatus shall be equipped with the following accessories:

3.11 Processing head (B) (see Fig. G1) having the dimensions shown in Fig. G2 and G3 and equipped with a teflon stopper for one thermometer well.

Note: The C. W. Brabender Instruments, Inc., Type 5 roller-mixer head meets these requirements.

3.12 Circulating silicone oil bath capable of being heated to 250°C (A).

3.13 Temperature regulators sensitive to ±0.5°C over a range of 150° to 250°C.

3.14 Thermometer graduated to 1°C.

3.15 Temperature recorder (J), to monitor the plastic melt temperature from head thermocouple (H) located as shown in Fig. G3.

3.16 Wood's metal for use in thermometer well.

3.17 Tachometer for continuously reading the speed of the slower left (L) of the two differential speed processing blades. See Fig. G3.

3.18 Torque strip recorder monitoring torque in meter-grams at a chart speed of 1 cm/minute.

3.19 Quick loading chute and ram with 5 kilogram weight, having the dimensions and design shown in Fig. G3.

4.0 SAMPLE PREPARATION

The plastic to be tested shall be in the form of granules with an average diameter not to exceed 0.5 cm. Thin pieces of strip approximately 1 by 5 by 0.03 cm may also be used except when the quick-loading chute is involved. A specimen charge of 45.5 cc (calculated from the density at 23°C) shall be used.

5.0 PROCEDURE

5.1 General

Preheat the torque rheometer oil bath (A) to the temperature required to achieve the specified equilibrium processing head temperature. To insure good heat transfer, fill the thermometer well in the processing head with a low melting alloy, such as Wood's metal. When the Wood's metal is molten insert the thermometer of 3.14. Plug the well with a teflon stopper when removing the head.

For all methods, make the zero adjustment of the machine with the scale multiplier at X1 and no load. With the machine running at the operating speed specified in required method, set the torque indicator scale (M) at zero. This is accomplished by adjusting weights (R) until the needle on the torque indicator scale (M) reads zero. Adjust the pen of the torque strip recorder (N) to coincide with the zero reading of the torque indicator scale (M) while the machine is running.

The machine zero should be verified prior to each determination. If the zero setting has changed and readjustment of the counterweight is indicated, first check the mixing unit for cleanliness. Sometimes material becomes lodged behind the processing blade and causes a small applied torque which is reflected as a change in the zero setting to a positive reading. This condition can usually be corrected by washing between the processing blades and the wall with a suitable solvent. If the zero setting has changed to show a negative torque, the above condition may have existed during the previous determination and a rerun is indicated.

After the charging procedure described below, adjust weight (P) to a position that will permit the torque indicator scale pointer (M) and torque strip recorder pen (N) to read on scale. Use a chart speed of 1 cm/ minute. Adjust temperature recorder to permit continuous reading of the plastic temperature. Time is plotted on the horizontal scale and torque (in meter grams) on the vertical scale of the torque/time chart. Oscillations in torque produce a line with a finite width. To read the torque at any given time take a mean value between the extremes of the oscillations.

When the plastic adheres to the blades following a test, special cleaning techniques may be required. High density polyethylene or polystyrene have been found useful in purging polyolefins. A cleaning agent such as Sol Speedi Dri (obtainable from Mineral & Chemicals Corporation of America, Menlo Park, N.J.) has been found effective in flushing out vinyl chloride plastics. A wire brush and steel wool may be necessary to complete the task.

5.2 METHOD

5.21 Conditions

Set the torque rheometer to the following conditions before charging with the sample:

a. Processing head temperature as specified.

b. Rotor speed as specified.

c. Sensitivity scale X5 with counterweights set to provide a range from 0 to 5,000 grams.

d. With the drive running, adust the oscillations of the recorder with the damping mechanism on the machine to give a line width not to exceed 0.2 cm.

e. Set weight (P) on lever arm (Q) for maximum torque.

5.22 Charging Procedure

Insert loading chute in hopper section of head and remove ram. Pour the full charge into the loading chute with drive running, insert the ram, and apply the 5 kilogram weight. Complete charging within 30 seconds. Adjust pointer, pen, chart speed, and temperature recorder as described in 5.1.

5.23 Operation

Allow the charge to run until the desired information has been obtained. Then dump the charge and clean the head and blades.

5.24 Chart Analysis

5.241 A typical torque/time chart for a vinyl chloride plastic may be seen by referring to Fig. G4. Determine the following properties from the chart: (If the curve obtained deviates significantly from that illustrated in Fig. G4, other parameters may have to be used to characterize the plastic).

Fluxing torque, M_b - This torque is determined from the point of tangency between a construction line at 30 degrees with the horizontal and the trace line following the peak torque.

