DuPont™ Crastin® PBT

thermoplastic polyester resin

Crastin® CE2510LM BK591

Crastin® CE2510LM BK591 is a 30% glass fibre reinforced, laser markable hydrolysis resistant polybutylene terephtalate resin for injection moulding.

Property	Test Method	Units	Value
Identification			
Resin Identification	ISO 1043		PBT-IGF30
Part Marking Code	ISO 11469		>PBT-IGF30<
Mechanical			
Stress at Break	ISO 527	MPa	120
Strain at Break	ISO 527	%	3
Tensile Modulus	ISO 527	MPa	8500
Flexural Strength	ISO 178	MPa	180
Notched Izod Impact Strength	ISO 180/1A	kJ/m^2	13
Notched Charpy Impact Strength	ISO 179/1eA	kJ/m^2	16
Unnotched Charpy Impact Strength	ISO 179/1eU	kJ/m^2	70
Thermal			
Deflection Temperature	ISO 75f	°C	
1.80MPa			210
Melting Temperature	ISO 11357-1/-3	°C	
10°C/min			224
Other			
Density	ISO 1183	kg/m^3	1450

Contact DuPont for Material Safety Data Sheet, general guides and/or additional information about ventilation, handling, purging, drying, etc.
ISO Mechanical properties measured at 4.0mm, ISO Electrical properties measured at 2.0mm unless otherwise stated.
Test temperatures are 23°C unless otherwise stated.

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040802/040804

The information provided in this data sheet corresponds to our knowledge on the subject at the date of its publication. This information may be subject to revision as new knowledge and experience becomes available. The data provided fall within the normal range of product properties and relate only to the specific material designated; these data may not be valid for such material used in combination with any other materials, additives or pigments or in any process, unless expressly indicated otherwise. The data provided should not be used to establish specification limits or used alone as the basis of design; they are not intended to substitute for any testing you may need to conduct to determine for yourself the suitability of a specific material for your particular purposes. Since DuPont cannot anticipate all variations in actual end-use conditions DuPont makes no warranties and assumes no liability in connection with any use of this information. Nothing in this publication is to be considered as a license to operate under or a recommendation to infringe any patent rights. DuPont advises you to seek independent counsel for a freedom to practice opinion on the intended application or end-use of our products. Caution: Do not use this product in medical applications involving permanent implantation in the human body.
For other medical applications see "DuPont Medical Caution Statement", H-50102.

Crastin® CE2510LM BK591

Property	Test Method	Units	Value
Processing			
Melt Temperature Range		°C	240-260
Melt Temperature Optimum		°C	250
Mold Temperature Range		°C	30-130
Mold Temperature Optimum		°C	80
Drying Time, Dehumidified Dryer		h	2-4
Drying Temperature		°C	110-130
Processing Moisture Content		%	<0.04

Contact DuPont for Material Safety Data Sheet, general guides and/or additional information about ventilation, handling, purging, drying, etc.
ISO Mechanical properties measured at 4.0mm, ISO Electrical properties measured at 2.0mm unless otherwise stated.
Test temperatures are 23°C unless otherwise stated.

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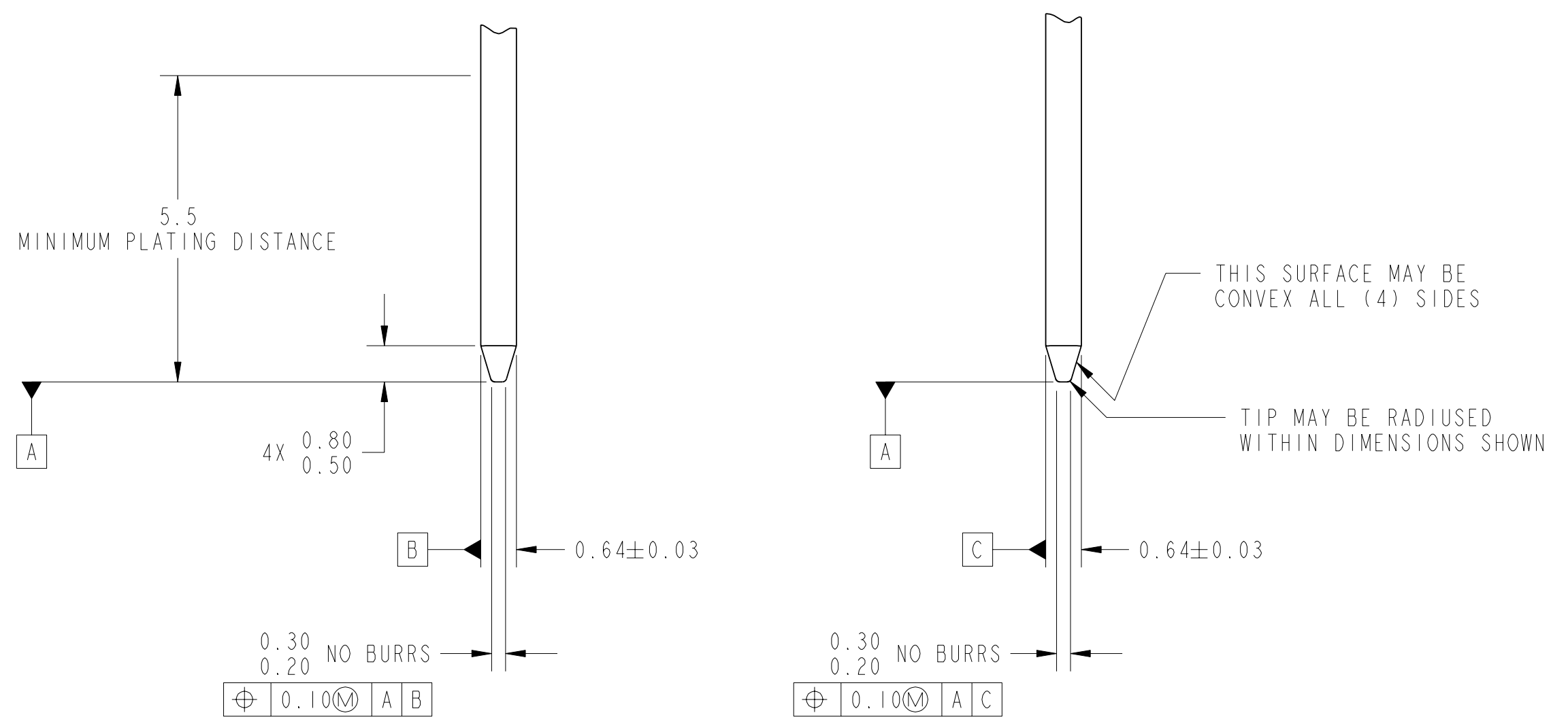
064-T001

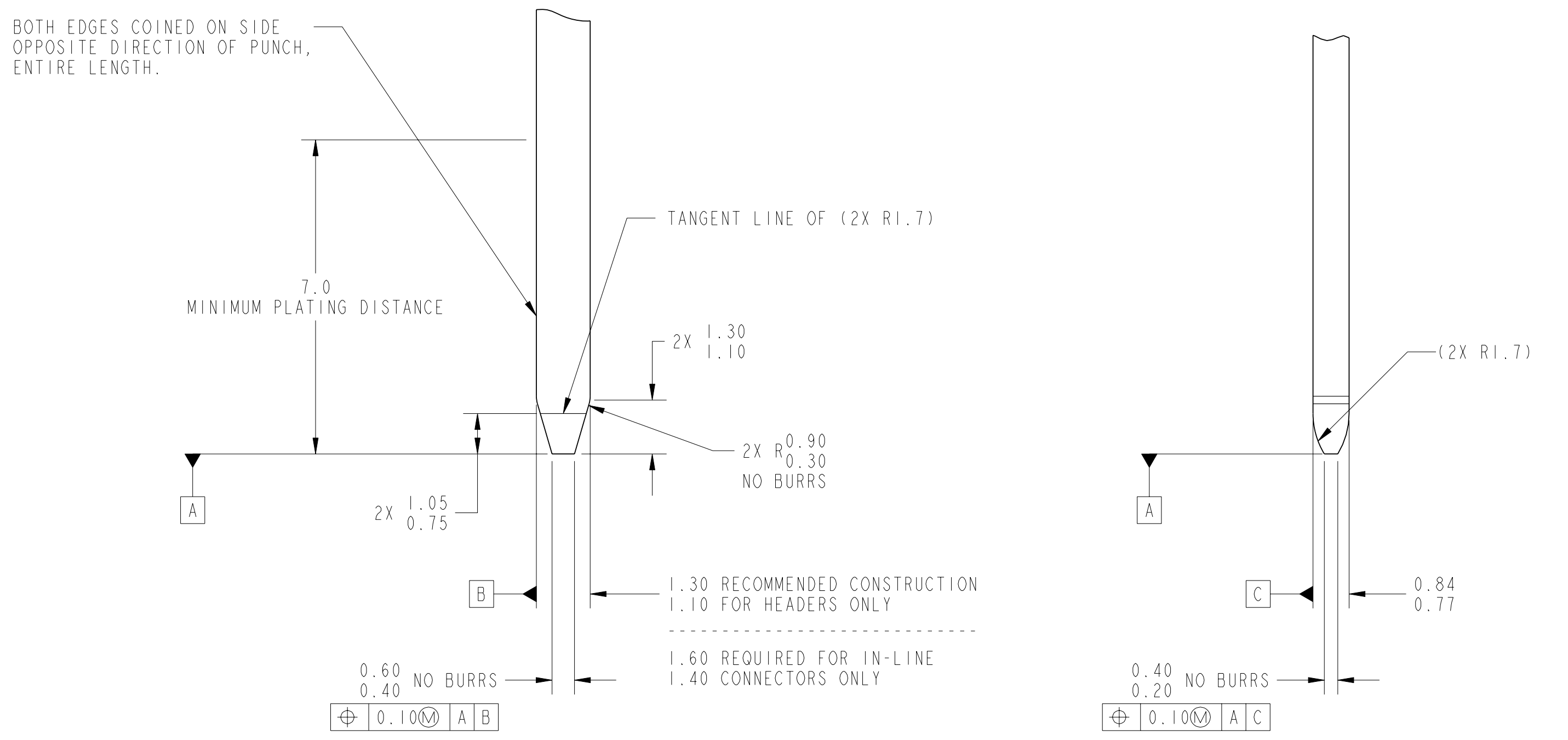
0.64 TERMINAL BLADE CONFIGURATION
SCALE = 10:1



1. PIN MUST BE SYMMETRICAL WITHIN TOLERANCE SHOWN
2. ALL TIP OR PIN EDGES MAY BE RADIUSED - R0.08 MAX
3. NO BURRS ON TIP OR PIN EDGES
4. ALL SURFACES OF PIN MUST BE PLATED TO THE MINIMUM PLATING DISTANCE SHOWN
5. ALL PIN DIMENSIONS INCLUDE PLATING IF APPLICABLE

150-T001

1.50 TERMINAL BLADE CONFIGURATION
SCALE = 10:1



280-T001

2.80 TERMINAL BLADE CONFIGURATION
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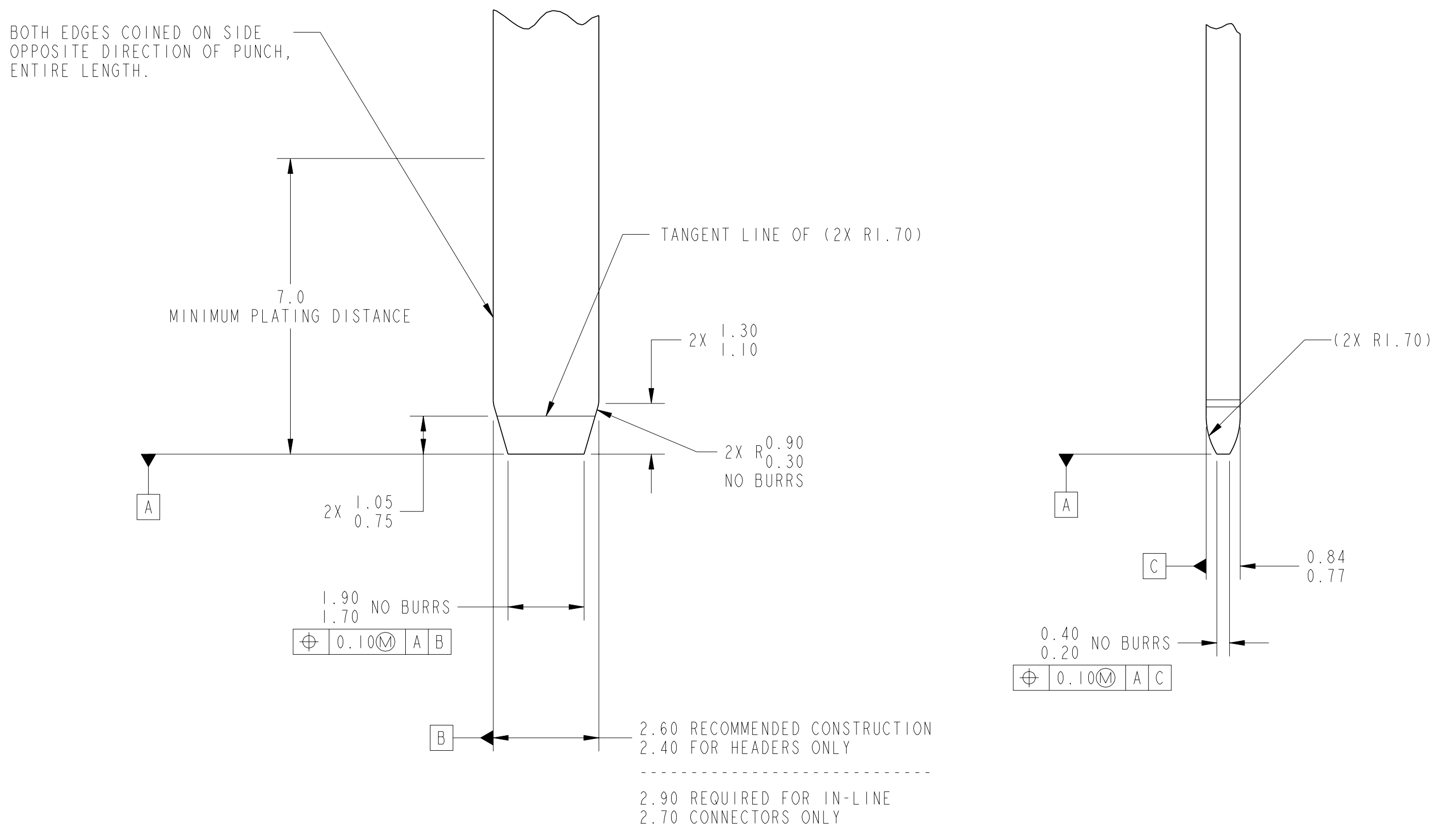
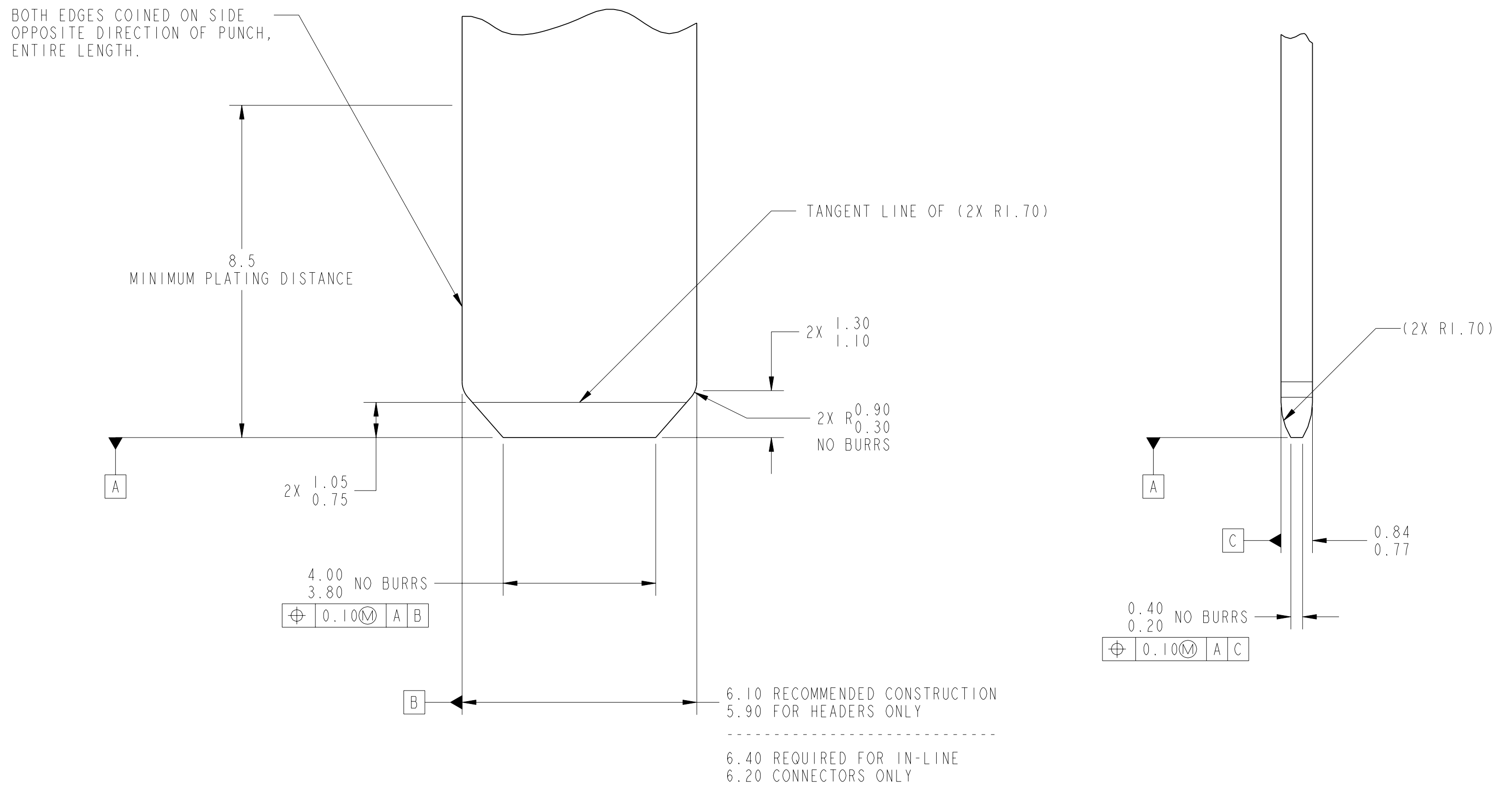


630-T001

6.30 TERMINAL BLADE CONFIGURATION
SCALE = 10:1



NOTICE

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MALE TERMINAL AND ELECTRICAL REQUIREMENTS

(EXCEPTIONS MUST BE APPROVED BY THE RESPONSIBLE ENGINEER)

BASE MATERIAL - COPPER ALLOY

ELECTRICAL CONDUCTIVITY - >=28% IACS AT 20°C (AS ANNEALED).
USE OF MATERIALS WITH CONDUCTIVITY <28% IACS OR NON-COPPER ALLOYS ARE ACCEPTABLE WHEN APPROVED BY THE RESPONSIBLE ENGINEER.

CONTACT AREA PLATING -
- **TIN** - FOR UP TO 125°C MAX. CONTINUOUS TEMPERATURE
  - **OPTION A**
    - **BARRIER PLATE** - (OPTIONAL FOR SOLDERABILITY) UNDERPLATE WITH COPPER 2.5 MICRO-METERS (100 MICRO-INCHES) MIN. THICKNESS.
    - **TOP LAYER** - ELECTRO-DEPOSITED TIN (MATTE FINISH-NO BRIGHTENERS) 2.5-4.0 MICRO-METERS (100-160 MICRO-INCHES)
  - **OPTION B**
    - **BARRIER PLATE** - NICKEL ELECTROPLATE 0.25-0.75 MICRO-METERS (10-30 MICRO-INCHES)
    - **TOP LAYER** - ELECTRO-DEPOSITED TIN (MATTE FINISH-NO BRIGHTENERS) 2.5-4.0 MICRO-METERS (100-160 MICRO-INCHES)
- **PRECIOUS METAL** - (WHEN SPECIFIED)
  - **BARRIER PLATE** - (OPTIONAL FOR SOLDERABILITY) UNDERPLATE WITH COPPER 2.5 MICRO-METERS (100 MICRO-INCHES) MIN. THICKNESS.
  - **INTERMEDIATE LAYER #1** - NICKEL - 1.2 MICRO-METERS (50 MICRO-INCHES) MIN. NICKEL ELECTROPLATE
  - **INTERMEDIATE LAYER #2** - (OPTIONAL) - 0.5 MICRO-METERS (20 MICRO-INCHES) MIN. PALLADIUM ELECTROPLATE
  - **TOP PLATING** - 0.1 MICRO-METERS (4 MICRO-INCHES) MIN. HARD-GOLD ELECTROPLATE IF INTERMEDIATE LAYER #2 IS APPLIED.
    0.5 MICRO-METERS (20 MICRO-INCHES) MIN. HARD-GOLD ELECTROPLATE IF INTERMEDIATE LAYER #2 IS NOT APPLIED.

PROCESS LUBRICANT:
ANY PROCESS LUBRICANT REMAINING ON THE TERMINAL MUST NOT VARNISH OR DEGRADE ITS ELECTRICAL PERFORMANCE UP TO A MAXIMUM CLASS AMBIENT TEMPERATURE PER SAE/USCAR-2 FOR 1008 HOURS. PROCESS LUBRICANTS SHOULD BE APPROVED BY THE RESPONSIBLE ENGINEER.