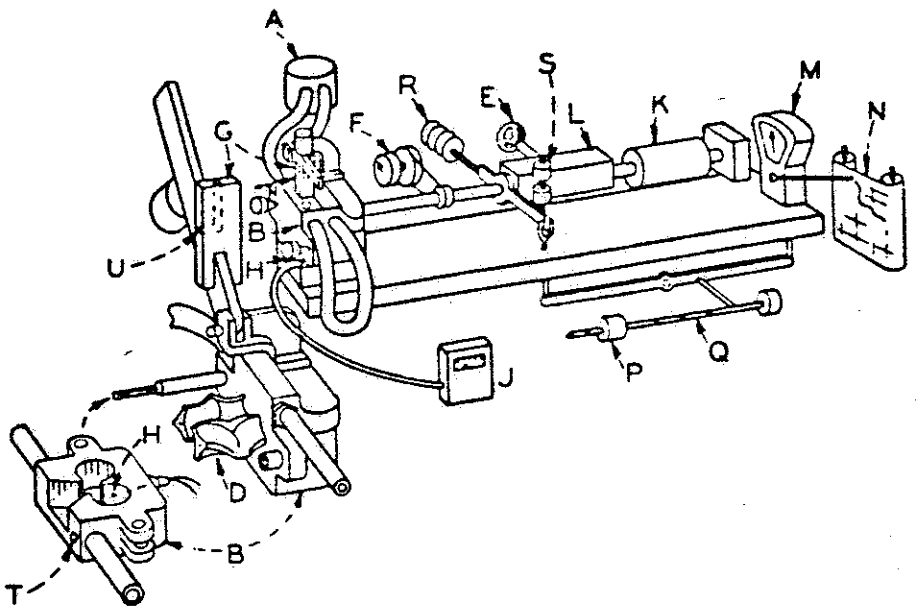
Breakdown torque, M_d - The torque at the end of the run just prior to the onset of degradation as evidenced by a rapid increase above the minimum torque. This is determined from the point of tangency between construction line at 30 degrees with the horizontal and that point of the trace line showing a sharp increase in torque.

Processing time - The time between the fluxing torque and the breakdown torque.

5.242 Temperature change, ΔT, defined as the difference between starting head temperature, T_h, and the plastic temperature at minimum torque, T_e, shall also be noted.

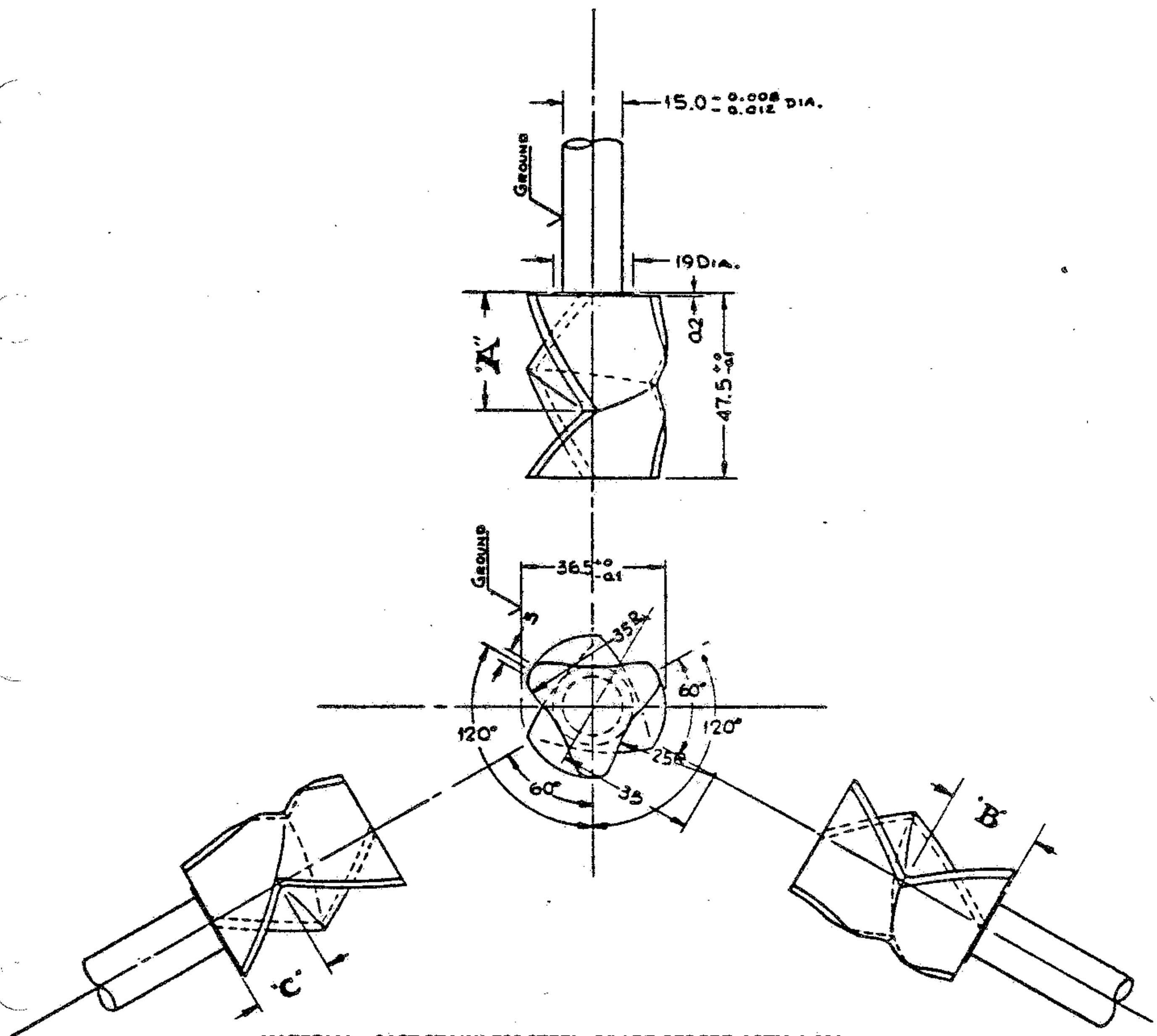
5.25 Report

Report the processing time in minutes.



A – THERMOSTATICALLY CONTROLLED SILICONE OIL BATH
B – STAINLESS STEEL JACKETED HEAD
D – COUNTER ROTATING PROCESSING BLADES
E – SPEED CONTROL
F – SPEED INDICATOR SCALE
G – RAM CLOSURE
H – IRON-CONSTANTAN THERMOCOUPLE
J – TEMPERATURE STRIP RECORDER AND INDICATOR SCALE
K – CONSTANT HORSEPOWER MOTOR
L – SPEED REDUCER HOUSING
M – TORQUE INDICATOR SCALE
N – TORQUE STRIP RECORDER
P – WEIGHT (1000 GRAM)
Q – LEVER ARM
R – WEIGHTS; ZERO ADJUSTMENT FOR TORQUE INDICATOR SCALE
S – WEIGHT; FOR OFFSET OF TORQUE INDICATOR SCALE
T – THERMOMETER WELL
U – GAS PURGE PORT

FIG. G1 – TORQUE RHEOMETER



MATERIAL: CAST STAINLESS STEEL, GRADE CF8 PER ASTM A 296

FINISH: POLISHED

ITEM	DESCRIPTION	DIMENSION "A"	DIMENSION "B"	DIMENSION "C"
1	FLUTES AS SHOWN	28 ± 0.5	24 ± 0.5	20 ± 0.5
2	FLUTES OPP. HAND	21 ± 0.5	30 ± 0.5	17 ± 0.5