CHANGE SERIAL NUMBER	LET	REVISION RECORD	DATE	DWN	CHK
-	A	INITIAL RELEASE	020912	SAF	SAF

TOLERANCES (UNLESS OTHERWISE SPECIFIED)
DIMENSIONS ARE IN MILLIMETERS
ANGLES ± 2°
X.X ± 0.25 X.XX ± 0.10

THIRD ANGLE PROJECTION

EWCAP

SCALE 4:1
DRAWN BY S. FINSTROM
CHECKED BY S. FINSTROM
DATE 020904

TITLE
TERMINAL BLADE DETAIL
0.64, 1.50, 2.80, 6.30

SHEET 1 OF 1
DRAWING NUMBER EWCAP-001
SIZE E
DO NOT SCALE DRAWING
COMPUTER AIDED DRAWING
REVISION LEVEL A

E SIZE SHEET

EWCAP-001

Mr. Scott Yon
Reference: NVS-212mjl;
RQ09-003 - September 3, 2009

Enclosure 10A: Subject Components Materials Summary

Part Description	Composition & Properties	Confidential	Enclosure	Submssion Date to NHTSA
Sensor				
Steel Bushing	Bosch dwg bushing.pdf	Y	10B	Sept. 18, 2009
Ultradur Housing	Ultradur Data Sheet.pdf	N	10A	Sept. 3, 2009
Crastin Housing	Crastin Data Sheet.pdf	N	10A	Sept. 3, 2009
Terminal Blade	ewcap_blade_001.pdf	N	10A	Sept. 3, 2009
	uscar 2-4.pdf	N	10A	Sept. 3, 2009
Connector Housing				
P/N 1438426-1	Tyco_Housing_1438426-1.pdf	N	10A	Sept. 3, 2009
Terminals				
P/N 1326028	Tyco_ Terminal_1326028.pdf	N	10A	Sept. 3, 2009
Wiring				
Cable - Primary - Thin Wall Cross-Linked Polyethylene Insulated	ms8288_rev_E.pdf	Y	10B	Sept. 3, 2009
Reinforcement - Side Frt Rail Otr Rt/Lt				
P/N 04860528,9 (MS-6000-44-VA-050-SK)	MS-6000 (Frame Rails).pdf	Y	10B	Sept. 3, 2009

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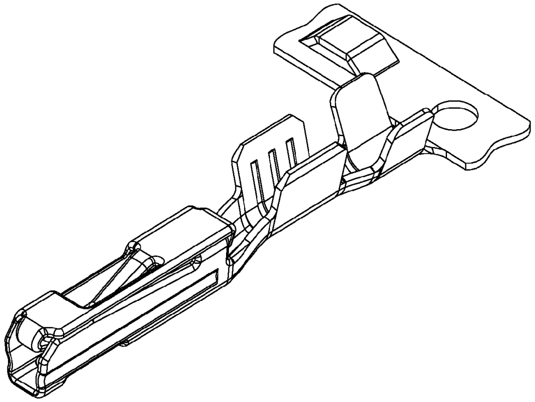
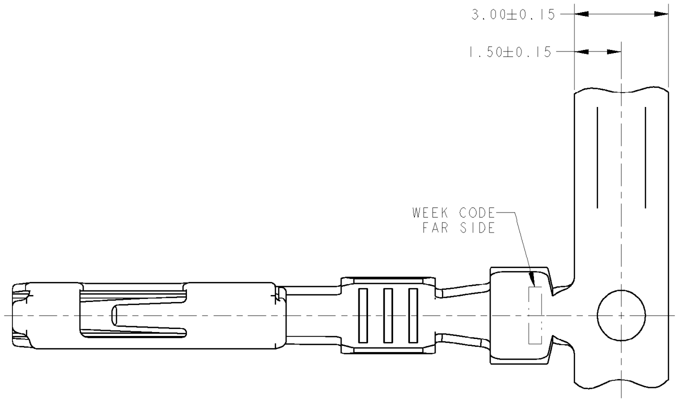
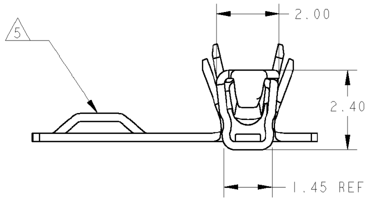
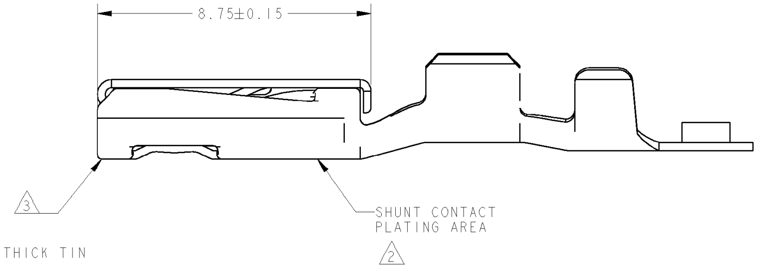
LOC	DIST
FX	00

REVISIONS					
P	LTR	DESCRIPTION	DATE	DWN	APVD
	0	RELEASED PER NPR 99037 WAS 97-4801-031	12-JUN-2002	JRS	FIK
	A	REV PER ECN 0K80-0123-00	17MAY2000	JRB	LTL
	B	REV PER EC 0K80-0100-02	18APR2002	RGV	AME
	C	REV PER EC 0K80-0150-02	12JUN2002	RGV	AME









1. FINISH: PLATED 0.00076 MIN THICK GOLD IN MATING AREA WITH 0.0025 MIN THICK TIN IN WIRE CRIMP AREA, ALL OVER 0.002 MIN THICK NICKEL.
2. FINISH: PLATED 0.00076 MIN THICK GOLD IN MATING AREA, PLATED 0.00038 MIN THICK GOLD IN SHUNT CONTACT PLATING AREA WITH 0.0025 MIN THICK TIN IN WIRE CRIMP AREA, ALL OVER 0.002 MIN THICK NICKEL.
3. GOLD FLASH THIS AREA PROVIDED FOR VISUAL INDICATION THAT TERMINAL IS GOLD PLATED.
4. PART LUBRICATED WITH CHEMLUBE 1102
5. FEATURE ON CARRIER STRIP IS RAISED ON GOLD PLATED PRODUCT. FEATURE APPEARS ADJACENT TO EVERY OTHER CONTACT MIN.
6. SEE FIGURE 1 FOR REELING DIRECTION.
7. SEE FIGURE 2 FOR REELING DIRECTION.
8. FOR LEVER ASSISTED CONNECTORS WITH SIDE SLIDE ACTION THE ALLOWABLE WIRE BRUSH LENGTH RANGE IS 0.10-0.70MM.

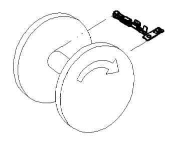


FIGURE 1

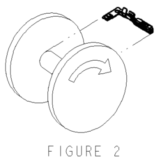


FIGURE 2

REELING DIRECTION OFF TOP OF REEL

REELING	LUBRICATION	FINISH	WIRE SIZE	PART NUMBER
7	4	2	22	1326028-8
			18-20	1326028-7
		1	22	1326028-6
			18-20	1326028-5
6		2	22	1326028-4
			18-20	1326028-3
		1	22	1326028-2
			18-20	1326028-1

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DIMENSIONS: mm

TOLERANCES UNLESS OTHERWISE SPECIFIED:
0 PLC ±-
1 PLC ±-
2 PLC ±0.20
3 PLC ±-
4 PLC ±-
ANGLES ±3°

MATERIAL -
0.25 THK COPPER ALLOY

FINISH SEE TABLE

DWN J R SHUEY 02SEP99
CHK J M MYER 02SEP99
APVD K DENLINGER 02SEP99
PRODUCT SPEC -
APPLICATION SPEC 114-13006
WEIGHT -

AMP Incorporated
Harrisburg, PA 17105-3608

NAME CONTACT, FEMALE, .64mm GOLD PLATED
-

SIZE A2
CAGE CODE 00779
DRAWING NO C-1326028
RESTRICTED TO -

CUSTOMER DRAWING
SCALE 10:1
SHEET 1 OF 1
REV C

AMP 1471-9 REV 27JUN96

Pro/ENGINEER DRAWING

Lead Free Conversion in Process - Refer to Specification 230-700 at www.tycoelectronics.com/leadfree

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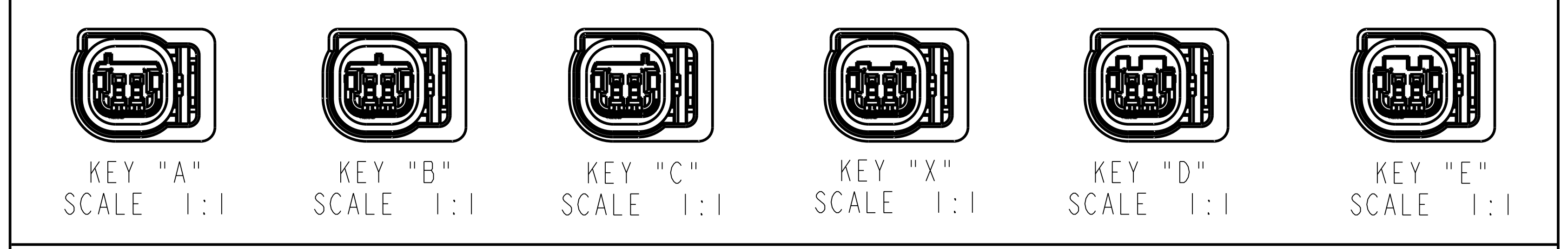
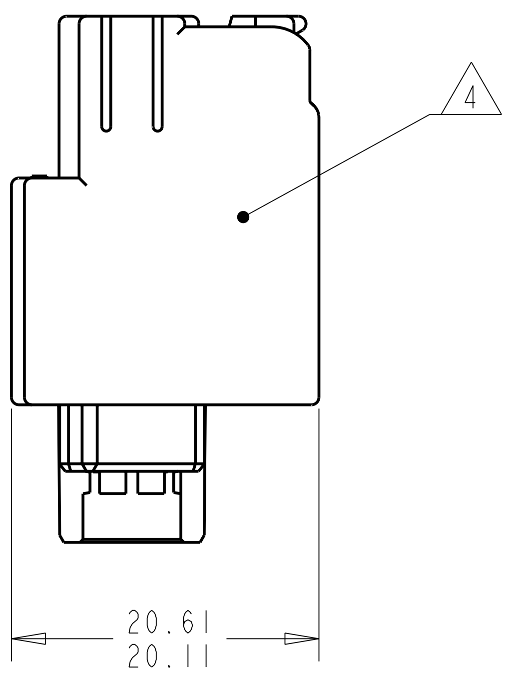
LOC	DIST
GE	00

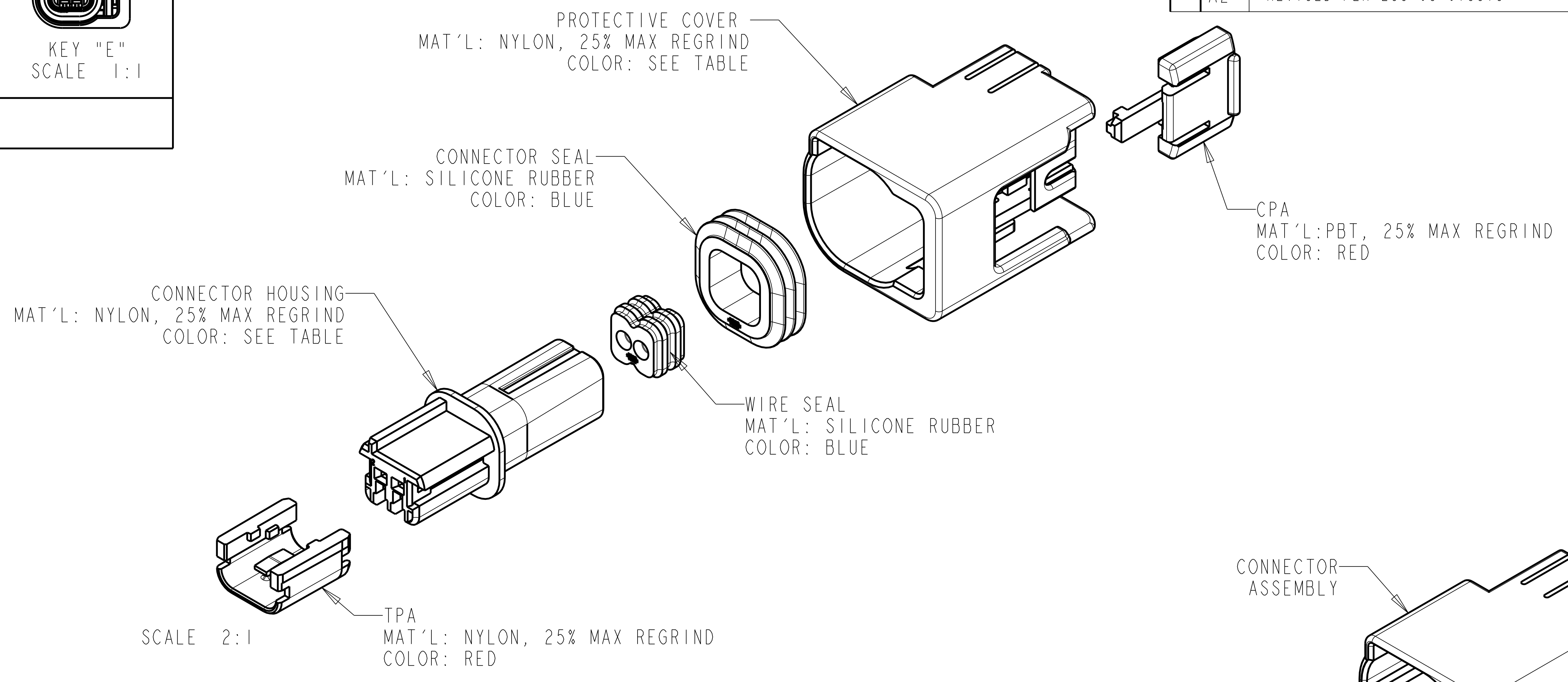
REVISIONS

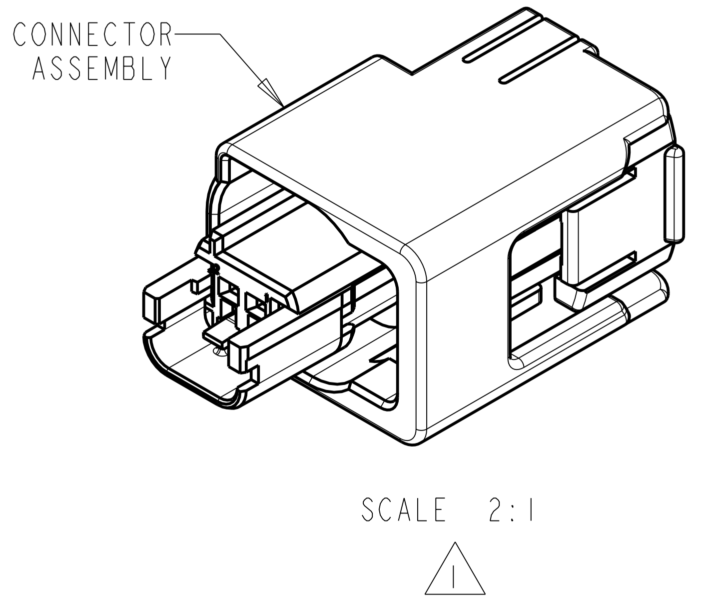
P	LTR	DESCRIPTION	DATE	DWN	APVD
	0	RELEASED PER EC 0K80-0169-03	20JUN2003	DJA	TMS
	A	ADDED: -21 PER EC 0K80-0180-04	02JUN2004	DLD	CJS
	A1	REVISED PER ECO-07-025000	01NOV2007	DLD	CJS
	A2	REVISED PER ECO-08-018575	30JUL2008	DLD	CJS

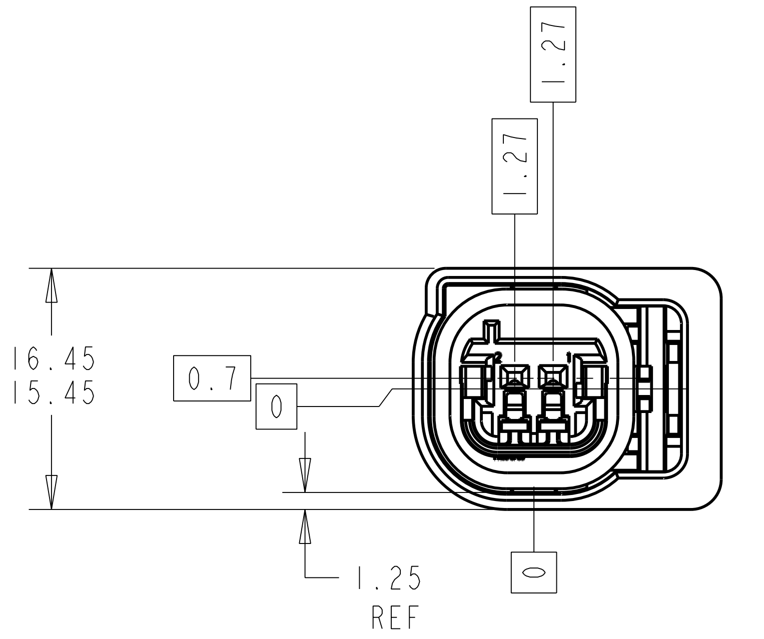


KEYING CONFIGURATION

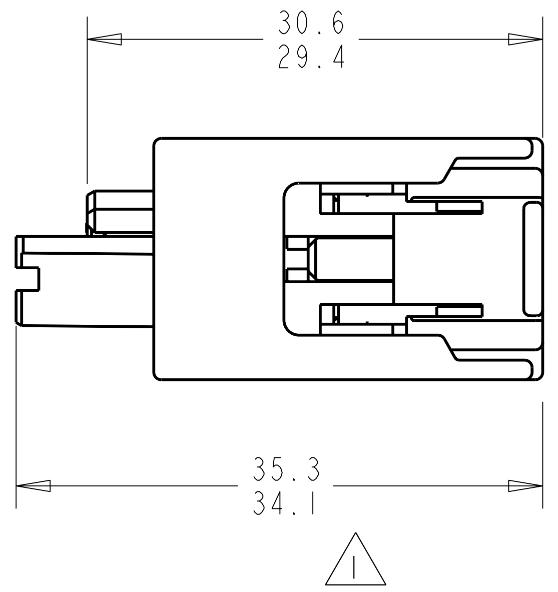


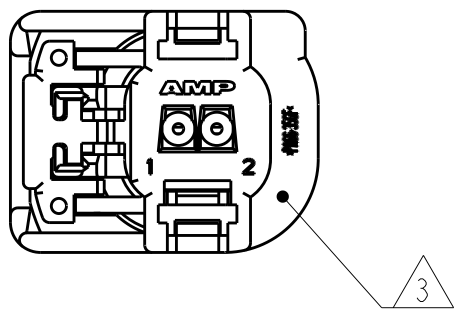






THE FEMALE CONTACT SPRING FINGER ENGAGES IN THE VERTICAL DIRECTION IN THIS VIEW





1. TPA SHOWN IN OPEN POSITION.
2. A "X" IN THIS TABLE INDICATES THAT THE CIRCUIT IS BLOCKED AND WILL NOT ALLOW INSERTION OF TERMINAL. A "-" INDICATES THAT INSERTION OF TERMINAL CAN OCCUR.
3. PART NUMBER 1438426-1 SHOWN.
4. AMP PART NUMBER AND DATE CODE MARKED IN THIS GENERAL LOCATION.
5. FOR SAFTY SYSTEM INNER & OUTER HOUSING COLOR: YELLOW.
6. INNER & OUTER HOUSING COLOR: BLACK.
7. INNER & OUTER HOUSING COLOR: GRAY.
8. TERMINALS SOLD SEPARATELY. SEE TYCO ELECTRONICS RECOMMENDED PART NUMBER 1326028 (GOLD PLATED) OR 638551 (TIN PLATED) FOR TERMINATION AND REELING OPTIONS.

FORCE REQUIREMENT	MIN(N)	MAX(N)
TPA ENGAGE PRESET TO FULL INSTALL	5	55
TPA DISENGAGE FULL TO PRESET	15	60
TPA REMOVAL FROM HOUSING	15	-
CPA ENGAGE PRESET TO LOCKED POSITION	-	30
CPA DISENGAGE LOCKED TO PRESET	-	30
CPA REMOVAL FROM HOUSING	15	-

NOTES	USED CIRCUIT PATTERN 2: CIRCUIT 2	CIRCUIT 1	KEY CONFIGURATION (DRAWING ZONE D3)	PART NUMBER
6	X	X	A	2-1438426-1
6	-	-	X	1438426-7
6	-	-	E	1438426-6
6	-	-	D	1438426-5
5	-	-	C	1438426-4
7	-	-	B	1438426-3
6	X	-	A	1438426-2
6	-	-	A	1438426-1

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DIMENSIONS: mm

TOLERANCES UNLESS OTHERWISE SPECIFIED:
0 PLC ±-
1 PLC ±.5
2 PLC ±0.10
3 PLC ±-
4 PLC ±-
ANGLES ±0.5

MATERIAL -
FINISH -

DWN D. AHERON 11JUN03
CHK M. SHORE 11JUN03
APVD M. SHORE 11JUN03
PRODUCT SPEC -
APPLICATION SPEC SAE/USCAR-2 8/97
WEIGHT -

Tyco Electronics
Tyco Electronics
Harrisburg, PA 17105-3608

NAME
CONNECTOR ASSEMBLY, FEMALE, 2 POSITION SEALED, 0.64mm

SIZE A2
CAGE CODE 00779
DRAWING NO C-1438426
RESTRICTED TO -
CUSTOMER DRAWING
SCALE 2:1
SHEET 1 OF 1
REV A2

1438426

AMP 1471-9 REV 31MAR2000
Pro/ENGINEER DRAWING

Product Information

07/2004

Ultradur® B4300G6

Polybutylentherephthalat (PBT)

BASF
The Chemical Company

Product description

Injection molding grade with 30% glass fibers for industrial parts, rigid, tough and dimensionally stable, for example for eg windshield wiper arms,printed circuit boards PCBs),housing,consoles,contact carriers,covers).

Physical form and storage

Standard packaging includes the 25-kg bag and the 1000 kg octabin (octagonal container). Other forms of packaging are possible subject to agreement. All containers are tightly sealed and should be opened only immediately prior to processing. Further precautions for preliminary treatment and drying are described in the processing section of brochure. The bulk density is about 0,7 to 0,8 g/cm³.
Ultradur should generally have a moisture content of less than 0,04% when being processed.
In order to ensure reliable production, therefore, pre-drying should generally be the rule and the machine should be loaded via a closed conveyor system. Appropriate equipment is commercially abailable. Pre-drying is also recommended for the addition of batches, e.g. in the case of inhouse pigmentation.
In order to prevent the formation of condensed water, containers stored in unheated rooms must be opened when they have attained the temperature prevailing in in the processing area. This can possibly take a very long time. Measurements have shown that the interior of a 25-kg bag originally at 5°C had reached the temperature of 20°C in the processing area only after 48 hours.

Product safety

Ultradur melts are thermally stable at the temperatures up to 280°C and do not give rise to hazards due to molecular degradation or the evolution of gases and vapors. Like all thermoplastic polymers, however, Ultradur decomposes on exposure to excessive thermal stresses, e.g. when it is overheated or as a result of cleaning by burning off. In such cases gaseous decomposition products are formed. Decomposition accelerates above 300°C approximately, the initial products formed being mainly tetrahydrofuran and water. At temperatures above about 350°C small quantities of aldehydes and saturated and unsaturated hydrocarbons are also formed. When
Ultradur is properly processed and there is adequate suction at the die no risks to health are to be Expected.
Safety data sheet could be ask for at the Ultra-Infopoint under tel: 0621/60-7 87 80 or fax 0621/60-7 87 30.

Note

The information in this puplication is based on our current knowledge and experience. In view of the many factors that may effect the processing and application of our products these data do not relieve processors of the responsibility of carrying out their own tests and trials. No legally binding assurance af certain properties or of suitability for a specific purpose can be inferred from our information. Recipients of our products are themselves responsible for observing any proprietary rights and existing laws and regulations.

Ultradur® B4300 G6

Typical values at 23°C for uncolored products	Test method	Unit	Value
Product Features			
Symbol	ISO 1043	-	PBT
Density	ISO 1183	g/cm^3	1.53
Reinforcing filler: Glass fiber (GF), Glass beads (GB), Mineral (M)		%	GF30
Viscosity number (solution 0,05 g/ml phenol/1,2 dichlorbenzene 1:1)	ISO 307	ml/g	102
Colors: natural (n), colored (c), black (bk), special colors (sp)	-	-	n,c,sp,bk
Water adsorption, saturation in water at23°C	DIN 53495/1L	%	0,4
Moisture absorption, saturation in standard conditioning atmosphere 23°C/50% r.h.	-	%	0,2
Processing methods			
Melting temperature,DSC	ISO 3146	°C	220-250
Melt volume rate MVR 250/2,16	ISO 1133	cm^3/10 min	14
Melt temperature range, injection molding/extrusion	-	°C	250-275
Mold temperature range, injection molding	-	°C	60-100
Moulding shrinkage, longitud./transvers. (260°/80°C) 6)	ISO 294	%	0,3/1,0
Flow spiral length /2mm) 260°C/80°C	BASF	cm	25
Fire behavior			
Flammability according to UL-Standard at h = 1,6 mm thickness	UL 94	Klasse	94HB
Flammability according to UL-Standard at h = 0,8 mm thickness	UL 94	Klasse	94HB
Flammability of interior materials in passenger cars at ≥1mm thickness	FMVSS 302	-	+
Flammability of insulating materials for electrical applications Method BH	BH	Stufe	BH3-15mm/min
Mechanical properties			
Tensile modulus of elasticity	ISO 527-2	MPa	10000
Tensile stress at yield (v=50mm/min), stress at break (v=5mm/min)*4)	ISO 527-2	MPa	135*
Elongation at yield (v=50mm/min), at break (v=5mm/min)* 4)	ISO527-2	%	2,5*
Tensile creep modulus, 1000 h, elongation ≤ 0,5%, +23°C	ISO 899-1	MPa	7500
Flexural strength	ISO 178	MPa	200
Charpy impact strength +23°C	ISO 179/1eU	kJ/m^2	67
Charpy notched impact strength +23°C	ISO 179/1eA	kJ/m^2	11
Impact-failure energy E$_{50,}$ moulding +23°C	ISO 6603-1	J	<5
Ball intendation hardness H 358/30, H 961/30^*	ISO 2039-1	Mpa	190*
Thermal properties			
Heat deflection temp. under 1,8 Mpa load (HDT A) 7)	ISO75-2	°C	205
Heat deflection temp. under 0,45 MPa load (HDT B) 7)	ISO75-2	°C	220
Max. service temperature (short cycle operation)2)	-	°C	210
Temperature-index, at 50% loss of tensile strength after. 20000h/5000h	IEC 216-1	°C	140/160
Thermal coefficient of linear expansion, longitud. (23-80)°C	DIN 53752	10-5/K	2-3
Thermal conductivity	DIN 52 612	5261W(m K)	0.27
Specific heat capacity	-	J(g K)	1.5
Electrical properties			
Dielectric constant at 100 Hz/1 MHz	IEC 250	-	4/3,8
Dissipation factor at 100 Hz/1 MHz	IEC 250	-	0.0025/0.017
Volumne resistivity	IEC 93	Ω cm	10^{16}
Comperative tracking index CTI, test solution A	EC 112	-	CTI 375
Comperative tracking index CTI, test solution B	IEC 112	-	CTI 125M

Fußnoten:

2) Typical values for parts required to withstand repeated exposure to this temperature for several hours over years of use, assuming appropriate shaping and processing for the material

4) Tensile stress at yield, Elongation at yield: v = 50 mm/min, Tensile stress at break, Elongation at break: v = 5 mm/min

6) Plate with film gate, dimensions (60*60*2)mm, long = in flow direction, transv. = transverse

7) without konditioning

Technical Information

TI-KTU/AS-28 e
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BASF Plastics
key to your success

Resistance of Ultramid®, Ultraform® and Ultradur® to chemicals

® = Registered trademark of
BASF Aktiengesellschaft

1 General information

The information given in this publication is based on our current knowledge and experience. In view of the many factors that may affect processing and application, these data do not relieve processors of the responsibility of carrying out their own tests and experiments; neither do they imply any legally binding assurance of certain properties or of suitability for a specific purpose.

The information given relates to unreinforced, unmodified base grades (eg, Ultramid A3K and B3S, Ultraform N 2320, Ultradur B 4250). Reinforced and impact-modified grades may behave slightly differently. For example, glass-fibre reinforced Ultraform is less resistant to hot water than unmodified grades, or impact-modified Ultra products may be more prone to swelling in polar solvents, fuels and oils than unmodified ones.

If you cannot find the information you require here, please contact our Technical Centre.

2 Column headings

wt. %: Figures under this heading refer to the concentration in wt.% of (unless otherwise stated) an aqueous solution of the substance; **SS** refers to a saturated solution of the substance; a blank means the information given relates to the pure substance.

°C: The temperature at which the given data is valid. RT means “room temperature” which is taken to be between 15°C and 35°C.

Notes: Miscellaneous information such as references to other publications, figures, permeability data (diffusion coefficient at 20 °C, D_{20}; permeability at 50°C, P_{50}) is given here. Values are written in scientific notation, eg, 2.5E-9 means 2.5 x 10^{-9}.

The degree of saturation w_t/w_s of a specimen after a given time can be found from the expression:

$$\frac{w_t}{w_s} = \frac{2.256}{s}\sqrt{Dt}$$

where:
w_t = increase in mass at time t (in s)
w_s = increase in mass at saturation
s = wall thickness in cm
D = diffusion coefficient in cm^2/s
t = time in seconds

The above formula can also be used to determine the diffusion coefficient for a particular chemical substance by measuring the rate of absorption.

BASF

3 Symbols used to describe the chemical resistance

+ : Resistant. Only slight changes to weight, dimensions, properties. According to current knowledge, the medium causes no irreversible damage to the polymer.

○ **:** Limited resistance. Noticeable change in properties. Prolonged exposure to the medium may cause irreversible damage (eg, polymer degradation).

– : Not resistant. Medium attacks polymer and/or causes environmental stress-cracking within a short time. Irreversible damage.

S : Plastic dissolved by the chemical.

Number after the resistance symbol: This number refers to the mass increase after the polymer specimen has been saturated. The values given are only rough values and refer to unreinforced grades. The actual weight change depends on the grade of plastic and its crystallinity. The percentage change in length can be taken as being roughly a quarter of the percentage weight change.

Overview of the chemical resistance of Ultramid, Ultraform and Ultradur

Rating	Ultramid	Ultraform	Ultradur
Very resistant	Aliphatic and aromatic hydrocarbons Alkalis Brake fluids Ethers, esters Greases Ketones Fuels (gasoline, diesel) Paints Lubricants Detergent	Aliphatic and aromatic hydrocarbons Alkalis Alcohols Brake fluids Ethers, esters Greases Ketones Fuels (gasoline, diesel) Paints Detergent Water up to approx.100 °C	Aliphatic and aromatic hydrocarbons Brake fluids Ethers, esters Greases Ketones Fuels (gasoline, diesel) Paints Acids (dilute) Lubricants Detergent Water up to approx. 40 °C
Not resistant	Halogens (fluorine, chlorine, bromine, Iodine) Mineral acids and certain organic acids Oxidants Phenols Zinc chloride solutions	Halogens (fluorine, chlorine, bromine, iodine) Nitrous gases Oxidants Acids Sulfur dioxide Concentrated zinc chloride solutions at elevated temperature	Alkalis Halogens (fluorine, chlorine, bromine, Iodine) Water above approx. 60 °C
Solvent for the resin			
1. Room temperature	Formic acid (> 60 %) Fluorinated solvents m-Cresol Phenol Sulfuric acid (96 %)	Fluorinated solvents (eg, hexafluoroisopropanol)	Fluorinated solvents (eg, hexafluoroisopropanol)
2. Elevated temperature	Benzyl alcohol Glycols Formamide	N-methylpyrrolidone Dimethylformamide	Phenol Dichlorobenzene

	Wt. %	**°C**	**Ultramid**	**Ultraform**	**Ultradur**	**Notes**
Acetaldehyde soln.	40	RT	○ (12%)	+		
Acetamide soln.	50	RT	○ (7%)	+		[2], [11]
Acetamide soln.	50	> 140	S			
Acetic acid	95	RT	–	–	–	
Acetic acid	10	RT	○	+	+	POM: up to 1000 h no damage
Acetic acid	5	RT	+ (10%)	+	+	PA: D_{25} = 1.4E-8 cm^2/s
Acetone		RT	+ (2%)	+	○	PA: creep strength see fig. 2; P_{20} = 0.01 (g.mm/m^2h)
Acetone		60	+	+	–	
Acetophenone		RT	+	+	+	
Acetyl chloride		RT	–	–		
Acetylene		RT	+	+	+	
Acrylic acid		> 30	S	–		[11]
Acrylic acid (soln. in aliphatic hydrocarbons)	3	80	○ (2%)	–		
Air		RT	+	+	+	
Alcohols: see “Methanol”, “Ethanol” etc.						
Aliphatic hydrocarbon blend		RT	+	+	+	
Alkylbenzenes (Shellsol® A)		RT	+	+		
Allyl alcohol		RT	○		+	
Aluminium acetate soln.	SS	RT	+	+	+	
Aluminium hydroxide soln.	SS	RT	+	+	+	
Aluminium salts of mineral acids in soln. (eg, chloride, sulfate, nitrate)	20	RT	○	○	+	PA: may cause stress cracking [6]
Aluminium salts of mineral acids in soln. (eg, chloride, sulfate, nitrate)	SS	50	–	–		
Amines, aliphatic		RT	+ (≤ 8%)	+	+	
Amino acids	SS	RT	+	+	+	
Ammonia soln.		RT	+	+	○	PA 6 (10 bar/50°C): D_{50} = 2E-8 cm^2/s [9]; PA: P_{20} = 1E-10 (cm^2/s · mbar)
Ammonia soln.		70	○	+	–	
Ammonia soln.	20	RT	+	+	+	PA: P_{20} = 0.06 (g · mm/m^2 · h)
Ammonia soln.	20	60	+	+	–	
Ammonium thiocyanate soln.	SS	RT	+	+		
Ammonium hydrogen carbonate soln.	SS	RT	+	+	+	
Ammonium salts of minerals acids in soln.	10	RT	+	+	+	
Ammonium salts of minerals acids in soln.	10	50	○	○		

	Wt. %	°C	Ultramid	Ultraform	Ultradur	Notes
Amyl acetate		RT	+	+	+	
Amyl acetate		100	–		–	
Amyl alcohol		RT	+ (≤ 5%)	+	+	PA: creep strength see fig. 1
Aniline		RT	○	○		
Anodizing baths (30% nitric acid/10% sulfuric acid)		RT	○	–	○	
Anthraquinone		85	○	+		
Antifreeze: see “Coolants”						
Antimony trichloride soln.	SS	RT	–	–		
Aqua regina (HCl/HNO_3)		RT	–	–	–	
Argon		RT	+	+	+	
Aromatic hydrocarbon blend		80	+	+	○	
Asphalt		RT	+	+	+	
Asphalt		> 100	○	○	○	
Bacteria (DIN 53739)		RT	+	+	+	
Baking enamels		150	+	○	+	Baking up to 30 min; particularly suitable for glass-reinforced grades
Barium salts of mineral acids		RT	○	+	+	PA: conc. solns. of barium thiocyanate cause stress cracking [9]
Benzaldehyde		RT	○	+		
Benzene		RT	+	+	+	PA: $P_{20} = 0.5\ (g \cdot 100\ \mu m/m^2 \cdot h)$
Benzene		80	+	+	–	
Benzoic acid soln.	20	RT	○	○	+	
Benzoic acid soln.	SS	RT	–	–	+	
Benzyl alcohol		RT	○ (3–30%)	+		
Beverages		RT	+	+	+	See also “Fruit juices”, “Brandy”, “Wine”
Bitumen (DIN 51567)		RT	+	+	+	
Bitumen (DIN 51567)		> 100	○	○	○	
Bleaching agent (aqueous; 12.5% active chlorine)		RT	–	–	○	
Boric acid soln.	10	RT	○	○	+	
Boron trifluoride		RT	–	–	–	
Brake fluids		RT	+ (3–10%)	+	+	
Brake fluids: (DOT 3–5, FMVSS 116)		125	○	+	+	Weight change after 14 days’ immersion at 120 °C: Ultramid A3WG6 +3% POM at 120 °C stable over 2000 h

	Wt. %	°C	Ultramid	Ultraform	Ultradur	Notes
Brake fluids: (SAE J 1703; DIN 53521)		150	–	–		
Brake fluids: Hydraulan® (BASF)		60	+	+	+	
Brake fluids: Hydraulan® (BASF)		120	+	+		Weight change after 14 days' immersion: Ultramid A3WG6 + 3%; Ultraform N 2200G53 +6%
Brandy		RT	+ (10%)	+	+	
Bromine vapour		RT	–	–	–	
Bromine water	SS	RT	–	–	–	
Bromochlorodifluoromethane		RT	+	+	+	
Bromotrifluoromethane		RT	+	+	+	
Butadiene		RT	+	+	+	
Butane		RT	+	+	+	PA 66: $P_{20} < 10$ ($cm^3 \cdot 100\ \mu m/m^2 \cdot d \cdot bar$)
Butanediols		RT	+	+	+	
Butanediols		> 140	○	–	–	
Butanols		RT	+ (2–9%)	+	+	PA: P_{20} approx. 2E-12 mol/cm · s; D_{20} = 3E-12 cm^2/s
1-Butene, cis-2-butene, (liquefied gas DIN 51622)		RT	+	+	+	
Butene glycol		RT	+	+	+	
Butene glycol		> 160	○	○	–	
Butter, buttermilk		RT	+	+	+	
Butyl acetate		RT	+	+	○	
Butyl acrylate		RT	+	+	○	
n-Butyl ether		RT	+	+	+	
n-Butyl glycol (glycol monobutyl ether)		RT	+	+	+	
Butyl glycolate		RT	+	+	+	
Butyl phthalate		RT	+	+	+	
Butyric acid soln.	20	RT	○	○	+	
γ-Butyrolactone		RT	+ (2%)	+		[16]
γ-Butyrolactone		>90	○	○		[16]
Calcium chloride soln.	SS	RT	+ (10%)	+	+	
Calcium chloride soln.	SS	60	○			
Calcium chloride soln. (alcoholic)	20	RT	○	+		Dissolves PA
Calcium hydroxide soln. (lime water)	SS	RT	+	+	+	

	Wt. %	**°C**	**Ultramid**	**Ultraform**	**Ultradur**	**Notes**
Calcium hypochlorite and bleaching powder soln.	SS	RT	–	–	○	
Camphor soln. in alcohol	50	RT	+	+	+	Weight increase owing to alcohol uptake
ε-Caprolactam (aqueous solution)	50	RT	+	+	+	
ε-Caprolactam (aqueous solution)	50	> 150	○			Dissolves PA 6 above 150 °C, PA 66 above 170 °C
ε-Caprolactam (molten)		> 120	○	–	–	[2]
Carbon dioxide		70	+	+	+	PA: P_{20} = 40–60 (cm^3 · 100 µm/m^2 · d · bar)
Carbon disulfide		RT	+	+		PA: P_{20} = 0.02 (g.mm/m^2 · h)
Carbon disulfide		60	–			
Carbon monoxide		70	+	+	+	
Casein		RT	+	+	+	
Caustic soda soln.: see “Sodium hydroxide soln.”						
Cellulose lacquers		RT	+	+	+	see also “Paint solvents”
Cement		RT	+	+	+	[1], [8]
Ceresin		RT	+	+	+	
Chloral hydrate		RT	–			[11]
Chloramines	< 10	RT	–		–	
Chlorinated biphenyls		80	○			see also “Clophen A 60/petroleum ether”
Chlorine, chlorine water		RT	–	–	–	see also “Bleaching agent”
Chloroacetic acid soln.	10	RT	–	–	–	
Chlorobenzene		20	+	+	+	PA: P_{50} = 1.0 (g · mm/m^2 · 10^3 h)
Chlorobenzene		50	+	+	–	
Chlorobromomethane		RT	○ (3–30%)		+	
Chlorodifluoroethylene		RT	+	+	+	
Chlorodifluoromethane, chlorodifluoroethane		RT	+	+	+	
Chloroform		RT	○ (5–25%)	○	–	PA: P_{20} = 0.1 (g · mm/m^2 · h)
Chlorosulfonic acid soln.	<10	RT	–	–	–	
Chlorothene®: see 1,1,1-Trichloroethane						
Chromic acid	10	RT	–	–	○	
Chromic acid	1	RT	○	○	+	
Chromyl chloride		RT	–	–		
Citric acid soln.	10	RT	+ (≤ 10%)	○	+	PA: D_{25} = 1E-8 cm^2/s
Citric acid soln.	10	50	+	–	○	

	Wt. %	°C	Ultramid	Ultraform	Ultradur	Notes
Citric acid soln.	20	80	+	–		
Citrus fruit juices		RT	+	+	+	
Citrus oils		RT	+	+	+	
Cleaning agent: all-purpose cleaner		RT	+	+	+	
Cleaning agent: household cleaner (Ajax, ATA, Domestos, Rilan)	10	RT	+	+	+	
Cleaning agent: toilet cleaner (pH < 3)		RT	○	–	+	
Cleaning agent: window cleaner		RT	+	+	+	
Clophen A 60/petroleum ether (1 : 1)		RT	+	+	+	
Cobalt salt solns.	20	RT	○	+		PA: stress cracking possible eg, with $CoCl_2$, $Co(SCN)_2$; [6], [15]
Concrete		RT	+	+	+	PA: [1]
Coolants: Glysantin®/Water 1 : 1		106	○	+	–	PA: see figs. 3 & 4
Copper (II) salt solns.	10		○	+	+	PA: nitrate and chloride cause stress cracking; [6], [10]
Coumarone and coumarone resins		RT	+	+	+	
Cresols		RT	S		S	
Crude oil: see “Petroleum”						
Cutting oils: see Lubricating oils						
Cycloalkanes		RT	+	+	+	
Cyclohexane, cycloheptane		RT	+	+	+	
Cyclohexanol (and esters thereof)		RT	+ (2–6%)	+	+	
Cyclohexanone		RT	+	+	+	
Decontaminating agent (MIL-D-50030 F)		RT	+	+	+	= diethylenetriamine/NaOH/ethylene glycol monoethyl ether (70 : 2 : 28)
Dekalin®		RT	+ (1–2%)	+	○	
Descaler (based on formic, acetic, citric acids)	10	RT	+	○	+	
Descaler (based on formic, acetic, citric acids)	10	50	○	–	○	
Descaler (based on sodium hydrogen sulfate)	10	RT	+	○	+	
Detergent soln, heavy-duty	< 10	RT	+	+	+	
Detergent soln, heavy-duty	< 10	80	○	+	○	POM: oxidizing detergent may cause corrosion
Developer soln. (Rodinal®, Agfa, pH 11)		RT	+	+	+	
Dibutyl phthalate		RT	+	+	+	
Dibutyl phthalate		60	+	+	○	
p-Dichlorobenzene		RT	+ (2%)		–	

	Wt. %	°C	Ultramid	Ultraform	Ultradur	Notes
1,2-Dichloroethane		RT	+ (2–5%)	+	–	
Dichloroethylene		RT	+	–	–	
Dichlorofluoromethane		RT	+	+	+	
Dichloromethane: see “Methylene chloride”						
Dichlorotetrafluoroethane		RT	+	+	+	
Diesel fuel: see “Fuels”						
Diethyl ether		RT	+ (3%)	+	+	PA: $P_{20} = 0.03$ ($g \cdot mm/m^2 \cdot h$)
Diethylene glycol		> 140	S		–	See also “Glycol”
Difluoromethane		RT	+	+	+	
Dimethyl ether		RT	+	+	+	
Dimethylacetamide		RT	+	+		PA 6 and POM on prolonged exposure: ○; [11]
Dimethylacetamide		> 150	–			
Dimethylamine		RT	+			
Dimethylformamide		RT	+ (5%)	+	+	
Dimethylformamide		90	○ (15%)			
Dimethylformamide		> 140		S		
Dimethylsilane		RT	+			
Dimethylsulfoxide (DMSO)		RT	+		+	
Dimethylsulfoxide (DMSO)		125	S			
Dioctyl phthalate		RT	+	+	+	
Dioxan		RT	+	+	+	PA: $P_{20} = 0.001$ ($g \cdot mm/m^2 \cdot h$)
Dioxan		60	+		–	
Diphyl® (biphenyl and diphenyl ether)		80	+	+	–	
Disopropyl ether		RT	+	+	+	PA: $P_{20} = 0.005$ ($g \cdot mm/m^2 \cdot h$)
Dishwasher detergent soln.	< 10	95	+	○	–	POM: oxidizing detergents may cause corrosion
Disinfectant (alcohol-based)	< 10	RT	+	+	+	[3], [4]
Disinfectant (aldehyde-based)	< 10	RT	+	+	+	[3], [4]
Disinfectant (based on phenols)	< 10	RT	○	○	○	PA is however resistant under normal conditions of use
Disinfectant (based on quaternary ammonium compounds)	< 10	RT	+	+	+	[3], [4]
Disinfectant (based on quaternary phosphonium compounds)	< 10	RT	+	+	+	[3], [4]
Disinfectant (chlorine-based)	< 10	RT	○	–	+	[3], [4]
Disinfection by boiling		100	+	+	○	

	Wt. %	°C	Ultramid	Ultraform	Ultradur	Notes
Disinfection by fractional vacuum process			+	+		
Disinfection by gas sterilization: see “Ethylene oxide”						
Disinfection by hot air/steam/hot air			+	+	○	See also “Steam (sterilization over 50 cycles)”
Disinfection by irradiation (25 kGy for 6 h)			+	○	+	PA: slight yellowing
Dispersions, aqueous (BASF Acronal®, Propiofan®)			+	+	+	
Edible fats and oils		100	+	+	+	
Electroplating baths, acidic		RT	–	–	+	see also: “Anodizing baths” and solutions of metal salts
Electroplating baths, alkali (cyanides)		RT	+	+	○	
Engine oils: see “Lubricating oils”						
Epichlorhydrin		RT	○			
Ethane		RT	+	+	+	PA: $P_{20} < 10$ (cm$^3 \cdot$ 100 µm/m$^2 \cdot$ d $\cdot$ bar)
Ethanol		RT	+(15%)	+	+	PA: $P_{20} = 0.2$ (g.mm/m$^2 \cdot$ h)
Ethanol, dilute	40 vol.	RT	+	+	+	
Ethereal oil		RT	+	+	+	
Ethyl acetate		RT	+ (1%)	+	○	PA: $P_{20} = 0.008$ (g $\cdot$ mm/m$^2 \cdot$ h)
Ethyl chloride		RT	+	+		
Ethylene		RT	+	+	+	PA: $P_{20} < 10$ (cm$^3 \cdot$ 100 µm/m$^2 \cdot$ d $\cdot$ bar)
Ethylene carbonate		50	+		–	
Ethylene carbonate		100	–		–	
Ethylene chlorohydrin		RT	○			
Ethylene oxide		RT	+	+	+	PA: $P_{20} < 100$ (cm$^3 \cdot$ 100 µm/m$^2 \cdot$ d $\cdot$ bar)
Ethylene oxide		> 80	–			
Ethylene oxide (gas sterilization)			○	+		PA: 30–70 °C up to 8 h: +
Ethylenediamine		RT	+ (8–15%)			
Exhaust fumes from internal combustion engine		RT	+	+	+	
Fats and waxes, edible fats		RT	+	+	+	see also “Edible fats and oils”
Fatty acids		RT	+	+	+	
Fatty alcohols		RT	+	+	+	
Fatty alcohols, sulfonated		RT	+	+	+	
Fluorinated hydrocarbons, fluorocarbons		70	+	+	+	POM: $P_{20} = 50–150$ (cm$^3 \cdot$ 100 µm/m$^2 \cdot$ d $\cdot$ bar)

	Wt. %	°C	Ultramid	Ultraform	Ultradur	Notes
Fluorine		RT	–	–	–	
Formaldehyde		RT	+	+	+	
Formaldehyde solution	30	RT	+ (5–15%)	+	+	
Formamide		RT	+	+		
Formamide		> 150	S			
Formic acid soln.	10	RT	○	○	+	POM: no damage after 1000 h Conc. acid dissolves nylons (50% for PA 6, 80% for PA 66); [2]
Formic acid soln.	10	50	–	–	○	
Fruit juices		RT	+	+	+	
Fuel, engine: Diesel		85	+	+	+	PA: $P_{40} = 0.001$ (g · mm/m^2 · h)
Fuel, engine: FAM test fuel (5% ethanol)		55	+ (9–14%)	+	+	
Fuel, engine: Gasoline (normal & premium grade)		RT	+	+	+	PA: $P_{40} = 0.006$ (g · mm/m^2 · h); POM: see figs. 24–25
Fuel, engine: Gasoline (normal & premium grade)		85	+	+		
Fuel, engine: High-performance fuels (Dekalin®, perhydrofluorene)		85	+	+	○	
Fuel, engine: M15 mixture (15% methanol)		55	+ (9–14%)	+	+	PA: see figs. 8–10; D_{20} = 1E-8 cm^2/s; POM: see figs. 24–25
Fuel, engine: M15 mixture (15% methanol)		70	○	+	○	PA: see figs. 8–10; PBT: see figs. 26–27
Fungi (DIN 53739; ISO 846)			+	+	+	[19]
Furfural		RT	+ (2–7%)	+	+	
Furfuryl alcohol		RT	+	+	+	Solvent for PA 610 above 90 °C
Gas sterilization: see “Ethylene oxide (gas sterilization)”						
Gasoline: see Fuels						
Gear oils (EP, hypoid, ATF, manual transmission)		≤ 110	+	○	+	See also “Lubricating oils”; PA: temperature/time limits see fig. 13
Gelatine		RT	+	+	+	
Glue		RT	+	+	+	
Glycerol		RT	+	+	+	PA: creep strength see fig. 5
Glycerol		170	S	–	–	
Glycolic acid soln.	30	RT	–	–		
Glycols, alkyl glycol ethers		RT	+ (2–10%)	+	+	See also “Brake fluids”, “Coolants”; [11]
Glysantin® (BASF): see “Coolants”						
Grease (based on ester oils, diester oils, phosphoric acid esters, synthethic oils)		≤ 110	○	+	+	[5]