FIG. G2 – PROCESSING BLADE

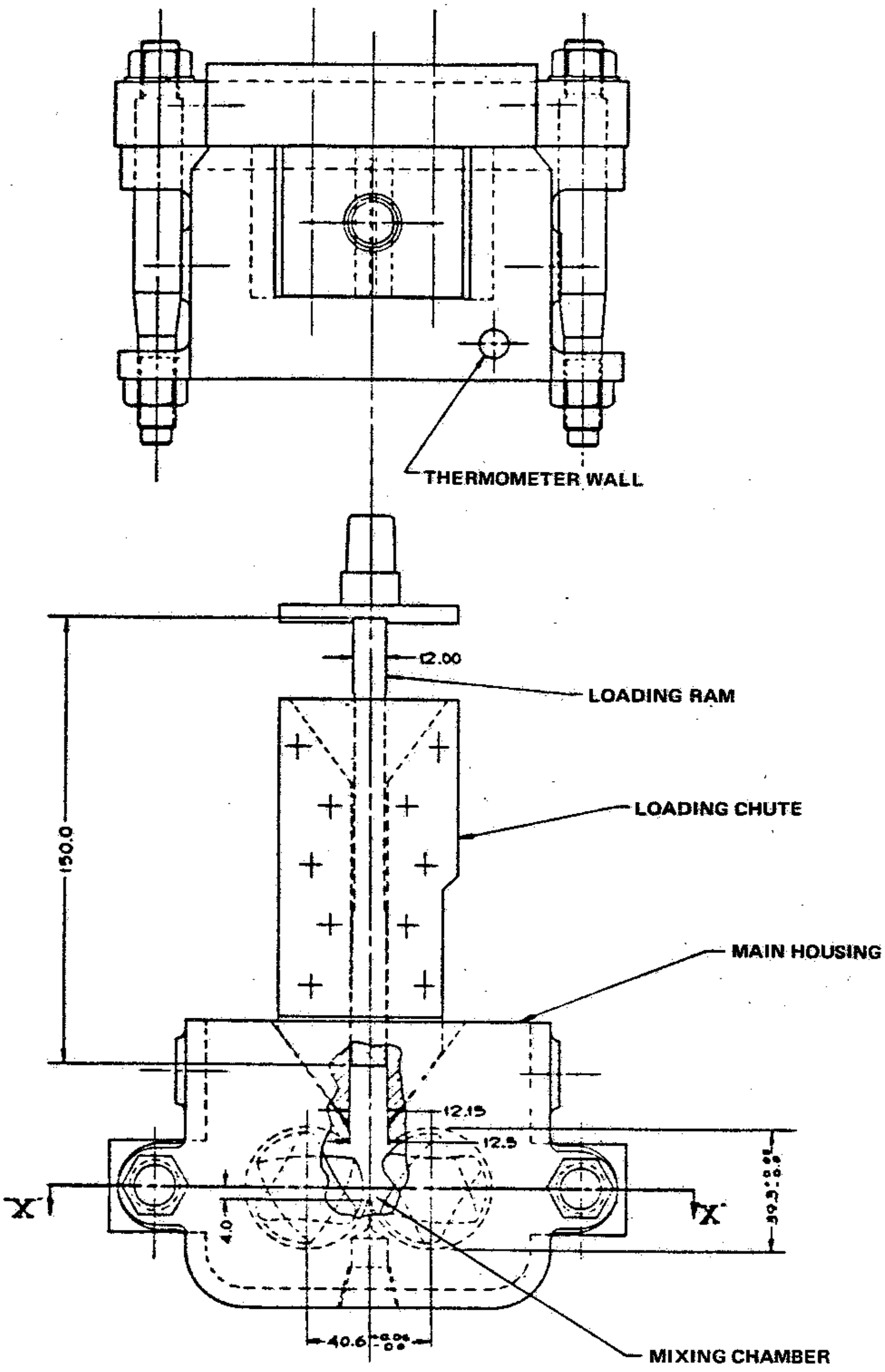


FIG. G3A – PROCESSING HEAD ASSEMBLY

TORQUE/TIME CHART FOR METHOD A (VINYL CHORIDE PLASTICS)