	Wt. %	°C	Ultramid	Ultraform	Ultradur	Notes
Grease (based on polyphenylester)		≤ 110	+	+		
Grease (based on silicone oils): see “Silicone oils”						
Grease: antifriction bearing grease DIN 51825 (based on metal soaps)		≤ 110	+	+	+	PA: temp./time limits correspond to fig. 13; Lithium grease may cause increased swelling under some circumstances.
Hair dyes		RT	○ (≤ 11%)	+		
Hardening oils		RT	+	+	+	
Heating oil (DIN 51603)		RT	+	+	+	
Helium		RT	+	+	+	
Heptane		RT	+	+	+	PA: $P_{20} = 0.1\ (g \cdot mm/m^2 \cdot h)$
Hexachloroethane		RT	+	+		
Hexachlorobenzene		80	+ (1%)	+		
Hexafluoroisopropanol		RT	S	S	S	
Hexamethylenetetramine		RT			+	
Hexane		RT	+	+	+	
Humic acids		RT	○	○	+	PA, POM: chemical attack possible under extreme conditions
Hydraulic fluids		100	+	+	+	
Hydraulic oil (DIN 51525)		100	+		+	
Hydraulic oil (MIL-H 5606)		100	+		+	
Hydraulic oil (VDMA 24318)		100	+		+	
Hydrazine		RT		+		
Hydriodic acid, hydrogen iodide soln.		RT	–	–	○	
Hydrobromic acid soln.	10	RT	–	–	○	
Hydrochloric acid	> 20	RT	–	–	○	
Hydrochloric acid	2	RT	–	○	+	PA: figs. 1 & 12; [17]
Hydrofluoric acid	40	RT	–	–	–	
Hydrofluosilicic acid	30	RT	–	–	–	
Hydrogen		RT	+	+	+	PA: $P_{20} = 300 - 400\ (cm^3 \cdot 100\ \mu m/m^2 \cdot d \cdot bar)$
Hydrogen chloride gas		RT	–	–	–	see also “Hydrochloric acid”
Hydrogen fluoride		RT	–	–	–	
Hydrogen peroxide soln.	0.5	RT	+	+	+	
Hydrogen peroxide soln.	30	RT	–	–	+	

	Wt. %	°C	Ultramid	Ultraform	Ultradur	Notes
Hydrogen sulfide	< 10	RT	○	○	+	PA & POM: possible damage by sulfuric acid formed by oxidation
Hydrogen sulfide (dry)		RT	+	+	+	PA: P_{20} = 2.4E-12 (cm^2/s · mbar)
Hydroquinone soln.	5	RT	–		+	
Hyraulan® (BASF): see “Brake fluids”						
Impregnating oils		RT	+	+	+	
Ink		RT	+	+	+	
Iodine (alcoholic solution)		RT	–	–		
Iron (III) chloride	SS	RT	–			
Iron (III) chloride soln., acidic	10	RT	–	–		
Iron (III) chloride soln., neutral	10	RT	+ (4–10%)		+	
Iron (III) thiocyanate soln.	10	RT	○		+	
Isocyanates, aromatic		RT	+	+	+	
Isooctane		80	+	+	+	
Isopropanol		RT	+ (5–15%)	+	+	PA: P_{20} = 20 (g · 100 µm/m^2 · d); D_{20} = 1E-11 cm^2/s
Isopropanol		60	+	+	○	PA: creep strength see fig. 7
Ketones (aliphatic)		RT	+	+	○	
Lactic acid		10	+	+	+	
Lactic acid		90	–	–		
Laughing gas: see “Nitrous oxide”						
Lead acetate soln.	10	RT	+	+	+	
Lime: see “Cement”						
Linseed oil		RT	+	+	+	
Lithium bromide, lithium chloride soln. (aqueous)	10	RT	○	+	+	PA: environmental stress-cracking in saturated solutions
Lithium chloride soln. (alcoholic)	20	RT	S	+		
Lithium hydroxide	10	20	+	+	+	
Lithium hydroxide	10	80	–	+	–	
LPG (DIN 516222): see “Propane, propene”						
Lubricating oils						
Lubricating oil: gear oil (eg, ATF)		≤ 130	+	+	+	PA: temperature/time limits see fig. 13

	Wt. %	**°C**	**Ultramid**	**Ultraform**	**Ultradur**	**Notes**
Lubricating oil: HD engine oils, hydraulic oils, transformer oils		≤ 130	+	+	+	PA: temperature/time limits see fig. 13; PBT see fig. 28.
Lubricating oil: hypoid gear oil (with EP additives, MIL-L 2105 B)		≤ 110	+	○	○	PA: see fig. 13
Lubricating oil: hypoid gear oil (with EP additives, MIL-L 2105 B)		120	–			
Lubricating oil: without HD or EP additives (ASTM reference oil)		100	○	○	+	Possible attack by acids formed by oxidation
Lutensit®, Lutensol® (BASF)		RT	+	+	+	
Magnesium salt solns. (chloride, nitrate, sulfate)	10	RT	+ (5–10%)	+	+	
Maleic acid soln.	25	RT	○	–		
Malic acid	SS	RT	+	○	+	
Malt		RT	+	+	+	
Manganese salt solns (chloride, sulfate)	10	RT	+	+	+	
MAPP gas (C_3, C_4 aliphatic hydrocarbons)		RT	+	+	+	
Mercury		RT	+	+	+	
Mercury (II) chloride	SS	RT	–			
Mersolates®		RT		+	+	
Methane		RT	+	+	+	
Methanol		RT	+ (9–14%)	+	+	PA: P_{20} = 0.2 (g · mm/m^2 · h); D_{20} = 1E-8 cm^2/s; creep strength see fig. 11
Methyl acetate		RT	+ (2%)	+	○	
Methyl chloride		RT	+	+		
Methyl chloroform: see “1,1,1-Trichloroethane”						
Methyl ethyl ketone		RT	+ (2%)	○	+	PA: P_{20} = 0.001 (g · mm/m^2 · h)
Methyl formate		RT	+	+	+	
Methyl glycol		RT	+			
Methylamine		RT	+ (7%)	+		
Methylaniline		RT	+ (3–15%)			
Methylbromide		RT	+	+		PA: P_{60} = 6E-13 (cm^2/s · mbar)
Methylene chloride		RT	○	○	–	
N-methylpyrrolidone		RT	+	+		
N-methylpyrrolidone		> 150		S		
Microbes		RT	+	+	+	
Milk		RT	+	+	+	
Mineral oils: see “Lubricating oils”						

	Wt. %	°C	Ultramid	Ultraform	Ultradur	Notes
Molasses		RT	+	+	+	
Mortars: see “Cement”						
Moulds (DIN 53739; ISO 846 A, B; MIL-T 18404)		RT	+	+	+	[19]
Naphtha		RT	+	+	+	
Naphthalene		RT	+	+	+	
Naphthalenesulfonic acids		RT	–	–		
Naphthenic acids		RT	+	+	+	
Naphthols		RT	–			
Natural gas		RT	+	+	+	
Nekanil®, Nekal® surfactants (BASF)	< 10	50	+	+	+	PA: see fig. 1
Neon		RT	+	+	+	
Nickel nitrate	10	RT	○			PA: environmental stress-cracking possible; [6]
Nickel plating baths: see “Electroplating baths”						
Nickel salt solns. (chloride, sulfate)	10	RT	+	+	+	
Nitric acid	> 50	RT	–	–	○	
Nitric acid	2	RT	–	–	+	
Nitrilotriacetic acid (sodium salt)		RT	+	+	+	
Nitrobenzene, nitrotoluene		RT	○	○	+	
Nitrobenzene, nitrotoluene		> 100	S			[12]
Nitrocellulose lacquers (alcoholic, hazard class A I)		RT	○	+	○	
Nitrocellulose lacquers (alcohol-free, hazard class A II)		RT	+	+	○	
Nitrogen (200 bar)		RT	+	+	+	PA: $P_{20} = 6$ ($cm^3 \cdot 100\ \mu m/m^2 \cdot d \cdot bar$)
Nitrogen oxides (dinitrogen tetraoxide)		RT	○	–	+	[8]
Nitrogen oxides (under pressure)		RT	–	–		
Nitromethane, nitropropane		RT	○			
Nitrous fumes		RT	○	–	○	
Nitrous oxide		RT	+	+	+	
Noble gases (argon, helium, neon)		RT	+	+	+	PA: for helium $P_{20} = 340$ ($cm^3 \cdot 100\ \mu m/m^2 \cdot d \cdot bar$)
Octane, octene		RT	+	+	+	
Oil, for transformers, switchgear (DIN 51507)		50	+	+	+	PA: creep strength see fig. 1

	Wt. %	°C	Ultramid	Ultraform	Ultradur	Notes
Oils (vegetable, ethereal, mineral)		RT	+	+	+	See also “Lubricating oils”
Oleic acid		RT	+	+	+	
Oleum		RT	S	–	–	
Oxalic acid soln.	10	RT	○	–	+	
Oxalic acid soln.	10	80	–	–		
Oxygen (atmospheric pressure)		RT	+	+	+	PA: P_{20} = 10–15 ($cm^3 \cdot 100\ \mu m/m^2 \cdot d \cdot bar$); D_{20} = 1.3E-9 cm^2/s
Oxygen (high pressure)		RT	– (*)	– (*)	– (*)	(*): not BAM-approved (German materials testing institute)
Ozone		RT	–	–	–	
Ozone (1 ppm in water)		RT	+		+	
Ozone (20 ppm in air)		RT	○	○	+	[8]
Paint solvents		RT	+	+	○	Alcoholic solvents cause PA to swell
Paints: see “Paint solvents”, “Baking enamels”						
Palamoll®, Palatinol® grades (BASF)		RT	+	+	+	
Palatal® resins (BASF): see “Polyester resins”						
Palmitic acid		80	+	+	+	
Paraffin wax, liquid paraffin		RT	+ (< 0.2%)	+	+	
Peracetic acid		RT	–	–		
Perchloroethylene: see “Tetrachloroethylene”						
Perfume (alcoholic solution)		RT	+	+	+	
Perhydrol: see “Hydrogen peroxide soln.”						
Petroleum		RT	+	+	+	
Petroleum ether, petroleum solvents		80	+	+	+	
Phenol		> 43	S	–	–	[11], [12]
Phenol	88	RT	S	–	–	
Phenol (alcoholic soln.)	70	RT	○	–	–	
Phenyl ether (guaiacol, cresol)		RT	–			
Phenylethyl alcohol		RT	○			[11]
Phenylethyl alcohol		> 160	S			
Phosphate (inorganic) solns. (neutral and alkaline)	10	RT	+	+	+	
Phosphate esters: see “Hydraulic fluids”						
Phosphine		RT	+	+	+	

	Wt. %	°C	Ultramid	Ultraform	Ultradur	Notes
Phosphoric acid	10	RT	–	–	–	
Phosphoric acid	85	RT	S	–	–	
Photographic developer		RT	+	+	+	
Photographic fixer		RT	+	+	+	
Phthalic acid soln.	SS	RT	○	+	+	
Plasticizers: see “Palamoll®, Palatinol®”						
Plastomoll® (adipates, BASF) DDA, NA, DIDA		RT	+	+	+	
Polyester resins (eg, BASF Palatal® resins)		RT	+	+	+	
Polyglycols, polyols		RT	+	+	+	
Potassium bromide soln.	10	RT	○	+	+	
Potassium chloride soln.	10	RT	+	+	+	
Potassium chloride soln.	10	70	+	+	–	
Potassium dichromate soln.	5	RT	○	+	○	
Potassium hydroxide soln.	50	RT	○	○	–	Unfilled PA & POM: +; glass fibres attacked in reinforced grades.
Potassium nitrate soln.	10	RT	+	+	+	
Potassium permanganate soln.	1	RT	–	+	+	
Potassium thiocyanate soln.	SS	RT	–			
Propane, propene		RT	+	+	+	PA: $P_{20} < 10$ ($cm^3 \cdot 100\ \mu m/m^2 \cdot d \cdot bar$) for propane
Propanol (n-, iso-)		RT	+ (5–15%)	+	+	PA: $D_{20} = 1E\text{-}11\ cm^2/s$; $P_{20} = 20$ ($g \cdot 100\ \mu m/m^2 \cdot d$); creep strength see fig. 7
Propanol (n-, iso-)		> 100	S		–	
Propionic acid soln.	5	RT	+	+	+	
Propionic acid soln.	10	RT	–	○	+	
Propionic acid soln.	50	RT	–	–		
Protein solutions		RT	+	+	+	
Pulp slurries		≤ 60	+			
Pulp slurries		95	–		–	
Pyridine		RT	+	○		PA: $P_{20} = 0.0002$ ($g \cdot mm/m^2 \cdot h$)
Pyridine		80	○ (15–20%)			
Pyrocatechol soln.	6	RT	–			
Pyrrolidone		RT	+			
Pyruvic acid soln.	10	RT	○	–	+	

	Wt. %	°C	Ultramid	Ultraform	Ultradur	Notes
Rainwater (acidic)		RT	+	+	+	
Refrigerator oil		RT	+	+	+	
Resorcinol (alcoholic soln.)	50	RT	○	○	–	
Resorcinol/methanol/benzene/water (40 : 35 : 10 : 5)		RT	○	○	–	adhesive solvent
Road salt, road-salt solutions		RT	+	+	+	PA and POM may be attacked by any zinc chloride that forms
Salicylic acid soln.	SS	RT	+	–	+	
Seawater: see “Water”						
Silane (tetramethylsilane)		RT	+		+	
Silicone oils		≤ 80	+	+	+	PA: see figs. 14–15
Silicone oils		> 100	○			PA: see fig. 15
Soap solution	< 10	80	+	+	+	
Soda soln.	10	RT	+ (3–10%)	+	+	
Sodium bromide soln.	10	RT	○			
Sodium chlorate soln.	10	RT	+	+	+	
Sodium chlorite soln.	10	RT	○			
Sodium dodecylbenzenesulfonate soln.		RT	+	+	+	
Sodium hydrogen carbonate soln.	10	RT	+	+	+	
Sodium hydrogen sulfate soln.	10	RT	+		+	
Sodium hydrogen sulfite soln.	10	RT	+	–	+	
Sodium hydroxide soln.	10	RT	+	+	–	
Sodium hydroxide soln.	50	RT	○	○	–	Unfilled PA & POM: +; glass fibres attacked in reinforced grades.
Sodium hydroxide soln.	10	80	–	○	–	
Sodium hypochlorite soln.	10	RT	○	○	○	POM: damage after more than 1000 h
Sodium hypophosphite soln.	10	RT	+	+	+	
Sodium lauryl sulfate paste	30	RT	+	+		
Sodium lignosulfonate		RT	+	+	+	
Sodium nitrilotriacetate soln.	10	RT	+	+	+	
Sodium oleate		RT	+	+	+	
Sodium pentachlorophenolate		RT	+			
Sodium perborate soln.	3	RT		+		
Sodium pyrosulfite soln.	10	RT	+			

	Wt. %	°C	Ultramid	Ultraform	Ultradur	Notes
Sodium salt solns. (neutral, eg, chloride, nitrate, sulfate)	10	RT	+	+	+	
Soil (acidic: pH 3)		RT	+	○	+	see also “Humic acids”
Soil (neutral; alkaline: pH 10)		RT	+	+	+	see also “Bacteria”, “Moulds”
Soldering fluid		RT	–	–	+	
Steam		100	○	+	–	
Steam (50-µm film)		116	–			Evidence of molecular degradation after 5 cycles
Steam (sterilization over 50 cycles)		134	○	+	○	Sterilization (DIN 58946 parts 1 – 5): PA 66: +; PA 6: –
Stearic acid, stearate, alkyl stearate		RT	+	+	+	
Sterilization, sterilizing agent see “Disinfectant”						
Stoving enamels: see “Baking enamels”						
Styrene		80	+	+	+	
Sulfolane (tetramethylenesulfone)		RT	+ (1%)	+	+	
Sulfolane (tetramethylenesulfone)		> 80	S			
Sulfonates (eg, alkyl aryl sulfonate)	<10	RT	+	+	+	
Sulfur		RT	+	+	+	
Sulfur dioxide (dry)		RT	+	–	+	PA: P_{20} = 2.3E-11 ($cm^2/s \cdot mbar$) [13]; high absorption under high pressure [16]
Sulfur dioxide (moist)		RT	○	–	+	
Sulfur hexafluoride (20 bar)		RT	+	+	+	
Sulfuric acid	> 80	RT	S	–	–	
Sulfuric acid	2	RT	–	○	+	POM: no damage caused by 5% solution up to 1000 h
Sulfurous acid soln.	SS	RT	○	○	+	
Sweat (DIN 54020)		RT	+	+	+	[7]
Tall oil		RT	+	+	+	
Tallow		RT	+	+	+	
Tar: see “Bitumen”						
Tartaric acid	10	RT	+ (4 – 10%)	+	+	
Tartaric acid	50	RT	○		+	
Termites		RT	+	+	+	Surface may be eaten into slightly
Tetrachloroethylene		RT	○	+	○	[18]
Tetrachloroethylene		80	–	○	–	[18]

	Wt. %	°C	Ultramid	Ultraform	Ultradur	Notes
Tetrachloromethane		RT	+ (1–4%)	○	+	PA: $P_{20} = 0.08$ (g · mm/m^{2}h)
Tetrafluoromethane		RT	+	+		
Tetrafluoropropanol		RT	–			
Tetrahydrofuran		RT	+ (2–10%)	○	+	PA: $P_{20} = 0.001$ (g · mm/m^{2}h)
Tetralin®		RT	+ (2–3%)	+	+	
Tin (II) salts of mineral acids	10	RT	○	+	+	
Toluene		RT	+	+	+	PA: $P_{20} = 0.005$ (g · mm/m^{2}h)
Toluene		100	+	+	–	
Town gas		RT	+	+	+	
Trichloroacetic acid ethyl ester		RT	○	–	–	PA 66: limited resistance; PA 6: not resistant
Trichloroacetic acid soln.	50	RT	–	–	–	
1,1,1-Trichloroethane (Chlorothene®)		45	+		+	[18]
Trichloroethanol, trifluoroethanol		RT	–		–	[11]
Trichloroethylene		RT	○ (4–10%)	–	–	PA: $P_{50} = 0.02$ (g · mm/m^2 · d)
Trichloroethylene		> 40	–	–	–	
Trichlorotrifluoroethane		RT	+	+	+	
Triethanolamine		RT	+	+	+	
Trilon® A, B (BASF)	10	RT	+	+	+	
Trilon® A, B (BASF)	10	60		+		
Trimethylamine		RT	+	+		
Tri-p-cresyl phosphate		RT	+	+	+	
Turpentine oil		RT	+ (1%)	+	+	
Turpentine substitute (white spirit)		RT	+	+	+	
Uranium fluoride		RT	–	–	–	
Uric acid soln.	20	RT	+	+	+	
Urine		RT	+	+	+	
Vacuum		RT	+	+	+	
Vaseline		RT	+	+	+	
Vinyl chloride, bromide, fluoride		80	+	+	+	
Vulcanization		≤ 180	+	○	–	

	Wt. %	°C	Ultramid	Ultraform	Ultradur	Notes
Water (including seawater)		RT	+	+	+	PA: see figs. 1, 17, 18, 19; POM: see figs. 22 & 23
Water (including seawater), chlorinated (≤ 0.5 mg/l)		80	+	+	○	
Water glass		RT	+	+	+	
Wax		80	+	+	+	
Wax polishes		RT	+	+	+	
WC cleaner (pH < 3)		RT	○	–	+	
Wine		RT	+	+	+	
Xylene		RT	+	+	○	
Xylene		100	+	+	–	
Yeast		RT	+	+	+	
Zinc (galvanized metal surfaces) exposed to weather		RT	+	+	+	Formation of zinc chloride possible on exposure to salt water (see “Zinc chloride”)
Zinc chloride		RT	+	+	+	
Zinc chloride soln.	10	RT	○	+	+	PA: stress cracking under certain circumstances (see figs. 20–21); POM: corrosion under certain circumstances above 60°C
Zinc chloride soln.	37	RT	–	○	+	POM: corrosion possible above 60°C
Zinc thiocyanate, bromide, iodide, nitrate	30	RT	–		+	

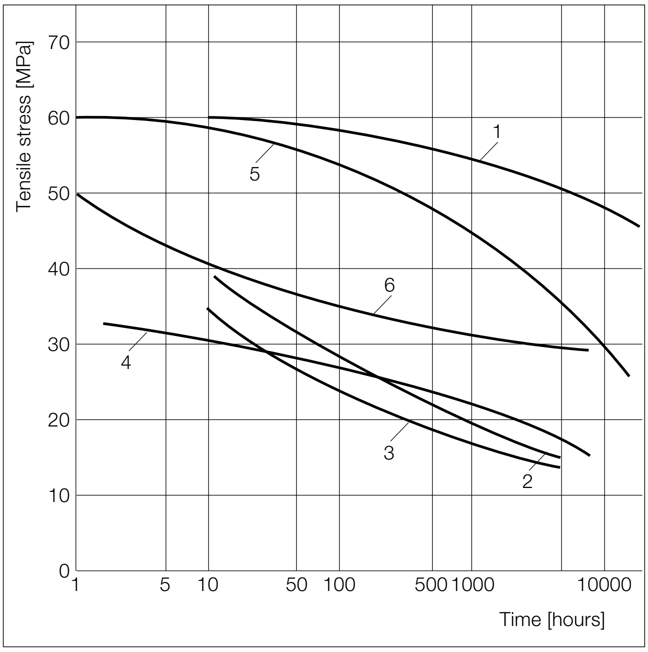

Fig 1: Creep behaviour of Ultramid B5 in air and various chemicals at 23, 40 and 50°C.
Test specimens: DIN 53455, no. 3, made from extruded sheet.

1 air, 23 °C/50 r.h.
2 water (distilled), 23 °C
3 hydrochloric acid, pH 1.5, 23 °C
4 Nikanil W Extra, 5 %, 50 °C
5 transformer oil, 50 °C
6 amyl alcohol, 23 °C

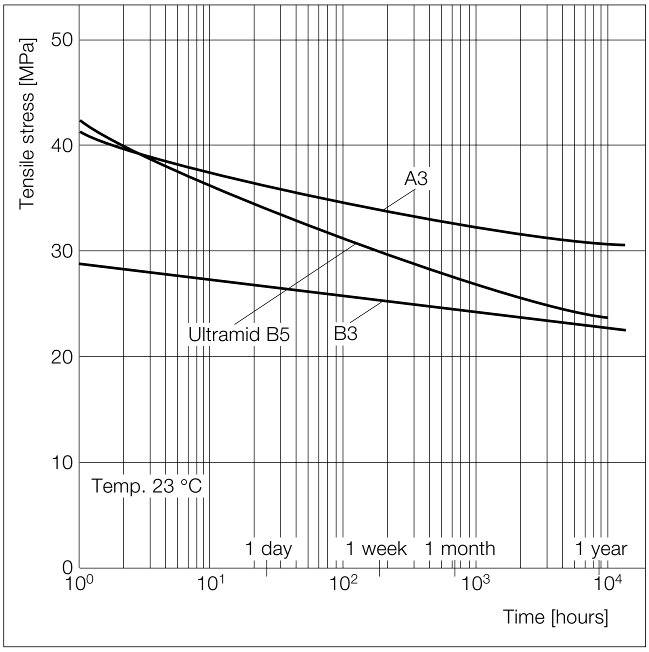

Fig 2: Creep behaviour of Ultramid A and B grades in acetone at 23°C.
Test specimens: DIN 53455, no. 3.

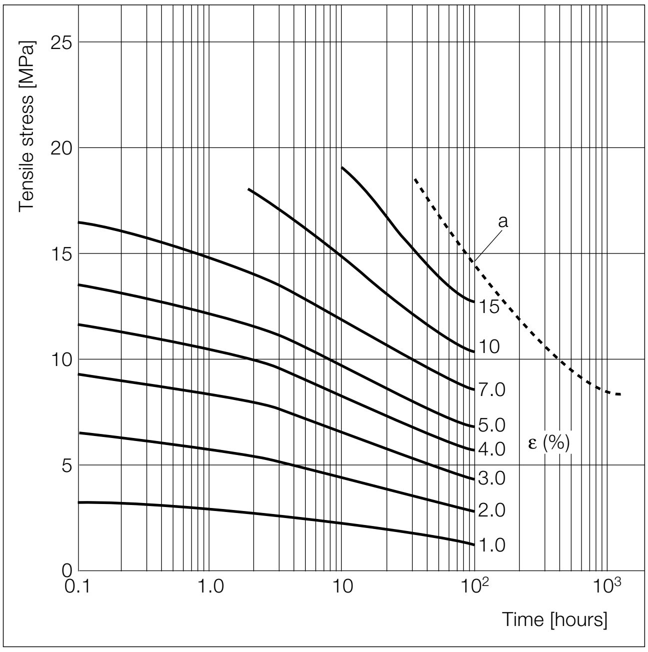

Fig 3: Creep behaviour of Ultramid A4K in a boiling 1 : 1 Glysantin®/water mixture at 106 °C.
Test specimens: 118 mm x 13 mm x 8 mm (initially dry).
Weight increase at saturation (150 h): 11.5 %.
a = creep-to-rupture curve; ε = strain

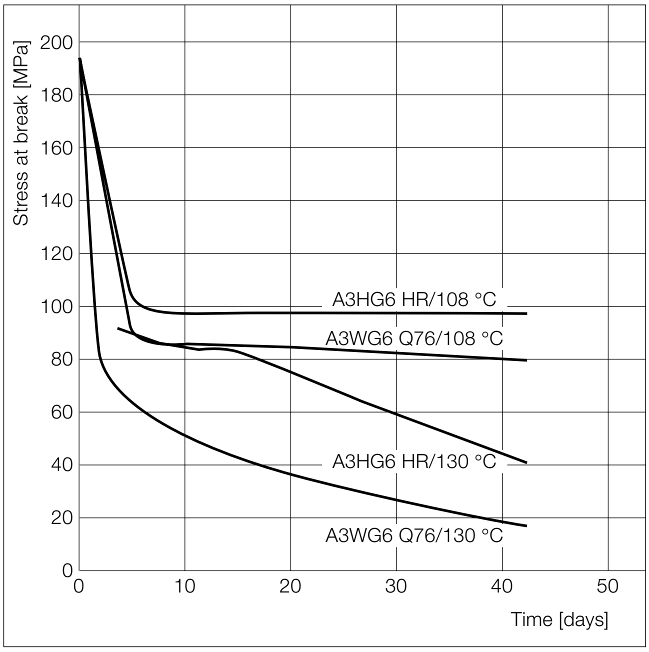

Fig. 4: Mechanical data after immersion in 1 : 1 Glysantin/water mixture at 108 °C and 130 °C.

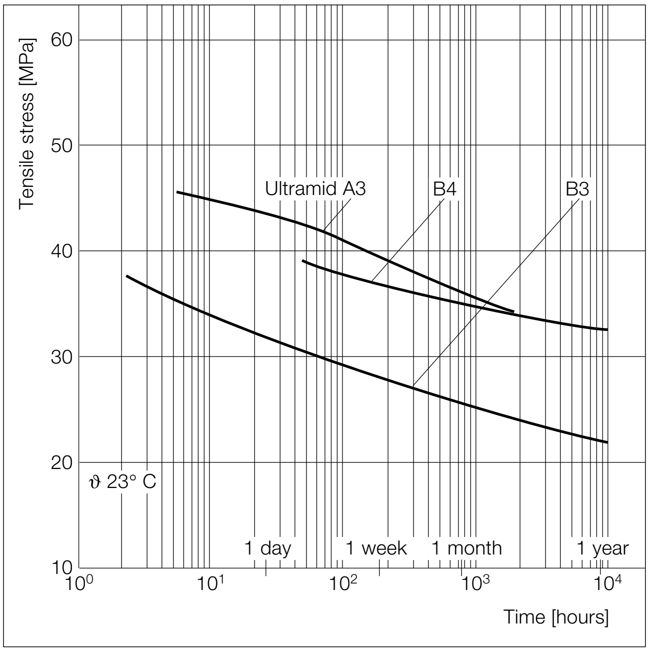

Fig 5: Creep behaviour of Ultramid A and B grades in glycerol at 23 °C.
Test specimens: DIN 53455, no. 3

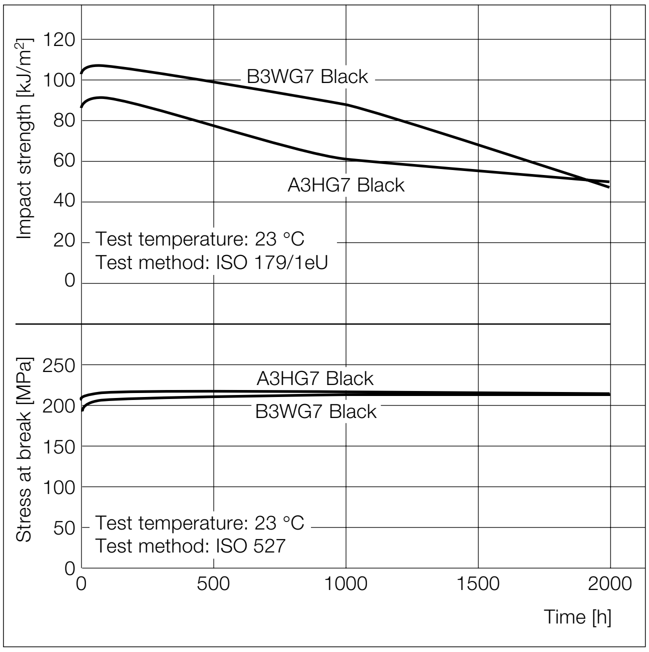

Fig. 6: Ultramid A3HG7 Black and B3WG7 Black Resistance to engine oil (Elf XT 3341) at 150 °C

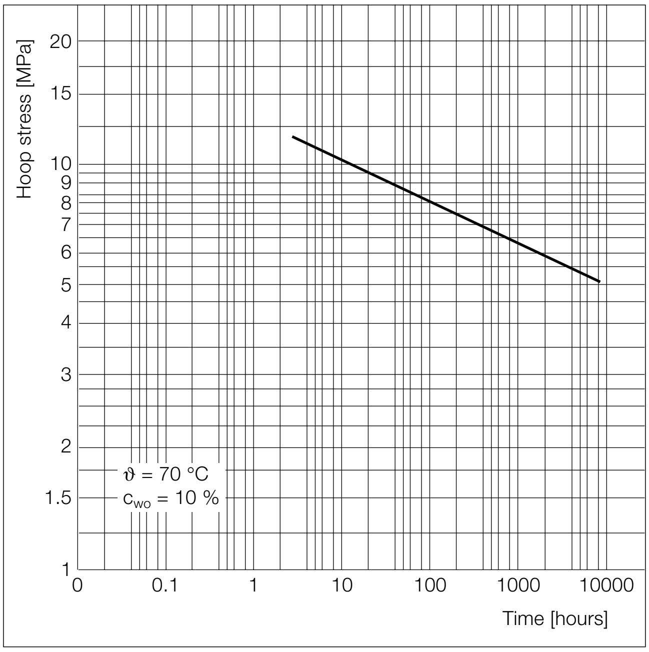

Fig. 7: Creep behaviour of water-saturated Ultramid B5 pipes in isopropanol at 70 °C

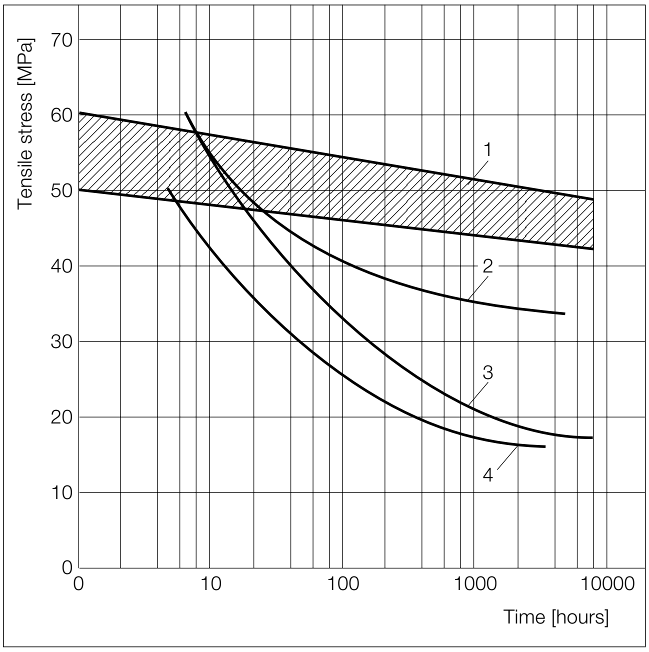

Fig. 8: Creep behaviour of Ultramid B grades in M15 fuel (85 : 15 gasoline/methanol), in water and in 23/50 standard atmosphere.
Test specimens: DIN 53455, no. 3
1 Ultramid B3S, B5 (conditioned at 23°C/50 r.h.)
2 Ultramid B3S (dry) in premium-grade gasoline at 23 °C
3 Ultramid B3S (dry) in M15 fuel at 23 °C
4 Ultramid B3S (initially dry) in water at 23 °C

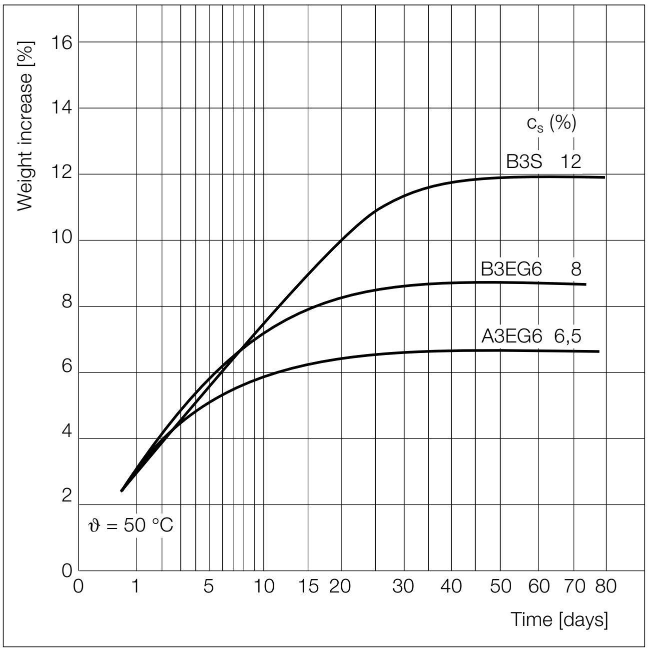

Fig. 9: Relative increase in weight of Ultramid grades in M15 fuel (85:15 gasoline/methanol) at 50 °C. C_s (%) is the relative increase in weight at saturation. Test specimens: DIN 53455, no. 3

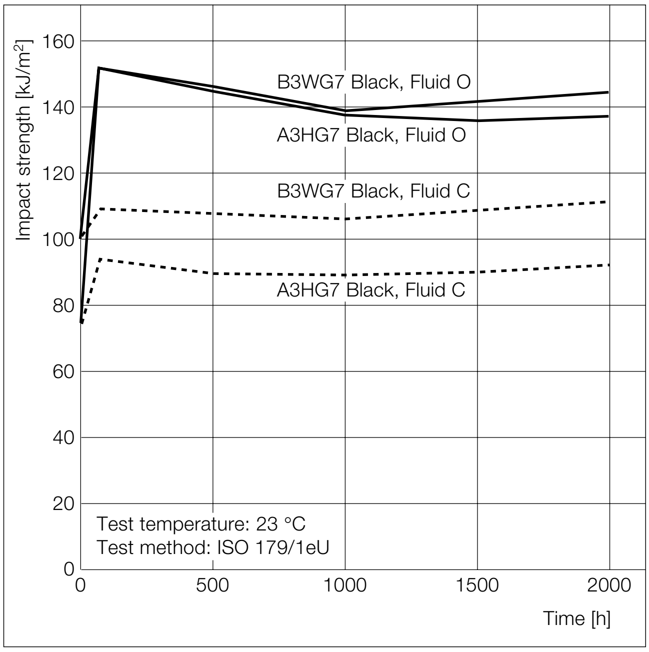

Fig. 10: Ultramid A3HG7 Black and B3WG7 Black Resistance to fuel mixtures at 70 °C: Fluid C (50 % isooctane + 50 % toluene); Fluid O (85 % Fluid C + 15 % methanol).

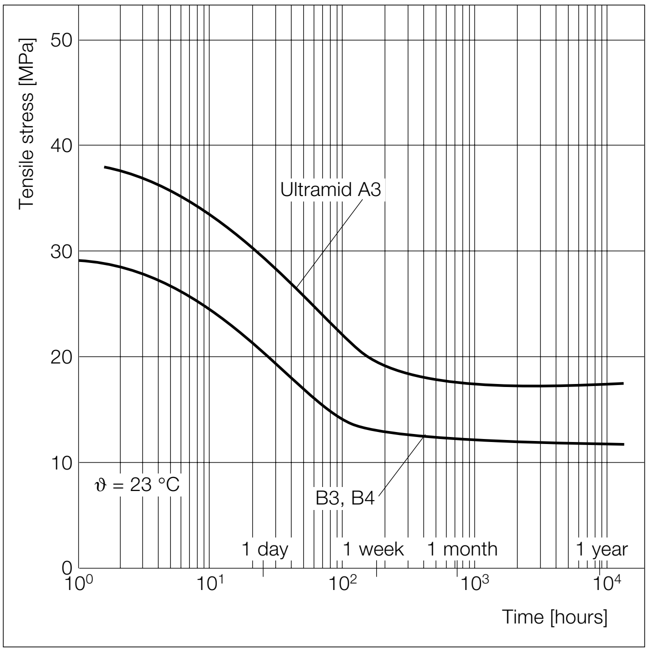

Fig. 11: Creep behaviour of Ultramid A and B in methanol. Test specimens: DIN 53455, no. 3; temp.: 23 °C

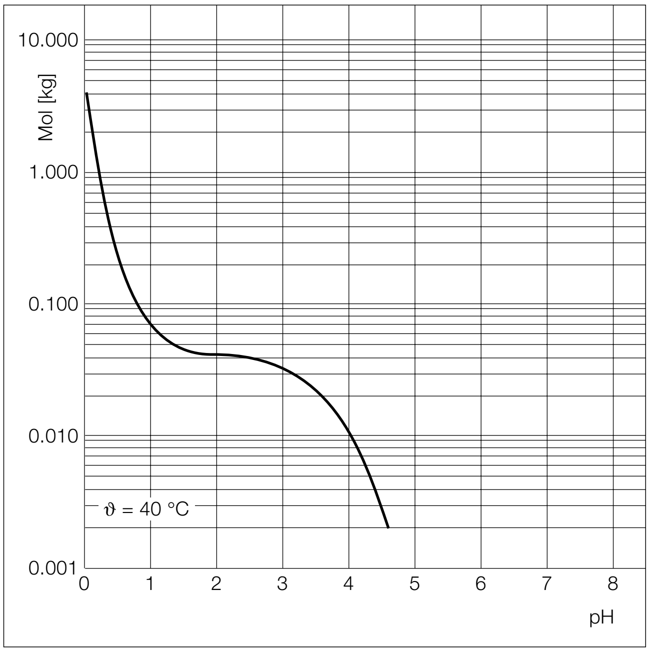

Fig. 12: Absorption of hydrochloric acid by Ultramid B3 as a function of the pH at 40 °C. Test specimens: disks (Ø 60 mm x 1 mm) injection-moulded with a cold mould

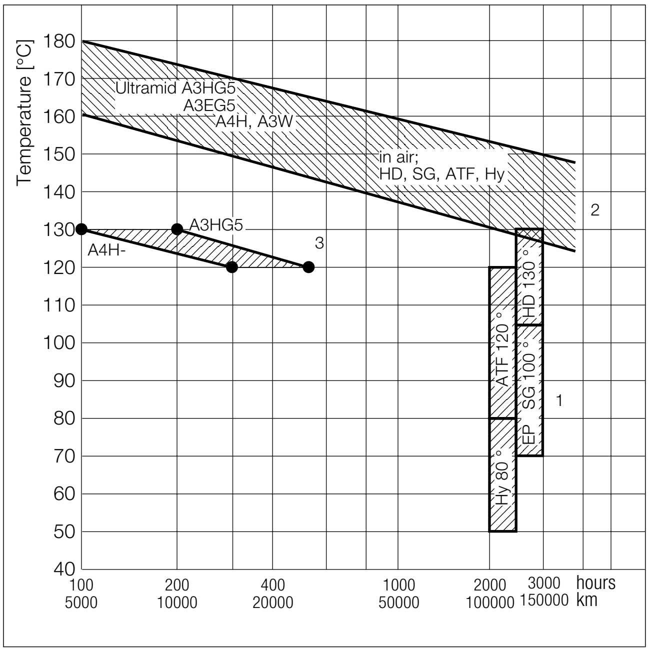

Fig. 13: Typical temperature and endurance data for Ultramid in contact with automotive lubricants
HD = HD engine oil
SG = Transmission oil (mechan.)
ATF = Transmission oil (autom.)
EP = EP hypoid-gear oil SAE90
Hy = Hydraulic oil (corresp. HD)

1 Long term temp. in driving operation (Peak temp. approx. + 130 °C)
2 In accordance with IEC-216
3 In EP hypoid-gear oil

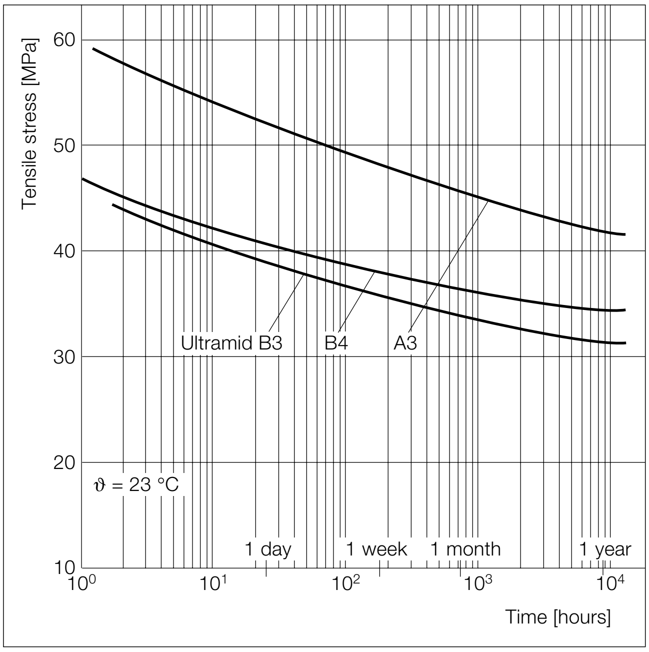

Fig. 14: Creep behaviour of Ultramid in silicone oil AK 1000 (Wacker)
Test specimens: DIN 53455, no. 3

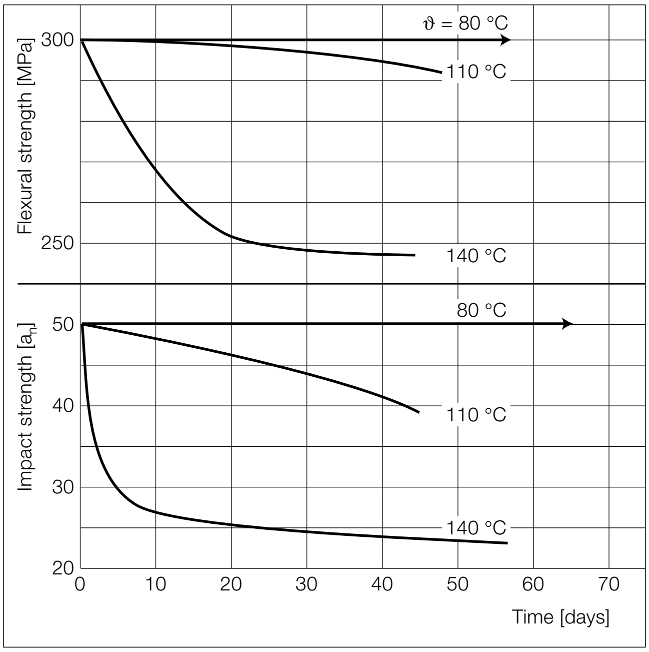

Fig. 15: Change in impact and flexural strength of Ultramid A3EG10 Black 564 in contact with silicone oil at 80, 110 and 140 °C (measured at 23 °C)

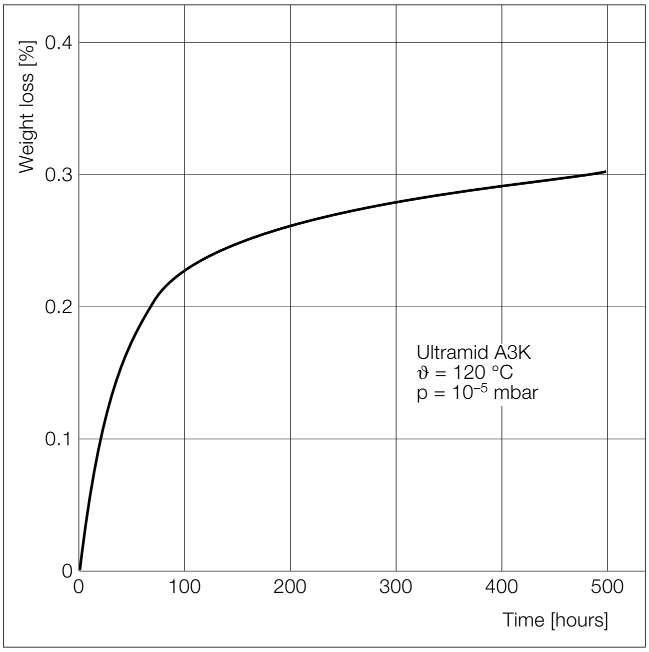

Fig. 16: Relative loss in weight of Ultramid A3K Black 464 (dry) at 120 °C in a 10^{-5}-mbar vacuum. (GLC analysis of volatile matter: 80% oligomers, 7% water).