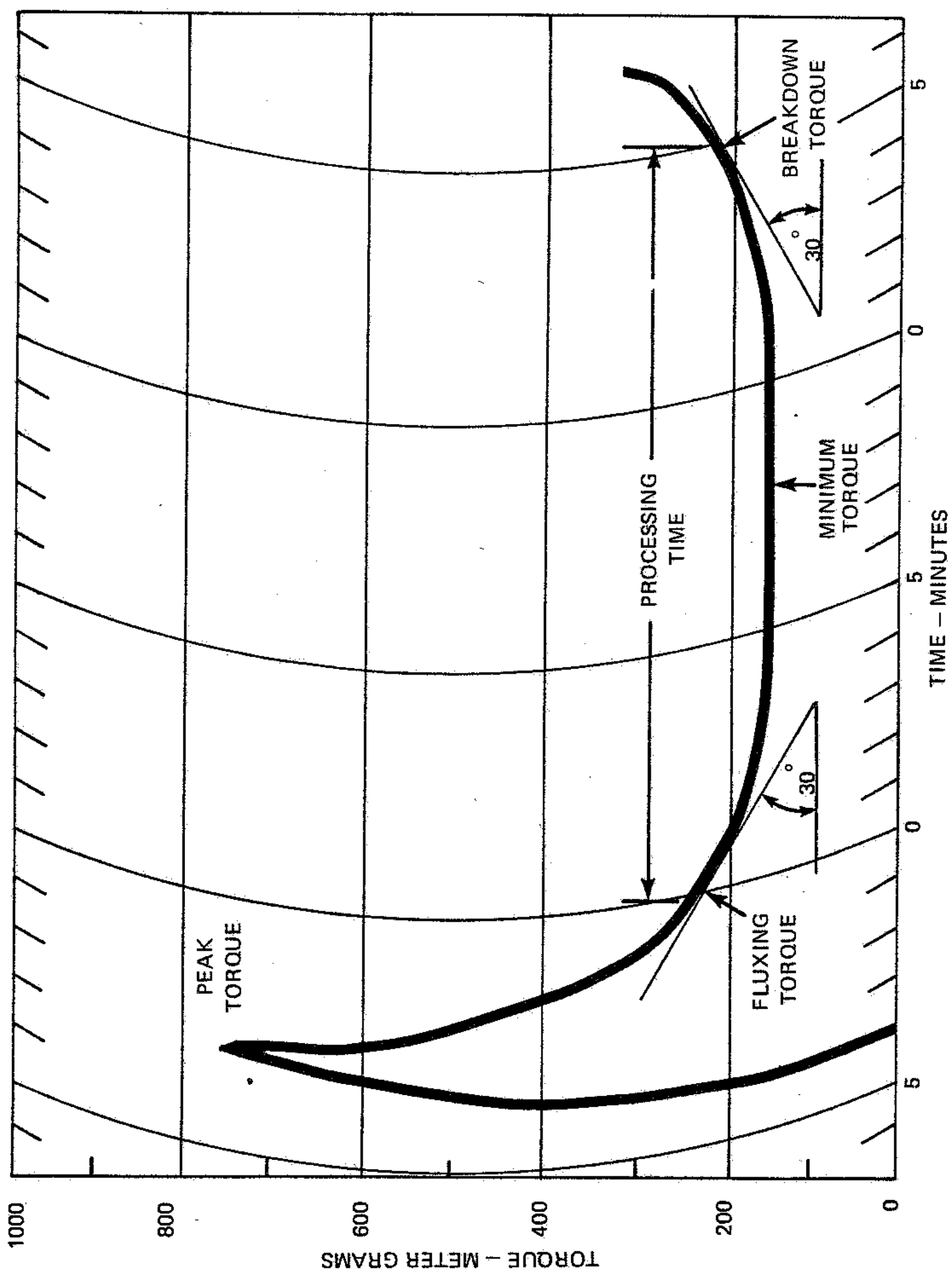
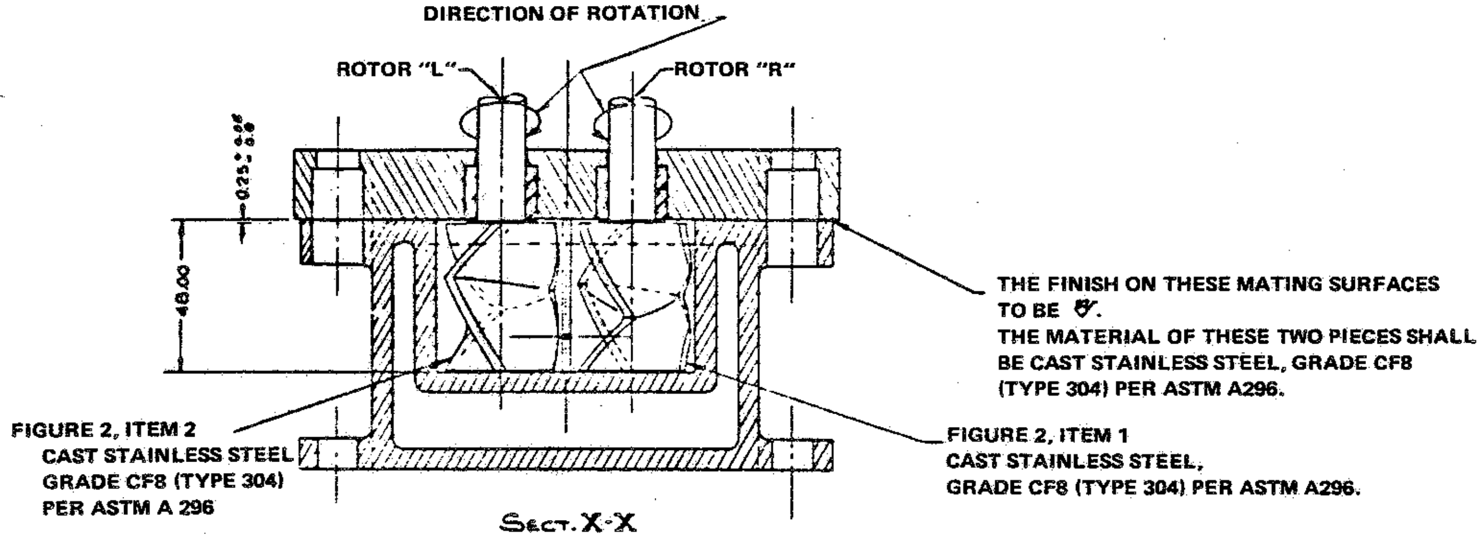
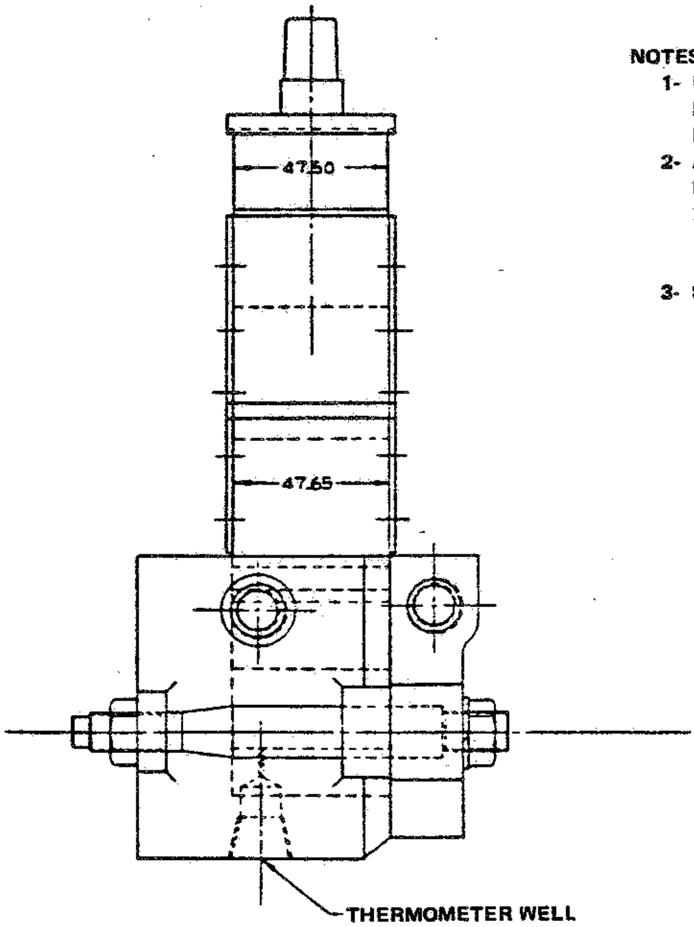