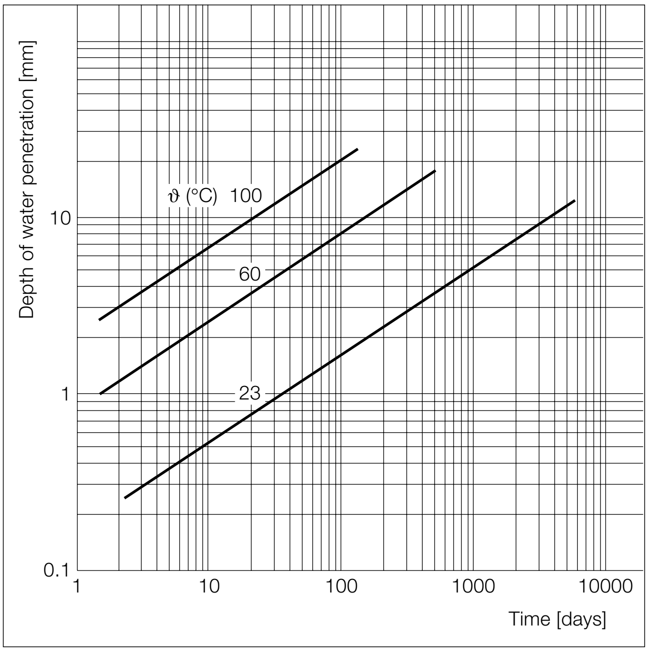

Fig. 17 *Penetration of water into Ultramid B at 23, 60 and 100°C*

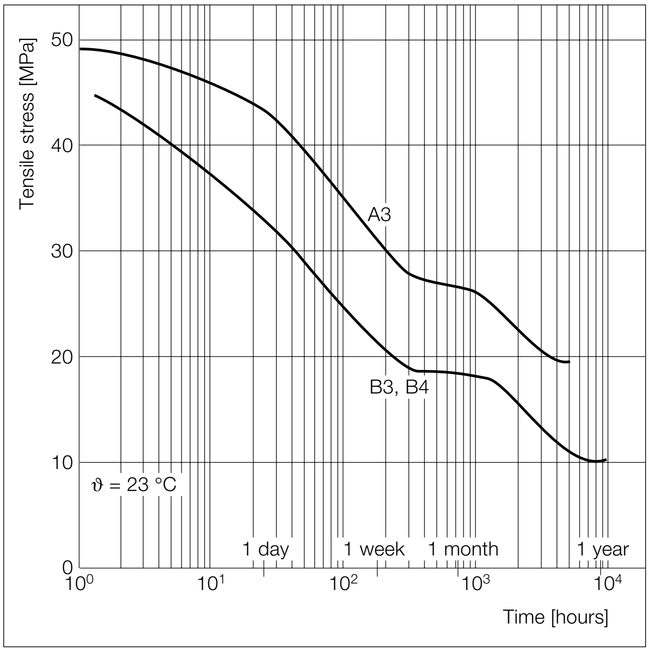

Fig. 18 *Creep behaviour of Ultramid in distilled water at 23 °C*
Test specimens: DIN 53455, no. 3

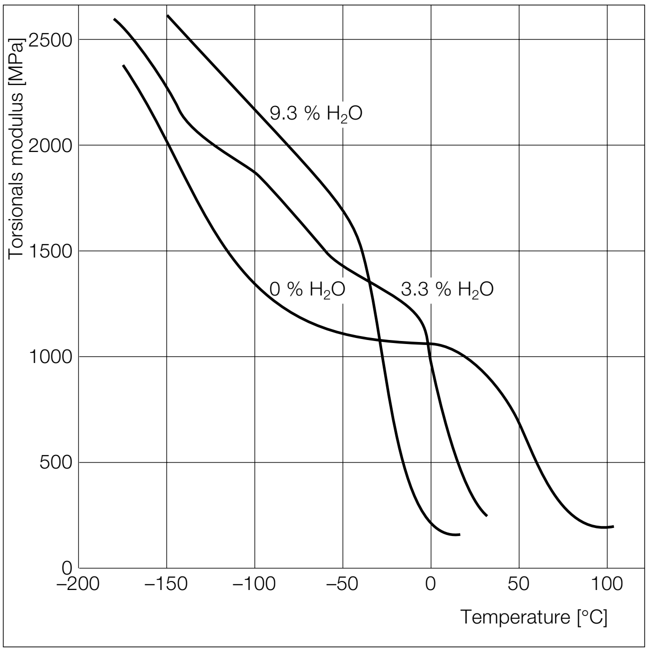

Fig. 19: *Variation in torsional shear modulus of Ultramid B3 as a function of temperature. Water content of specimens: 0 %, 3.3 % and 9.3 % (DIN 53445)*

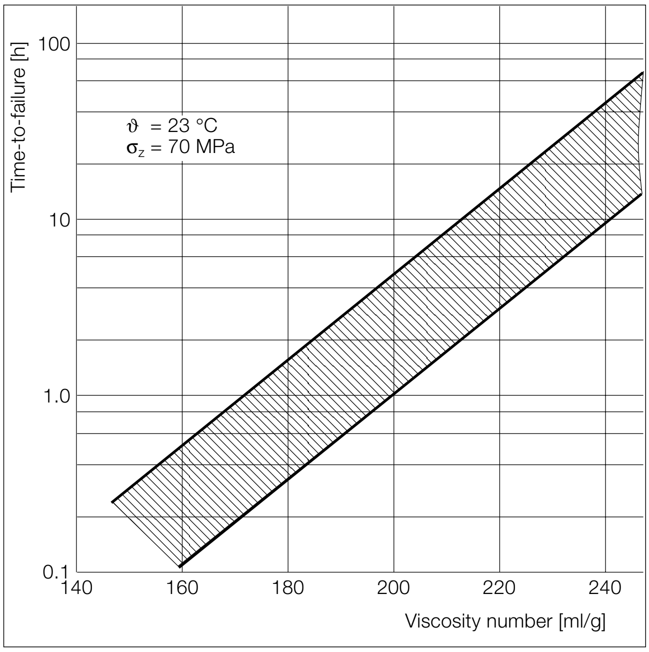

Fig. 20: *Time-to-failure of dry PA 66 in 37.5 % zinc chloride solution under a tensile stress of 70 MPa as a function of the viscosity number (DIN 53727, H_2SO_4 96 %).*

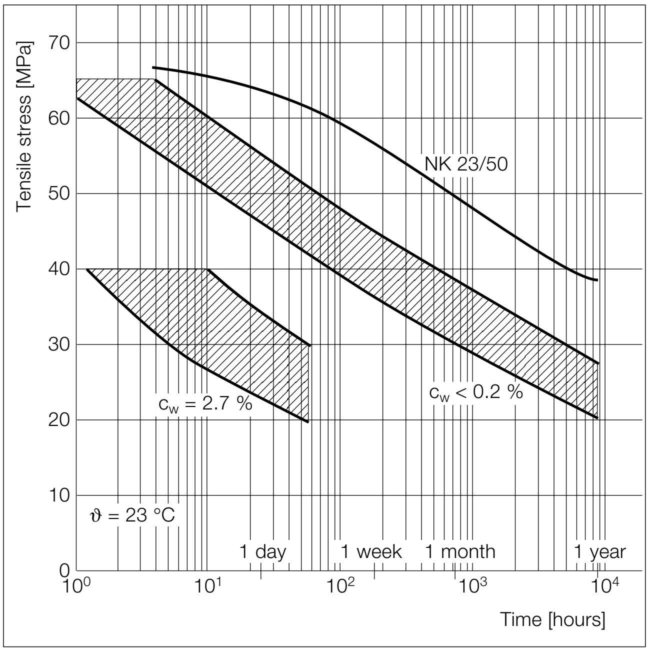

Fig. 21: Creep behaviour of stabilized high-molecular-weight PA 66 (dry and 2.7 % water content) in 37.5 % aqueous zinc chloride solution at 23 °C Test specimens: DIN 53455, no. 3

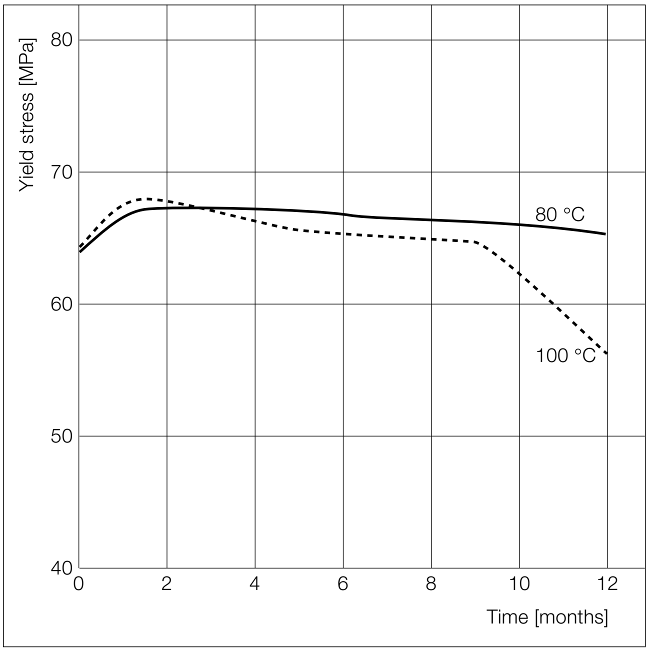

Fig. 22: Immersion of Ultraform N 2320 003 in water.

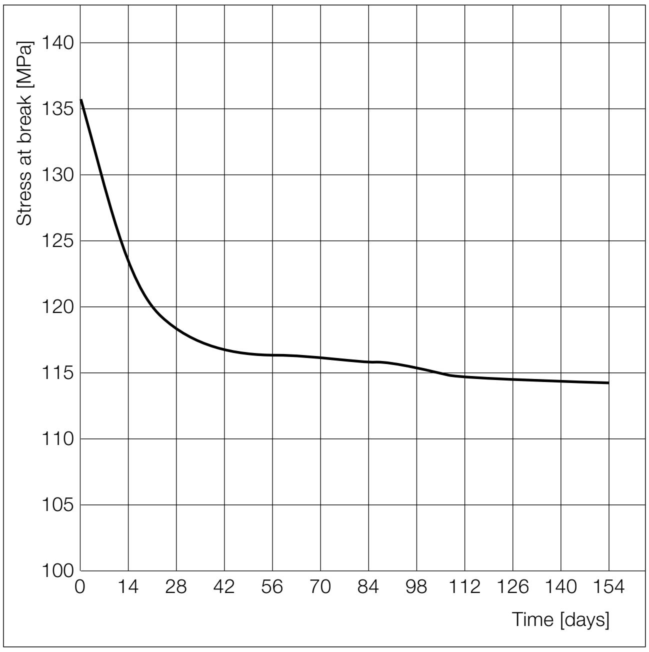

Fig. 23: Immersion of Ultraform N 2200 G53 in water at 40 °C

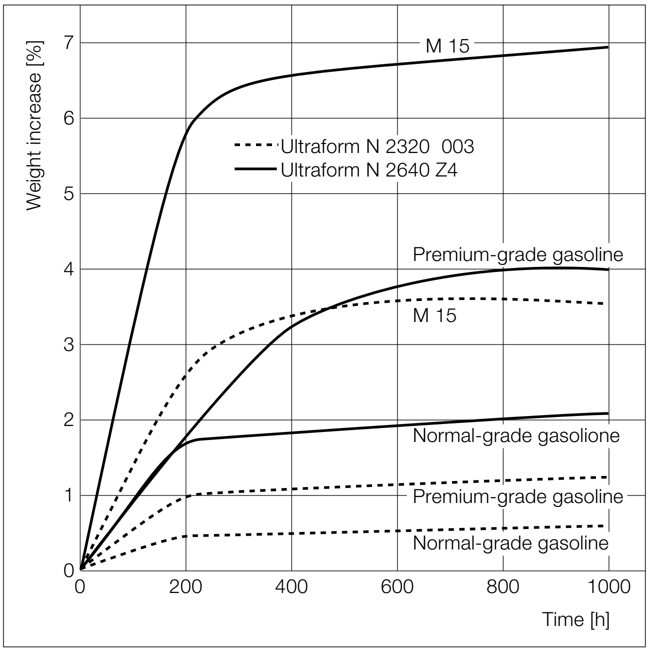

Fig. 24: Immersion of Ultraform in engine fuels at 50 °C

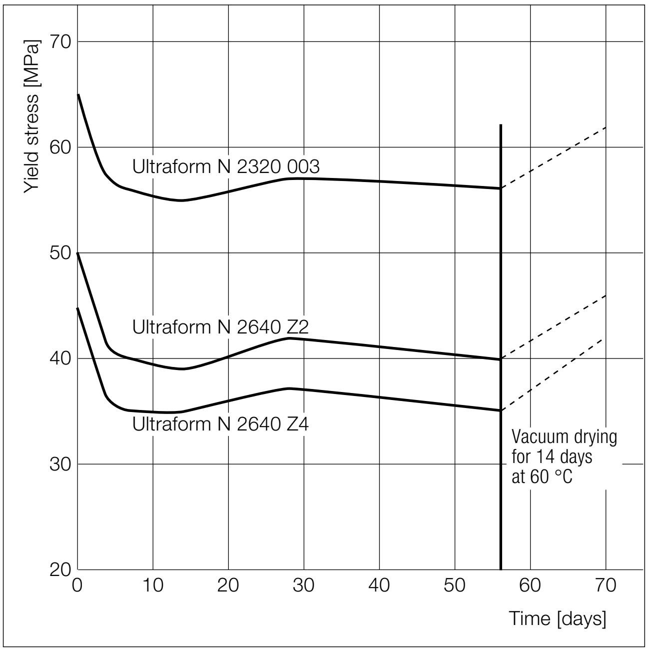

Fig. 25: Stress at yield after immersion in M15 fuel at 60 °C

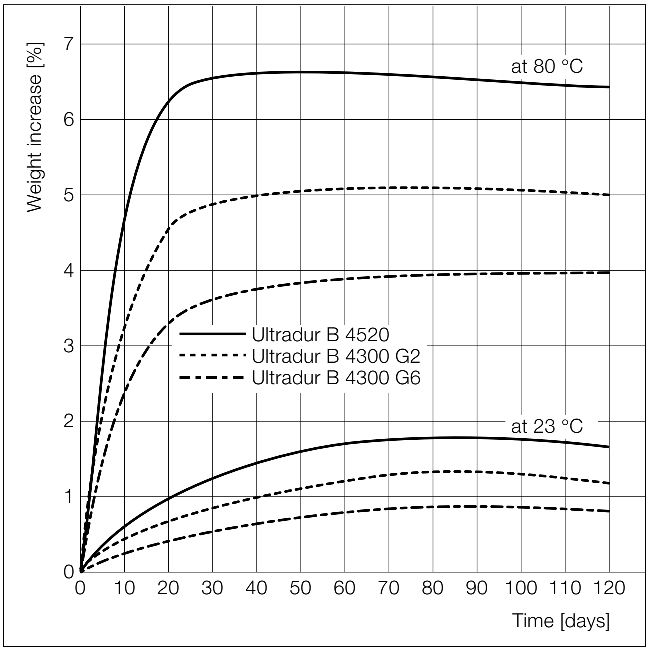

Fig. 26: Relative increase in weight of Ultradur after immersion in M15 fuel at 23 °C and 80 °C

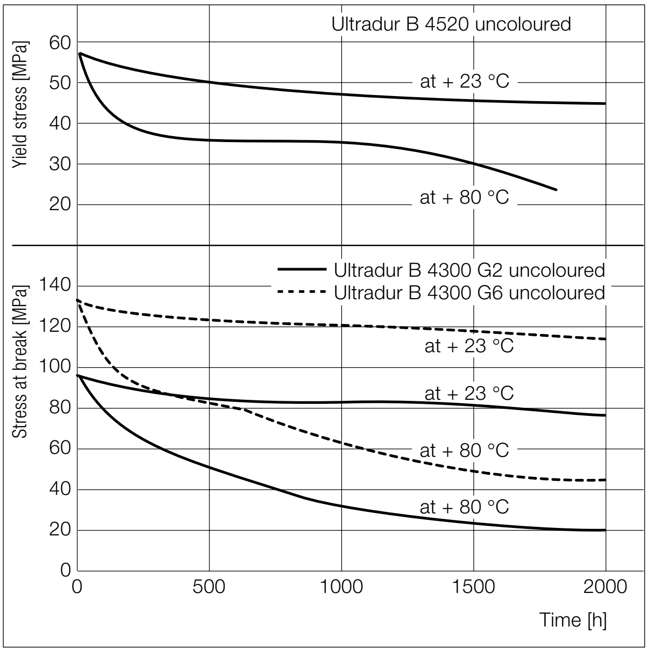

Fig. 27: Yield and breaking stress of Ultradur after immersion in M15 fuel at 23 °C and 80 °C

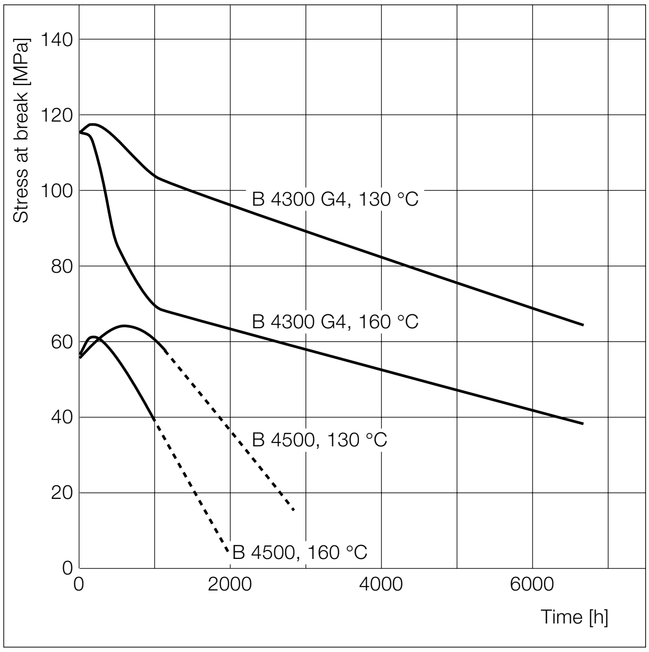

Fig. 28: Stress at break of Ultradur after immersion in synthetic engine oil (Castrol TXT Softec 10W-40)

Bibliography

[1] Schubert, H. E., Bericht TU München, PA6-Dübel (14. 08. 72); Plank, A., Bundesanstalt für Materialprüfung – Techn. Mitteilung-BMT 6, Juni 1977, S. 406 – 416 und BAM-Amts- und Mitteilungsblatt Bd. 7 (1977), Nr. 2, S. 91 – 95

[2] Kunststoff-Handbuch, Bd. 6, Polyamide, C. Hanser Verl., München, 1966, S. 490 und 677

[3] Liste der vom Bundesgesundheitsamt geprüften und anerkannten Desinfektionsmittel und -Verfahren, Stand 01. 06. 78 (7. Ausg.) Bundesgesundheitsbl. 21, Nr. 16 vom 04 .08. 78; Hygiene und Medizin Bd. 4 (1979), S. 7 – 39

[4] 4. Desinfektionsmittelliste, Stand 01. 01. 74 Pharm. Ind. 36 (1974), 3, S. 179 –194

[5] Kunkel, H., (SKF-Schweinfurt) „Warum Kunststoff-Käfige“; Wälzlagertechn. Sonderschrift SKF-Schweinfurt WTS 770301 (1977); „Plastic cages – why?“ Ball Bearing Journal 191 (April 1977)

[6] Dunn, P. und G. F. Sansom (Austral. Def. Sci. Serv., Melbourne) J. Appl. Pol. Sci. 13 (1969), S. 1641 –1688 und 14 (1970), S. 1799 –1806; Reimschüssel, A. C., und Y. J. Kim, J. Mat. Sci. 13 (1978), S. 243 – 252

[7] Hinterhofer, O. G. Kunstst. Rundschau 21 (1974) 8, S. 313 – 315

[8] Jellinek, H. G. u. a. Polymer Journal 4 (1973), 6, S. 601 – 606 J. Polymer Sci. A1, 10 (1972), S. 1773 –1788

[9] Zachariades, A. E. und R. S. Porter, J. Polymer Sci.-Polymer Letters 17 (1979), S. 277 – 279

[10] Hughin, B. u. J. Smith Angew. Makromol. Chemie 12 (1970), Nr. 172, S. 205 – 208

[11] Burke, J. S. u. T. A. Orofino J. Pol. Sci. 7 (1969), S. 1 – 25

[12] Gechele, G. B. und L. Crescentini J. Appl. Pol. Sci. 7 (1963), S. 1349 –1357

[13] Diels, K. und R. Jaeckel Leybold-Vakuumtaschenbuch, Berlin, 1972 (Ref. Kunstst. 64 (1974), 4, S. 167)

[14] Frohn, H. und F. Stelzer (KFA, Jülich) „Untersuchungen zur Eignung von Kunststoffen in Kryokabeln“

[15] Andrews, R. D. u. a., Polymer Preprints Am. Chem. Soc., Vol. 14 (1973), S. 1260 –1269

[16] Krejcar, E. Chem. Premsyl 15 (1965), 2, S. 77 – 79 (Ref.: Chemical Abstracts 62 [1965], 11183 g)

[17] Luck, A. P. (BASF), Kolloid-Zeitschr. 223 (1968), 2, S. 110 –117 „Über die Säureaufnahme von Polyamid“

[18] Hertel, H., Kunststoffe 71 (1981), 4, S. 240 – 241, „Chlorierte Lösemittel in der Kunststoff-Praxis“

[19] Kerner-Gang, W., BAM-Mitt. 14 (1984), 1, S. 3 – 7

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PERFORMANCE SPECIFICATION FOR AUTOMOTIVE ELECTRICAL CONNECTOR SYSTEMS

TABLE OF CONTENTS

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WARNING

No electrical connector, terminal, or related component may be represented as having met USCAR/EWCAP specifications unless conformance to <u>all</u> applicable requirements of this specification have been verified and documented. All required verification and documentation must be done by the supplier of the part or parts. If testing is performed by another source, it does not relieve the primary supplier of responsibility for documentation of all test results and for verification that all samples tested met all applicable Acceptance Criteria. See section 4.3.

1. SCOPE

Procedures included within this specification are intended to cover performance testing at all phases of development, production, and field analysis of electrical terminals, connectors, and components that constitute the electrical connection systems in low voltage (0 - 20 VDC) road vehicle applications. These procedures are only applicable to terminals used for In-Line, Header, and Device Connector systems with and without Shorting Bars. They are not applicable to Edge Board connector systems, > 20 VAC or DC, or to eyelet type terminals.

IMPORTANT NOTICE: In any intended vehicle application, if the products covered by this specification are, or may be, subjected to conditions beyond those described in this document, they must pass special tests simulating the actual conditions to be encountered before they can be considered acceptable for actual vehicle application. By way only of example, this includes products that may be subjected to temperatures beyond the extremes of Class 5 in Figure 5.1.4, or may be subjected to shock or vibration in the un-sprung portions of a vehicle, such as the wheel hub. Products certified by their supplier as having passed specific applicable portions of this specification are not to be used in applications where conditions may exceed those for which the product has been satisfactorily tested.

The Authorized Person is the final authority as to what tests are to be performed on his or her parts and for what purpose these tests are required. He or she is also the final authority for resolving any questions related to testing to this specification and to authorizing any deviations to the equipment or procedures contained in this specification. Any such deviation must be documented and included in the final test report.

Guidance as to the recommended tests for selected purposes is given in the charts in Appendix C and D. In the absence of contrary direction from the Authorized Person in the test request/order, all electrical connectors and their associated terminals and other components are required to meet all applicable portions of this document with the following exception:

Specific tests that are not required or additional test requirements as specified in any document in the hierarchy of Section 3.0.

2. OUTLINE & GLOSSARY OF TERMS

2.1 General

Diagrams are provided where necessary to clarify the details of the various test procedures. The tests in each section must be performed in the order given unless otherwise specified in the test request/order. Construction details for selected test fixtures and equipment are provided in this specification.

A glossary of terms is provided in Appendix B. Terms defined in the definitions or glossary are capitalized (i.e. Room Temperature, Steady State, PLR, etc.). A list of definitions is provided in Appendix A.

For the purposes of this specification there are only two types of electrical connectors: sealed and unsealed.

3. REFERENCED DOCUMENTS REQUIRED

3.1 Document Hierarchy

In the event there is a conflict between performance specifications, part drawings, and other related standards or specifications, the requirements shall be prioritized as follows:

1st - Applicable FMVSS requirements and other applicable state and Federal requirements.
2nd - Applicable part drawings
3rd - Applicable product design specification(s).
4th - Automotive Industry Action Group (AIAG) Production Part Approval Process (PPAP)
5th - Applicable USCAR/EWCAP performance specifications
6th - Other applicable standards and specifications

3.2 Part Drawing

The part drawing for each connection system component should contain or reference:

All dimensional requirements (which must be in GD&T format).
Performance requirements.
Component part number.
Reference to applicable portions of this specification.
The quantity and part number of terminals used.
The typical mating connector.
Maximum permissible Temperature Class (per Figure 5.1.4) for which the part is intended or has been successfully tested.

3.3 Product Design Specification

The product design specification may or may not be an integral part of the part drawing. Instructions must be included in the product design specification for any special tests required for the associated part and for any exceptions or modifications to the general specifications and requirements in this document.

3.4 Test Request/Order

3.4.1 Samples, Test Type and Special Tests

The laboratory test request/order shall provide location and documentation of test samples, identify the type of test to be performed (development, validation, special purpose, etc.) and describe any special tests that are not a part of this specification. Any required revisions to, or deviations from any tests in this specification must include detailed instructions for each change.

3.4.2 Test Request/Order Instructions

Instructions must be included in the test request/order concerning applicable tests and the order in which the tests are to be performed if different than outlined by this specification.

3.4.3 Performance and Durability Test Instructions

Instructions must be given in the test request/order concerning limits for performance and durability tests, including definition of the conditions under which those limits apply, if they are different than outlined in this specification.

3.4.4 Development Tests

Development tests are frequently used to evaluate specific areas of the design. They are tools for evaluating design alternatives, proposed improvements, cost reduction proposals, or determining root causes of field problems.

3.4.5 Validation Tests

Validation tests or sample approval tests are acceptance type tests. Consideration must be given to the inherent repeatability or subjectivity of certain tests outlined by this specification before designating it as a validation or compliance test.

3.4.6 Special Purpose Tests

Portions of this specification may be useful for special purpose testing. For example, verifying a process or material change may, in the judgment of the Authorized Person, require only one or two specific tests, or a portion of a test, to verify that no adverse consequence resulted from the change. Any portion of a test or any combination of tests contained in this specification may be used individually or may be combined with other testing, described outside this specification, in any phase of product development, production testing, or analysis of parts from the field.

3.5 Other Referenced Documents

SAE/USCAR-20: Field Correlated Life Test
SAE/USCAR-21: Performance Specification for Cable-to-Terminal Electrical Crimps
SAE/USCAR-23: Road Vehicles – 60V and 600V single core cables – Dimensions, test methods and requirements
SAE/USCAR-25: Electrical Connector Assembly Ergonomic Design Criteria
AIAG: Measurement Systems Analysis Reference Manual
ISO TS16949
IEC 68-2-32 – Basic Environmental Test Procedures – part 2

4. GENERAL REQUIREMENTS

4.1 Record Retention

The supplier shall maintain a central file for the storage of laboratory reports and calibration records. Such record storage must be in accordance with established ISO TS16949 and AIAG policies and practices.

4.2 Sample Documentation

All test samples shall be identified in accordance with the requirements of ISO TS16949 and the AIAG PPAP.

4.3 Sample Size

Minimum sample sizes are given for each test in this specification. A greater number of samples may be required by the test request/order. However, no part or device may be represented as having met this specification unless the minimum sample size has been tested and all samples of the group tested have met the applicable Acceptance Criteria for that test. It is never permissible to test a larger group, then select the minimum sample size from among those that passed and represent that this specification has been met.

4.4 Default Test Tolerances

Default Tolerances, expressed as a percentage of the nominal value unless otherwise indicated:

Temperature = ± 3 °C
Voltage = ± 5%
Current = ± 5%
Resistance = ± 5%
Length = ± 5%
Time = ± 5%
Force = ± 5%
Frequency = ± 5%
Flow Rate = ± 5%
Relative Humidity = ± 5%

4.5 Test Default Conditions

When specific test conditions are not given either in the product design specification, the test request/order or elsewhere in this specification, the following basic conditions shall apply:

Room Temperature = 23 ± 5° C
Relative Humidity = Ambient
Voltage = 14.0 ± 0.1 VDC

4.6 Equipment

Neither this list nor the list in each test section is all-inclusive. It is meant to highlight specialized equipment or devices with particular accuracy requirements. Many other items of customary laboratory equipment and supplies will also be required.

ITEM	DESCRIPTION	REQUIREMENTS*
1	DC Power Supply (Regulated)	0-20 V 0-150 A
2	Micro-ohmmeter	0-20 mV 0-100 mA Limits the open circuit voltage to 20 mV and limits the current applied to 100 mA. The micro-ohmmeter must also use either offset compensation or current reversal methods to measure resistance
3	Digital Multimeter (DMM)	* Capable of measuring the following at an accuracy of ≤0.5% of full scale: 0-50 Volts DC 0-10 Megohms
4	Current Shunts	100 mA or as required with accuracy of ± 1% of nominal
5	Millivolt Meter	Capable of measuring 0-100 mVDC at 0.5% full scale
6	Thermocouples	Type "J" or "T" and as required
7	Insertion/Extraction Force Tester	Capable of 1.0% accuracy, full scale
8	Data Logger	As Required
9	Temperature Chamber	-40°C to +175°C or as required by Temperature Class 0% to 95% RH
10	Vibration Controller	As Required
11	Vibration Table	2640N (600 Lbs.) Sine Force 2200N (500 Lbs.) RMS Force

12	Vacuum	As Required
13	Megohmeter	Accuracy <5% of full scale
14	High Pressure Spray Equipment	See table 5.8.1.3
15	Decibel Meter	+/- 1.5 dB “C” scale

Table 4.6.1: Equipment

NOTE: on requirements: Use of equipment with a lesser range is acceptable for specific tests where the required range for that test can be met. The equipment range specified does not preclude use of equipment with a larger range, but the accuracy must remain within the specified tolerance. For example, a DMM with a range of 0-100 volts could be substituted for one specified as 0-50 volts, with the provision that the accuracy could be maintained as ±0.5% of the 50 volts full scale, or 0.25 volts, not 0.5% of the 100 volt full scale of the substituted equipment.

4.7 Measurement Resolution

Unless otherwise specified, meters and gages used in measurements of the test sample(s) shall be capable of measuring with a resolution one decimal place better than the specified value. For example, even though a wire diameter specified as 0.1 mm might actually be the same as one specified as 0.10 mm, calipers capable of 0.01 mm resolution may be used to measure the first wire but a micrometer with 0.001 mm resolution is required to measure the second wire.

4.8 Test Repeatability & Calibration

All equipment used for test sample evaluation shall be calibrated and maintained according to the applicable standards and requirements set forth by ISO TS16949 and the AIAG publication Measurement Systems Analysis Reference Manual. Copies of this Manual can be obtained from the AIAG. (See Appendix B for contact information.) Documentation is to be recorded and retained in accordance with Section 4.1 of this USCAR/EWCAP specification.

4.9 Conformance Determination

Test conformance shall be determined by the performance requirements of the test being conducted. All samples must satisfy the performance requirements regardless of sample age, test cycles, or test temperature, except where a test to failure is specified.

4.10 Disposition of Samples

Should a premature non-conformance occur during a test, contact the requesting party to determine if the test is to be continued to gain additional product experience or if testing is to be suspended or terminated. When contact cannot be immediately made, the type of test shall determine the disposition of the samples. If the test order indicates that the test is investigative in nature, continue until the requesting party or parties are available. If the test order is for sample approval or validation, stop the test until the requesting party can be contacted. If the test must be stopped or terminated for any other reason (safety, equipment failure, etc.) the Authorized Person must be contacted for concurrence before the test is restarted. The test request/order should always specify desired sample disposition at the conclusion of the applicable testing.

4.11 Part Endurance

Successful completion of all requirements of this specification is intended to demonstrate that the design and construction of the components and connector systems tested are capable of operating in their intended vehicle environment and application.

5. TEST & ACCEPTANCE REQUIREMENTS

5.1 General

The tests detailed in this specification are qualitative in nature and are not expected to stress any part beyond its anticipated application limit, except where tests to failure are specified.

The test procedures that follow were written as stand-alone tests and may be used as such. However, they should be performed in sequence as specified in 5.8.2 – 5.8.8 via appendix C and D. Common sense is required to overcome any redundancies in sample preparation or in procedures. For example, if samples have already been prepared for the preceding test in a sequence, it should be obvious that the sample preparation step for that individual test (included so that test can be used as a stand alone test) should be skipped. Should any conflicts or questions arise concerning procedures and/or requirements, contact the Authorized Person.

5.1.1 Performance Requirements

All connection systems must meet all performance test requirements for the appropriate Temperature Class listed in Figure 5.1.4.

5.1.2 Dimensional Characteristics

Part construction shall conform to the dimensions, shape, and detail attributes specified on the latest revision of the applicable part drawing(s).

5.1.3 Material Characteristics

Parts are intended to be in their "as furnished for vehicle assembly" condition when testing begins, unless specific instructions as to any pre-test "conditioning" are contained in the test request/order. For example, electrical terminals typically have residual die lubricant on them when finally assembled into a vehicle. This same condition must prevail for test samples unless part cleaning is specified in the Test Request/Order.

All material used in each test sample shall conform to the material specifications shown on the latest revision of the applicable part drawing(s).

The material hardness specified for electrical terminals refers to the blank strip material and not the finished product because the terminal manufacturing process can modify the hardness values.

5.1.4 Temperature Classifications

Components to be tested must be assigned a class from the table below according to the expected environment in their intended vehicle application. "Rise" is defined as the temperature rise due to electrical heating caused by the maximum Steady State current flow expected for the component under test. Care must be taken to ensure that the conductor and insulation selected for the application or any test will itself withstand the maximum temperature for the class selected without exceeding the conductor manufacturer's maximum temperature recommendations.

Note also that terminals packaged such that they are surrounded by other terminals will dissipate heat more slowly, and thus experience a higher temperature "rise" with the same current flow, than terminals located on the periphery of a connector.

When "Maximum Temperature" is mentioned with respect to Figure 5.1.4, the highest ambient temperature in the right column, "Ambient Temperature Range" is to be used unless otherwise specified. If not specified in the Test Request/Order, the Authorized Person is expected to select the appropriate Temperature Classification. Considering the cost of testing and the time it takes, it generally will be best to qualify a given terminal and connector system to the highest possible Temperature Classification. See Section 11 Appendix F, for Application Guidelines.

Class	Ambient Temperature Range
1	-40° C to + 85° C
2	-40° C to +100° C
3	-40° C to +125° C
4	-40° C to +150° C
5	-40° C to +175° C

Figure 5.1.4: Component Temperature Classes

5.1.5 Testing Headers & Direct Connect Components

Cases frequently arise where only one half of a connector, usually the female half, is available and it mates directly to a Header or to a receptacle in an electrical component or device. This presents special problems for testing. In order to completely test the electrical connection, access must be gained to the terminals in the device or header. Great care must be taken in these cases so as not to introduce leak paths that are not present in the vehicle application. Where this risk is unacceptable, or making the necessary electrical connections is not feasible, the tests normally required to verify connection integrity must be modified.

Another problem sometimes arises due to the length of the terminals or buss bars in the device or header when conducting electrical tests. The general rule is to connect one of the millivolt test leads at the point where the Header or device terminal attaches to the circuit board or similar point in the device. The bulk resistance of the terminal "tail" is measured and subtracted during the connection resistance calculation.

However, if there is more than one "tail" length involved, but the bulk resistance per unit length is common, it may be more convenient to attach the millivolt leads at a common distance from the connection to be measured.

Therefore, in situations where there is more than 50 mm from the point of contact in the connection nearest to the Header or device to the point where the terminal "tail" or buss bar connects to the device, these two options are available. (1) Attach the millivolt lead at a convenient common distance 30 to 50 mm from the contact to be measured. Then subtract the bulk resistance of the selected common length when calculating the resistance of the associated Header or device connection. (2) Measure bulk resistance of each individual Header terminal or component buss bar from the connection to be measured to the point of millivolt lead attachment and subtract this resistance when calculating the resistance of the associated Header or device connection.

When attaching millivolt leads, take care that the heat applied does not damage platings or cause stress relaxation in any connection component. Application of an appropriate heat sink may be advisable. Refer to Figure 5.1.5.

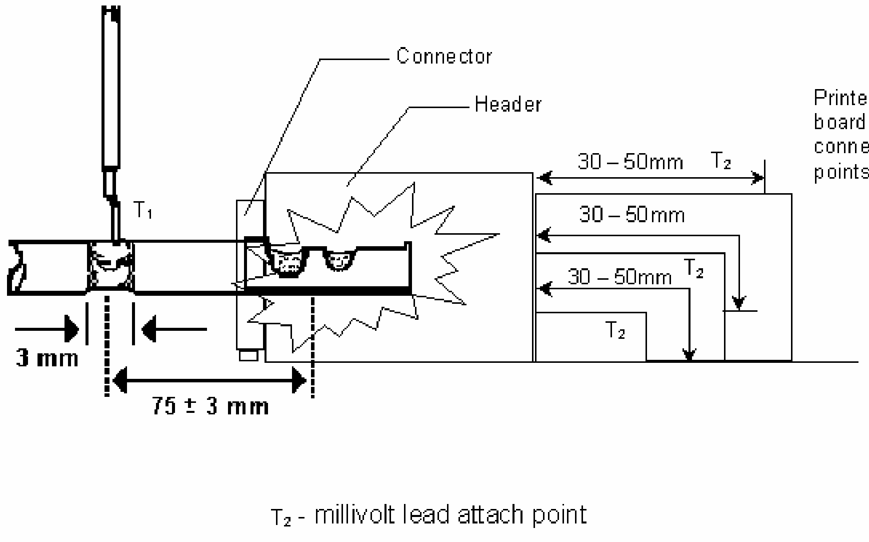


Figure 5.1.5: A - Method 1 - Milli-volt Lead Attachment

It may be that the electrical component or device being connected is not itself capable of withstanding the tests to which the connector is usually subjected. In these cases samples of just the connector receptacle portion of the device must be obtained. Then the required connections for testing can be made and sealed. Leak paths in devices may need to be sealed in order to test the integrity of mating connectors. Such modifications to the device are appropriate, but must be documented in the test report.

In any case, the Authorized Person must be consulted and must approve any deviation from the normal tests of this performance specification.

5.1.6 Terminal Sample Preparation

Terminals used for testing are machine crimped to leads using the manufacturers recommended tools. Crimp dimension physical characteristics and mechanical pull strength shall be within tolerance as applies to the respective terminal and wire gage. Crimp both the conductor and insulation grips unless otherwise specified in the individual test procedures. Use the appropriate cable seal as applicable. Assemble insulation displacement type terminals per their manufacturer's recommended assembly criteria. When testing Header type connectors with mating connectors, prepare samples only for the mating Female Connector (ref. Section 5.1.5). Record the crimp height and width of a representative group of samples of each terminal (except for insulation displacement type terminals) and number samples for tracking and later identification as appropriate.

Crimps shall be tested and validated separately per SAE/USCAR-21 Performance Specification for Cable-to-Terminal Electrical Crimps.

5.1.7 Connector and/or Terminal Cycling

5.1.7.1 Purpose

This procedure preconditions a connection system pair or terminal system pair prior to a test sequence. Connectors may be subjected to repeated cycling due to in-plant and/or service repair prior to and during the life of the connector. Complete this procedure only once when conducted as part of a series of test as in section 5.10.

5.1.7.2 Equipment

None

5.1.7.3 Sample Preparation

No special preparation required.

5.1.7.4 Procedure

Completely mate and un-mate each connector or terminal pair 10 times.

When working with terminals only, use caution to assure that mating and unmating is done along terminal centerlines to prevent side pressure that may distort either terminal.

On connectors with Shorting Bars, complete the Dry Circuit measurement across the shorted contacts (connector un-mated) per section 5.3.1. Record the number for later use in calculating the resistance change as part of the Dry Circuit Test procedure.

Re-mate connectors or terminals for one last time in preparation for future test sequences or follow directions in the respective procedure to follow.

5.1.7.5 Acceptance Criteria

None

5.1.8 Visual Inspection

5.1.8.1 Purpose

This test is used to document the physical appearance of test samples. A comparison can then be made with other test samples. Examinations in most cases can be accomplished by a person with normal or corrected vision, and normal color sensitivity, under cool white fluorescent lighting. Photographs and/or videos are encouraged as a more complete means of documentation. An appropriately identified untested sample from each test group must be retained for post-test physical comparisons.

5.1.8.2 Equipment

⇨ Camera
⇨ Video Recorder
⇨ Magnification Apparatus (as required)

5.1.8.3 Procedure

1. Visually examine each test specimen prior to testing and/or conditioning, noting in detail any manufacturing or material defects such as cracks, tarnishing, flash, etc. When specified in the test request/order, take photographs and/or video recordings of representative samples to be tested and keep a properly labeled control sample.

   After testing and/or conditioning, re-examine each test sample and note in detail any observable changes, such as swelling, corrosion, discoloration, contact plating wear, physical distortions, cracks, etc. Compare the tested and/or conditioned samples to the control samples, the videos, and/or the photographs, recording any differences in the test report. The Authorized Person will need to provide an additional sample for this purpose.

   Return test samples to requestor after all tests are completed and all necessary data have been obtained.

5.1.8.4 Acceptance Criteria

The connector assemblies must not show, with the aid of 10X magnification, any evidence of deterioration, cracks, deformities, etc. that could affect their functionality or distort their appearance. Connector locking mechanisms must function without breakage. Seals must remain serviceable and the connector must be capable of being reassembled without rolling or tearing of the seal.

5.1.9 Circuit Continuity Monitoring

5.1.9.1 Purpose

Some procedures require continuous circuit monitoring of connectors during conditioning. The purpose of circuit monitoring is to detect intermittencies caused by micro-motion and resultant wear or build-up of non-conductive debris at the contact interface. Use this procedure when specified in the individual test.

5.1.9.2 Equipment

⇨ Continuity Tester (CT)

5.1.9.3 Procedure

At least 10 individual terminal and 5 connector pairs must be monitored. Monitored terminal pairs should be distributed as evenly as possible among the connectors tested. Distribution of monitored pairs should be done per the following general patterns. The Authorized Person shall determine the final monitoring pattern. The pattern shall be documented in the test report.

X		X		X

X		X		X
X		X		X

X					X
			X		
		X			
X					X

Figure 5.1.9.3: General Pattern for Circuit Monitoring

NOTE: An ‘X’ pattern is suggested if practical

NOTE: Monitored terminals shall not be the same samples used for subsequent Dry Circuit readings for record, since the monitoring equipment may cause the potential across the circuit to exceed 20mvolts. Dry Circuit readings, however, may be taken as an aid in root-cause diagnosis.

1. Solder the conductors from each terminal in the CUT in series to form one continuous current path with only two free ends. Solder one of the free conductor ends to a 2 watt, 120 ± 1.2 ohm resistor. Solder the " – " (negative) lead to the free end of the resistor and the "+" (positive) lead to the remaining free conductor end of the CUT. Connect the Continuity Tester (CT) across the resistor, making sure that the negative lead of the CT is connected to the negative side of the resistor. Adjust the power supply to provide 100 mADC to the circuit. Set the CT to monitor the current through the resistor and record any instance where that current falls below 95 mA. As an option, the CT may be used to monitor one or more terminal pairs instead of the resistor. A reference illustration of the test set-up is shown in Figure 5.1.9.3. Other suitable continuity monitoring equipment may be used. The test fixtures, system layout, and test set-up must be approved by the Authorized Person prior to testing.

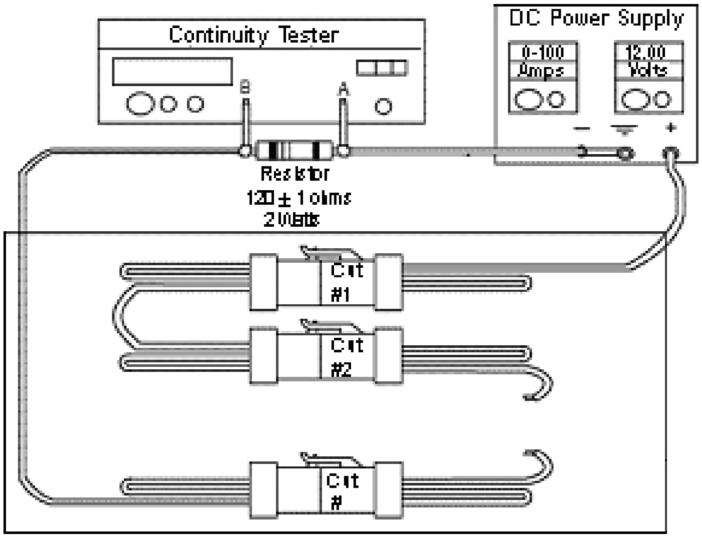


Figure 5.1.9.3: Connector Environmental Test Set-Up

5.1.9.4 Acceptance Criteria

Where continuity monitoring is required during any conditioning procedure, there must be no loss of electrical continuity (any instance of the resistor current dropping below 95 mA), for more than 1 microsecond. If one or more terminal pairs are monitored, rather than the series resistor, there must be no instance in which the resistance of any terminal pair exceeds 7.0 Ω for more than 1 microsecond. Figure 5.1.9.4 illustrates the acceptance criteria graphically.

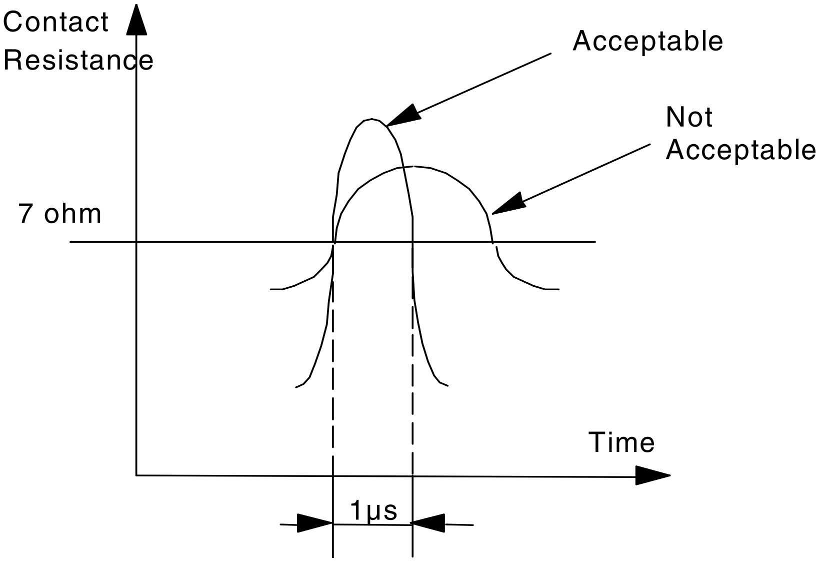


Figure 5.1.9.4: Intermittency Measurement

5.2 Terminal - Mechanical Tests

5.2.1 Terminal to Terminal Engage/Disengage Force

5.2.1.1 Purpose

This test determines the engagement and disengaging forces associated with compatible male and Female Terminal pairs. Determination of the number of terminals that can be packaged in a given connector design without exceeding allowable Mating Force limits is largely dependent on this information. Note that this test is written so that only the first engagement and the last (10th) disengagement are recorded and used to verify compliance with the Acceptance Criteria.

5.2.1.2 Equipment

- ⇨ Insertion/Extraction Force Tester with peak reading feature
- ⇨ Polished Steel Gage(s) (optional)

5.2.1.3 Procedure

1. Completely identify and number each terminal to be tested. A minimum of 20 samples (10 male and 10 female) are required. If the optional Step 8 is to be used, at least an additional 10 Female Terminal samples will be required.
2. Fixture one male and one Female Terminal so that proper alignment is achieved during testing.
3. Engage the mating terminals at a uniform rate not to exceed 50 mm/min. The force shall be applied parallel to the centerlines of the terminals. Proper alignment of the terminals is critical to avoid side loads and binding which can adversely affect the force measurement.
4. Record the peak force required to completely engage the terminal to its mating part and use this value to verify conformance to the Acceptance Criteria of Figure 5.2.1.4.
5. Disengage the mated terminals at a uniform rate not to exceed 50 mm/min. The force shall be applied parallel to the centerlines of the terminals.
6. Repeat Steps 3 & 5 nine (9) more times and record the 10th disengage force reading. Use this value to verify conformance to the Acceptance Criteria of Figure 5.2.1.4.
7. Repeat Steps 2-6 for each pair (one male and one female) of sample terminals.
8. (Optional) Repeat Steps 2-7 except use the applicable gage in place of the Male Terminals. Use new Female Terminals. The applicable gage is to be of polished steel made to within .01 mm of nominal. Surface finish must be at least .076-.305 micro meters (3-12 micro inches). Polish direction must be parallel to the blade/pin length. Test the additional 10 production Female Terminal samples to determine the force correlation between polished gage and actual samples.

5.2.1.4 Acceptance Criteria

Complete the Visual Examination per section 5.1.6

TERMINAL			GAGE (Optional)	ACTUAL PART	
Size (mm)	Type	Engage Max.(N)	Disengage Min. (N)	Engage Max. (N)	Disengage Min. (N)
0.64	Square Post	∗	∗	∗	∗
1.50	Blade	∗	∗	∗	∗
2.80	Blade	∗	∗	∗	∗
6.35	Blade	∗	∗	∗	∗
TBD					

NOTE: A "∗" denotes values to be inserted by the Authorized Person pending design completion and prototype evaluation.