FIGURE G4





NOTES:

1- UNLESS OTHERWISE SPECIFIED ALL MATERIAL TO BE TYPE 416 OR 303 STAINLESS STEEL PER ASTM A276.
2- ALL DIMENSIONS ARE IN MILLIMETERS. NONLIMITED DIMENSIONS SHALL BE HELD AS FOLLOWS WHEN EXPRESSED:
   TO ONE DECIMAL PLACE ± 0.1mm
   TO TWO DECIMAL PLACES ± 0.05mm
3- SPEED RATIO ROTOR "L" : ROTOR "R" = 2:3.

FIG. G3B – PROCESSING HEAD ASSEMBLY

APPENDIX H

STATIC COEFFICIENT OF FRICTION TEST

1. OUTLINE OF METHOD

The force required to start a flexible plastic material sliding over itself is measured. The method employs a sliding tripod sled on a stationary plane.

2. APPARATUS

2.1 Sled

An upper and lower plate (Fig. H1) between which is inserted one of the plastic specimens. The upper plate contains three spherical ended pins which depress the specimen through corresponding holes in the lower plate such that the sled can slide on the three plastic covered pins. The weight of the sled, including the specimen shall be 120±5 grams.

2.2 Supporting Base

A rigid, stationary metal base fitted with an upright support for a low friction pulley to which is clamped a second flat sheet (plane) specimen (see Fig. H2).

2.3 Low-Friction Pulley

A phenolic-type pulley mounted in hardened steel cone bearings on a metal fork.

2.4 Nylon Monofilament

0.33 ± 0.05 mm (0.013 ± 0.002 inch) diameter and capable of supporting a 3.6 kg (8 lb) load.

2.5 Force-Measuring Device

A tensile testing machine capable of applying and recording the force needed to pull the sled across the plane with an accuracy of ± 5 percent of its value. A Universal Testing Instrument, Model TTCMI-3. Instron Engineering Corp., Canton, Mass or its equivalent may be used.

3. PROCEDURE

3.1 Specimen Preparation

Self age specimen 7 days before test.

3.1.1 Sled Specimen

Prepare from a uniform sheet of the jacket material, 0.76 ± 0.05 mm (0.030 ± 0.002 inch) in thickness and cut to the design shown in Fig. H-1.

3.1.2 Plane Specimen

Plastic: A uniform rectangular sheet specimen of the jacket material: 150 x 200 x 2.0 ± 0.25 mm (6 x 8 x 0.075 ± 0.010 inch).

Note: Care shall be taken in handling not to contaminate test specimens.

3.2 Universal Testing Machine

Securely mount the supporting base assembly (Fig. H2) to the constant rate-of-motion lower crosshead of the universal testing machine with the low-friction pulley centered on the crosshead directly beneath the load cell.

Test the supporting base for levelness.

Set the crossheads speed to 152 ± 30 mm per minute.

Clamp a specimen between the upper and lower plates of the sled by means of the three screws provided. Tighten the screws gradually and in rotation so that the plastic specimen will be uniformally stressed by each of the three spherically headed pins.

Secure the plane specimen to the supporting base using the clamp provided.

3.3 Measurements

Place the sled gently on the plane specimen with the nylon monofilament attached as shown in Fig. H-2. The sled is located a minimum of 130 mm from the pulley and perpendicular to its shaft. The height of the pulley is so adjusted that the monofilament is parallel to the surface of the plane.

Allow the sled to rest on the plane for 3 minutes then apply sufficient force through the monofilament to move the sled across the plane at a uniform velocity of 152±30 mm per minute for a distance of approximately 130 mm. The initial force required to start the sled sliding is obtained from the recorded measurements.

Make three determinations using a new sled specimen each time and a section of the plane specimen not previously traversed by the sled.

4. CALCULATIONS

Calculate the static coefficient of friction as follows:

$$s = \frac{A}{B}$$

where:

A = Initial (maximum) force to start sled moving, grams.

B = Weight of sled plus specimen, grams.

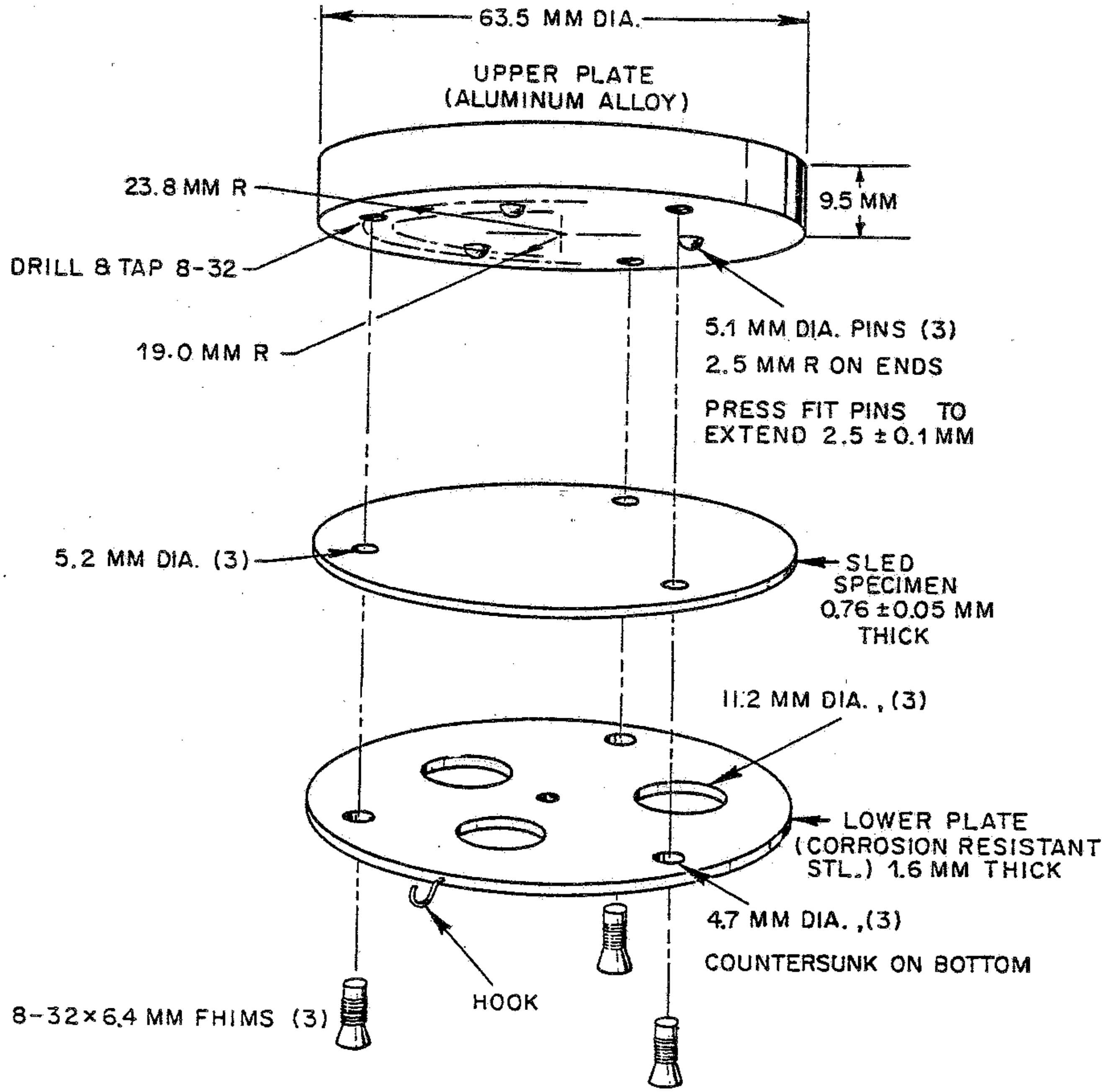


Fig. H1 — Sled (Exploded View)

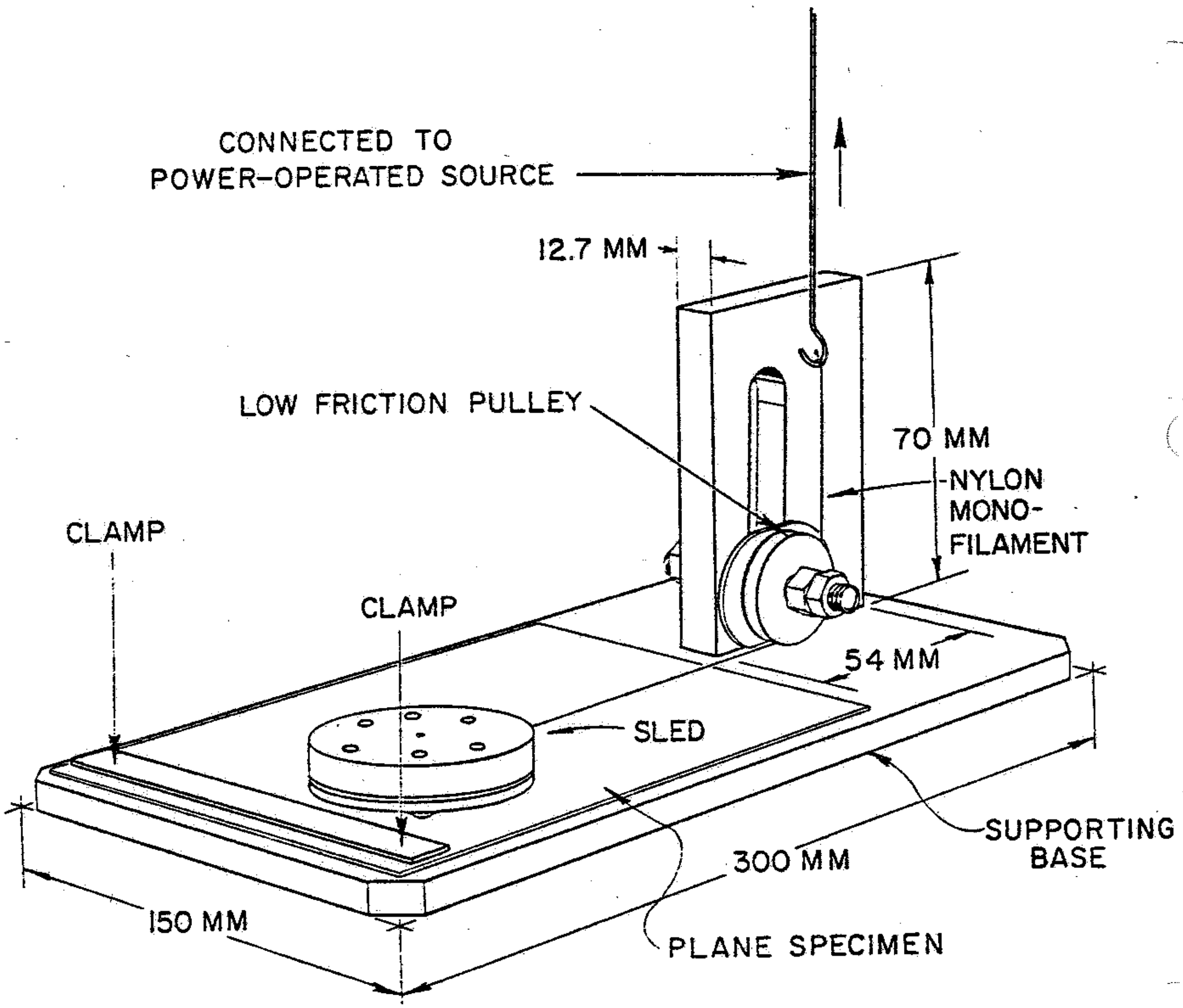


Fig. H2 – Sled and Supporting Base Assembly

APPENDIX I

REFERENCES

The following AT&T publications may be of interest to designers and manufacturers of wiring and terminal equipment:

Bell System Technical References

PUB 40000	Technical Reference Catalog - January 1980
PUB 41009	Transmission Parameters Affecting Voice Band Data Transmission - Measuring Techniques - May 1975
PUB 43601	Lightning and 60 Hz Disturbances at the Bell System Network Terminal Interface - Preliminary - June 1978
PUB 47001	Electrical Characteristics of Bell System PBX and Key Equipment at the Interface With Voice Band Ancillary and Data Equipment - Preliminary - August 1976
PUB 48002	Functional Product Class Criteria - PBX - Preliminary - September 1978
PUB 53250	Quality Program Evaluation

Requests for Technical References and related pricing information should be submitted in writing to:

American Telephone and Telegraph Company
Information Distribution Center, Room C190
Att: Technical References
P.O. Box 3513
New Brunswick, New Jersey 08903