Figure 5.2.1.4: Engage/Disengage Forces

5.2.2 Terminal Bend Resistance

5.2.2.1 Purpose

This test checks for at least a minimum level of terminal strength so as to resist bending or breakage during crimping, assembly, or service. Insufficient bend strength for the conductor size selected can lead to a high incidence of terminal damage during the assembly process. Since terminal material thickness varies so widely, and the bending force can be applied in any direction, only minimum values have been assigned to this test. Actual bending force values in each of three directions are recorded and it is then up to the Authorized Person to evaluate the results and determine the suitability of the tested terminal for its intended application.

5.2.2.2 Equipment

⇨ Special steel mounting fixture(s) appropriate to the terminal(s) under test.
⇨ Linear Force Tester with peak reading feature or weights per figure 5.2.2.4.

5.2.2.3 Procedure

1. From Figure 5.2.2.3-1, determine which design style most closely resembles the terminal under test (TUT).

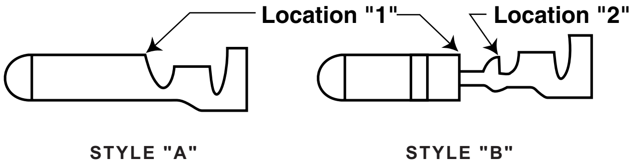


Figure 5.2.2.3-1: Terminal Design Style

2. Prepare terminal samples per section 5.1.6, Terminal Sample Preparation, using the smallest gage size conductor with the thinnest insulation applicable to the design of the terminal to be tested. For Style "A" terminals, prepare a total of at least 15 samples. For Style "B" terminals, prepare a minimum of 30 terminals, in order to test both bend locations.
3. Repeat Step 2 except use the largest conductor gage size with the thickest insulation applicable to the design.
4. Number each terminal.

NOTE: Use at least 5 new samples for each test sequence (Steps 6 - 9).

5. Mount the TUT in a fixture taking care that location "1" is positioned as shown in Figure 5.2.2.3-2.

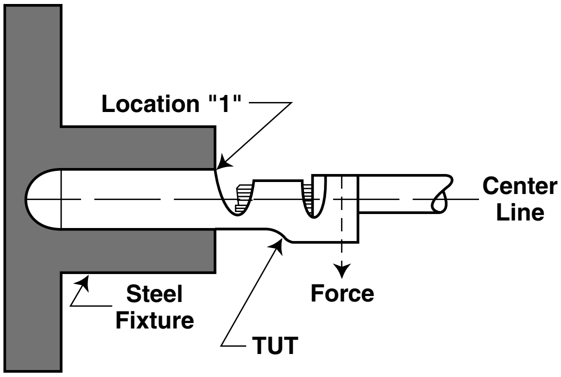


Figure 5.2.2.3-2: Terminal Bend Test

6. Apply force to the sample as shown in figure 5.2.2.3-2 for 15 seconds, then release. The required forces by material thickness are listed in table 5.2.2.4.

Terminal Material Thickness (mm)	Applied Force (N)
$\leq$0.20	4.0
$\leq$0.30	10.0
$\leq$0.40	15.0
>0.40	20.0

Table 5.2.2.4: Material Thickness Vs. Applied Bending Force

7. Inspect the area around the bend using at least 10X magnification. Note in the test report any signs of metal cracking or tearing. Straighten the terminal to its original position and re-inspect the terminal for cracks.
8. Select a new batch of at least 5 samples and mount them in the test fixture with the terminal rotated 180° from the position shown in Figure 5.2.2.3.2. Repeat Steps –5-7.
9. Select a new batch of at least 5 samples and mount them in the test fixture with the terminal rotated 90° from the position shown in Figure 5.2.2.3.2. Repeat Steps –5-7. Since terminals are typically symmetrical in this "side to side" direction, it is not necessary to test both directions. If the TUT is not symmetrical in this direction, it may be necessary to test both ways. Consult the Authorized Person for guidance in this regard.
10. For terminal style "B" designs (Figure 5.2.2.3.1), repeat Steps 5 - 9 with each TUT mounted such that location "2" is firmly retained at the edge of the fixture.

5.2.2.4 Acceptance Criteria

The TUT must not tear when subjected to the applied force for 15 sec. If the TUT was bent from its original position during the test, it must not tear or crack when straightened to its original position.

5.3 Terminal - Electrical Tests

5.3.1 Dry Circuit Resistance

5.3.1.1 Purpose

This test determines the combined resistance of the two conductor crimps (or single crimp in the case of a Header Connector) and the contact interface of a mated terminal pair under low energy conditions. Since it tests for the presence of thin insulating films that may have developed on the contact surfaces during field service or environmental type stress tests, it is important that no other electrical test be performed on the samples prior to this test.

5.3.1.2 Equipment

Micro-ohmmeter

5.3.1.3 Procedure

NOTE: Take care to avoid any mechanical disturbance of mated terminal samples submitted for this test. Such disturbance could rupture any insulating film which may have developed on the contact surfaces.

NOTE: If for any reason the terminals, when submitted for this test, are already contained in their mated connector housings, do not disconnect them unless otherwise directed by the Authorized Person. For terminals in mated connector housings, omit steps 1 and 5 - 7.

NOTE: If the samples submitted for this test have already been subjected to any other electrical test, the purpose of this test has likely been defeated and the Authorized Person must be contacted for approval before proceeding.

1. Prepare 20 (at least 10 male and 10 female) terminal samples per section 5.1.6, Terminal Sample Preparation, using the largest gage size conductor and insulation thickness applicable to the design of the terminal to be tested.
2. Do NOT mate the terminal pairs until after the millivolt leads have been attached, as directed in Step 5. For terminals that have been subjected to prior testing, do not disconnect their connector housings or remove any terminal from its housing.
3. Measure and record the resistance across 150mm of the conductor to be used for the test. For tests using a Header terminal as one half of the test connection, refer to Section 5.1.5 and measure only 75 mm of the conductor.

NOTE: For attachment points exceeding 75mm per side, the extra wire resistance shall be measured and subtracted per step 8. Record the conductor resistance.

4. Choose the preferred method of taking measurements (e.g. soldered sense lead or probe) and document the method chosen. In either case, the sense point T_1 (Figure 5.3.1.3) must be soldered for all stranded cable. For Header type connectors, T_2 is attached to the Header terminal per Section 5.1.5. All millivolt leads must be no larger than 0.22 mm^2 (24 AWG).

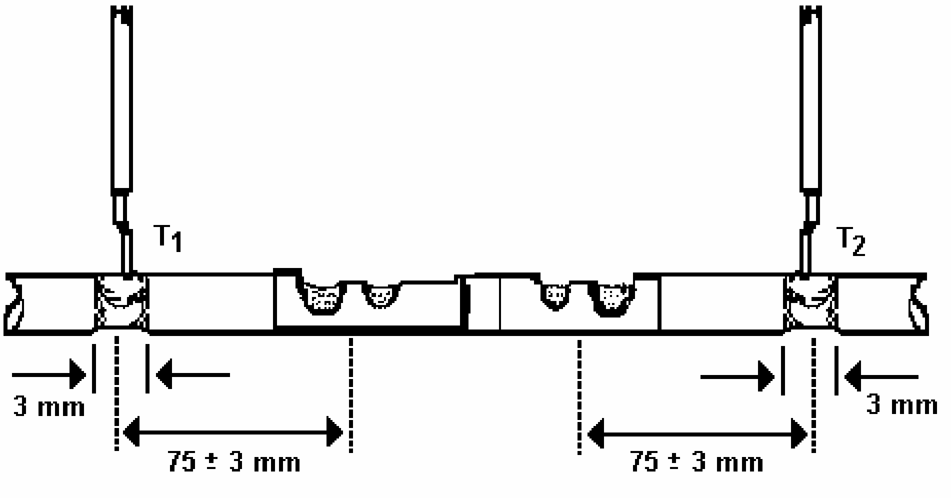
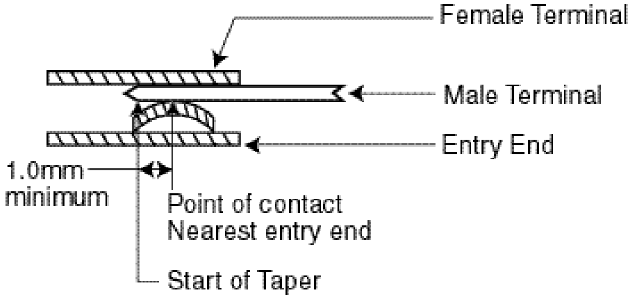


Figure 5.3.1.3: Connection Resistance Millivolt Lead Locations

5. For purposes of this test, the Male Terminal must be inserted to a precise depth into the female. Standard practice is that, in the worst case, there must be at least 1mm of excess insertion between the rearmost contact point with the Female Terminal and the start of any lead-in taper on the Male Terminal, as illustrated in Figure 5.3.1.4. This dimension is to be calculated from the terminal drawings by the Authorized Person, taking into account the worst-case tolerances. Each Male Terminal is to be suitably marked so test personnel can make the one and only mating of the test terminal pairs to the correct depth. Score marks or any other marking that might introduce contaminants or alter the strength or conductivity of the Male Terminal or the interface are not permitted.

SINGLE SPRING MEMBER EXAMPLE



MULTIPLE SPRING MEMBER EXAMPLE

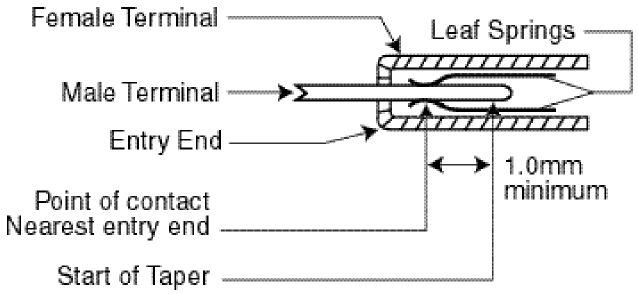


Figure 5.3.1.4: Terminal Insertion

6. Prior to mating the test terminal pairs, provision must be made for mounting them on an electrically non-conductive surface in such a manner that the mechanical stability of the male to female interface can be maintained.
7. Carefully mate the test terminal pair to the appropriate depth, as specified in Step 5 above. Use caution to assure that mating is done along terminal centerlines to prevent side pressure that may distort either terminal. Secure the TUT to the mounting surface so that the correct insertion depth is maintained throughout the test.
8. Using the appropriate equipment, measure and record the resistance between T_1 and T_2, as shown in Figure 5.3.1.3. Then deduct the conductor resistance to find the total connection Dry Circuit resistance.
9. Verify conformance to the Acceptance Criteria of Section 5.3.1.4.

5.3.1.4 Acceptance Criteria

The Total Connection Resistance calculated in Step 8 must not exceed the values listed in section 5.3.2.4.

For connectors with Shorting Bars, the change in connection series resistance of both contacts while in the “shorted” position shall be <40mΩ. Other requirements may apply depending on purpose of the shorting circuit.

5.3.2 Voltage Drop

5.3.2.1 Purpose

This test determines the voltage drop associated with the electrical resistance of the conductor crimp(s) and contact interface regions at nominal current conditions. This voltage drop is then used to calculate the Total Connection Resistance.

5.3.2.2 Equipment

- ⇨ Digital Multimeter (DMM)
- ⇨ DC Power Supply (0-20 VDC @ 0-150 A)
- ⇨ Current shunts

5.3.2.3 Procedure

1. Prepare 20 (at least 10 male and 10 female) terminal samples per section 5.1.6, Terminal Sample Preparation, using the largest gage size conductor and insulation thickness applicable to the design of the terminal to be tested.
2. Complete the Connector and/or Terminal Cycling procedure per section 5.1.7 if not already performed on the sample set.
3. For purposes of this test, the Male Terminal must be inserted to a precise depth into the female. Standard practice is that, in the worst case, there must be at least 1mm of excess insertion between the rearmost contact point with the Female Terminal and the start of any lead-in taper on the Male Terminal, as illustrated in Figure 5.3.1.4. This dimension is to be calculated from the terminal drawings by the Authorized Person, taking into account the worst case tolerances. Each Male Terminal is to be suitably marked so test personnel can make the final mating of the test terminal pairs to the correct depth. Score marks or any other marking that might introduce contaminants or alter the strength or conductivity of either terminal or the interface are not permitted. Do not use the connector housings, even unsealed, to control terminal insertion since the housings will alter heat dissipation during testing. This will compromise test repeatability and will invalidate comparisons of data collected for various terminals.
4. Prior to mating the test terminal pairs, provision must be made for mounting them on an electrically non-conductive surface in such a manner that the mechanical stability of the male to female interface can be maintained.
5. Carefully mate the test terminal pair to the appropriate depth, as specified in Step 4 above. Use caution to assure that mating is done along terminal centerlines to prevent side pressure that may distort either terminal. Secure the TUT to the mounting surface so that the correct insertion depth is maintained throughout the test.
6. Assemble the test circuit shown in Figure 5.3.2.3, Current Resistance Test Set-Up. Adjust the power supply to provide the required test current of 5A per square millimeter of conductor cross section for the conductor selected in Step 1. Refer to SAE Standards J1127 and J1128 or USCAR-23 for the cross sectional area of the conductor selected. More than one terminal pair may be tested in series. Refer to Figure 5.3.1.3: Connection Resistance Millivolt Lead Locations, for placement of the millivolt test leads. Record the test current used.

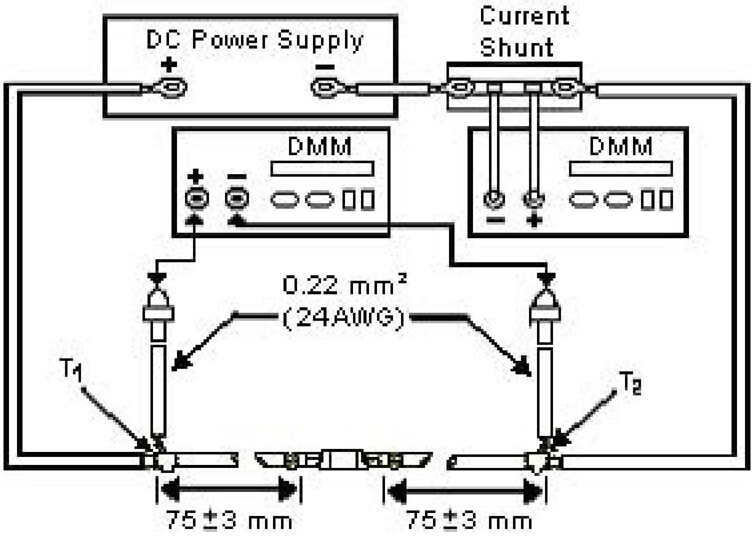


Figure 5.3.2.3: Current Resistance Test Set-Up

7. Measure and record the millivolt drop across 150mm of the conductor size and insulation type to be used during the test, using the test current determined in Step 6. For testing Header type connectors, refer to Section 5.1.5 and measure the millivolt drop across only 75 mm of the conductor used.

NOTE: For attachment points exceeding 75mm per side, the extra wire resistance shall be measured and subtracted per step 10.

8. Choose the preferred method of taking measurements (soldered sense lead or probe) and document the method chosen. In either case, the sense point T_1 (Figure 5.3.1.3) must be soldered for all stranded cable. For Header type connectors, T_2 is attached to the Header terminal per Section 5.1.5. All millivolt leads must be no larger than 0.22 mm^2 (24 AWG).
9. Set the power supply for the current determined in Step 6 and wait 30 minutes minimum to ensure that the test current stabilizes at the appropriate value. Allow sufficient time for all other test equipment to warm and stabilize per the manufacturer's recommendations.
10. Using the test current determined in Step 6, measure and record the millivolt drop (mVD) readings between test points T_1 and T_2. Use these values in the equation below to calculate the voltage drop across the entire connection, including the crimp(s) and terminal interface. In the case of Header type connectors, T_2 is attached to the "tail" of the Header Connector per Section 5.1.5.

    mVD Entire Connection = mVD(T_1 - T_2) - [mVD Conductor (Step 7)]

    Total Connection Resistance = mVD Entire Connection ÷ Test Current

    Use these results to verify conformance to the Acceptance Criteria of Section 5.3.2.4.

NOTE: Use the "After Test" values of Section 5.3.2.4 when this test is done following a stress test, such as Thermal Shock, Temperature/Humidity Cycling, etc. or on field samples.

5.3.2.4 Acceptance Criteria

Nominal Male Terminal Size*	Total Connection Resistance After Test (mΩ) Maximum
0.64mm	20.0
1.5mm	10.0
2.8mm	5.0
6.35mm	1.5
*	

* As defined by the male blade portion (width) of the TUT

Figure 5.3.2.4: After Test Values

NOTE: The "After Test" values are for "crimp - to - crimp" measurements (T_1 to T_2 in Figure 5.3.2.3 less the appropriate conductor resistance). For headers, the values are the “crimp – to – tail” (T_1 to T_2 in Figure 5.1.5) less the appropriate conductor resistance).

Note: Values for other terminal sizes between 0.64 and 6.35 are calculated by interpolation. Terminal sizes outside of this range are usually for specialized use. The requirements for these terminals shall be set by the Responsible Engineer. In no case may the Total Connection Resistance exceed 20 mΩ.

5.3.3 Maximum Test Current Capability

5.3.3.1 Purpose

This test is used to determine the maximum test current at which a terminal system can operate in a Room Temperature environment before excessive thermal degradation and/or resistance begins to occur. Temperature Rise (Y axis) vs. Current (X axis) shall be plotted for each applicable conductor size. These graphs are NOT to be used for actual terminal application in a vehicle (see Section 11). This test is conducted on terminals alone, thus eliminating the variation that may be introduced by variations in the heat dissipating characteristics of differing connector housing designs and sizes.

NOTE: A draft free environment is necessary to get accurate measurements.

5.3.3.2 Equipment

⇨ Digital Multimeter (DMM)
⇨ DC Power Supply (0-20 VDC @ 0-150 A)
⇨ Current shunts (Size as required, ± 1%)
⇨ Thermocouples (Type "J" or "T")
⇨ Data Logger (As required)

5.3.3.3 Procedure

1. Prepare 20 (at least 10 male and 10 female) terminal samples per section 5.1.6, Terminal Sample Preparation, using one of the conductor gage sizes and insulation thicknesses applicable to the design of the terminal to be tested.
2. Complete the Connector and/or Terminal Cycling procedure per section 5.1.7 if not already performed on the sample set.
3. Measure and record the voltage drop across 150mm of the conductor to be used for the test, using the expected Maximum Current Capability of the TUT in combination with that conductor size and insulation type. For testing Header type connectors, refer to Section 5.1.5 and measure the millivolt drop across only 75mm of the conductor used.
4. Assemble the circuit shown in Figure 5.3.3.3 in a draft free enclosure. Use at least 10 terminal pairs. Choose the preferred method of taking measurements (soldered sense lead or probe) and document the method chosen. In either case, the sense point T_1 (Figure 5.3.1.3) must be soldered for all stranded cable. Attach conductor ends of the terminal pairs to form one continuous series circuit and attach the thermocouples to each mated pair as shown in Figure 5.3.3.3. Attach the circuit to a non-conductive surface, such as wood or high temperature plastic, leaving a minimum of 50 mm between test samples.

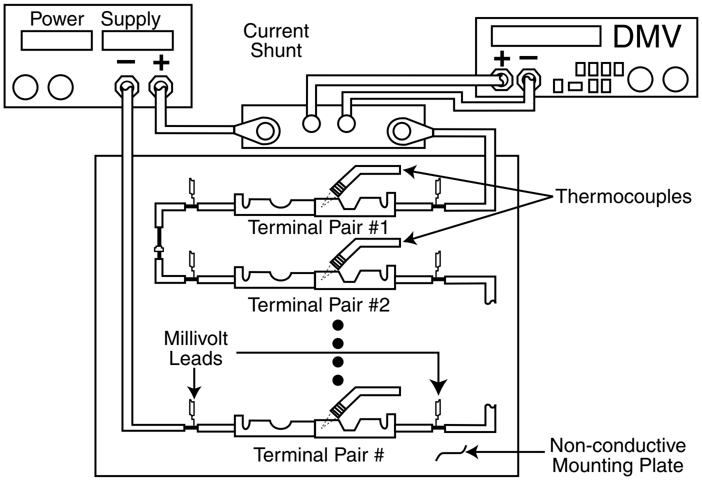


Figure 5.3.3.3: Set-Up for Maximum Test Current

5. Test the sample terminal pairs at 23°C (Room Temperature). The ambient temperature sensor must be placed on the same plane as the test samples, 30 to 60 cm from the nearest sample.
6. Adjust the power supply to zero amps output and then turn on the supply and the DMM's.
7. Slowly increase the power supply output until it is providing 50% of the expected Maximum Current Capability of the TUT.
8. Wait at least 15 minutes for the circuit temperature to reach Steady State. Then record the ambient temperature, the temperature of each terminal pair interface, and the millivolt drop across each terminal pair (T_1 to T_2 in Figure 5.3.1.3, less the millivolt drop of the conductor as determined in Step 3). Then calculate the resistance of the terminal pair interface.
9. Increase the current by 10% of the expected Maximum Current Capability of the TUT and repeat Step 8.
10. Repeat Step 9 until 80% of the expected Maximum Current Capability of the TUT is met.
11. Continue to increase the current in increments of 5% of the expected Maximum Current Capability of the TUT, repeating Step 8 after each incremental increase.
12. For samples to be used in subsequent tests, repeat Step 11 until one of the following conditions occurs:
    a. The temperature of any terminal interface exceeds a 55 °C rise, or the maximum temperature recommended by the terminal manufacturer, whichever is lower.
    b. The Total Connection Resistance of any terminal interface exceeds the "After Test" Acceptance Criteria listed in Section 5.3.2.4.
13. The maximum test current capability of the specific combination of the terminal and the conductor gage and insulation type used is then determined to be the current in the first increment in which either the condition described in A. or B. of Step 12 above was achieved, less 10% of that value.
14. As an optional step, at the discretion of the Authorized Person for samples that will not be used in subsequent tests, continue to increase the current in steps of 5% of the expected Maximum Current Capability of the TUT until the thermal stability of any one or more samples can no longer be achieved. Data from this test to failure step may be useful for statistical purposes or for estimating safety margins.
15. Repeat Steps 1 – 13 or 14 for each conductor size and insulation type applicable to the TUT.
16. Graph the data with temperature on the Y-axis and current (in amps) on the X-axis for all conductor sizes and insulation types tested.

NOTE: That this data is NOT to be used as guidance for any actual application of the TUT, see section 11.

5.3.3.4 Acceptance Criteria

For the current determined to be the "Maximum Test Current":

1. The measured temperature of the terminal must not exceed a 55°C rise over ambient, or the maximum temperature recommended by the terminal manufacturer, whichever is lower.
2. The calculated Total Connection Resistance of any sample must not exceed the "After Test" Acceptance Criteria of Section 5.3.2.4.

5.3.4 1008 Hour Current Cycling

5.3.4.1 Purpose

This test simulates the main function of the terminal over the expected life of the vehicle. Current cycling is an accelerated aging test which electrically heats terminal interfaces and core conductor crimps, then allows them to cool under no current conditions, causing expansion and contraction that may affect connection resistance due to wear, oxidation, inter-metallic growth and stress relaxation.

5.3.4.2 Equipment

- ⇨ Digital Multimeter (DMM)
- ⇨ DC Power Supply (0-20 VDC @ 0-150 A, timer controlled)
- ⇨ Current shunts (Size as required, ± 1%)
- ⇨ Thermocouples (Type "J" or "T")
- ⇨ Data Logger (As required)

5.3.4.3 Procedure

1. Prepare 60 (at least 30 male and 30 female) terminal samples per section 5.1.6, Terminal Sample Preparation, using one of the conductor gage sizes and insulation thicknesses applicable to the design of the terminal to be tested.
2. Attach the millivolt leads in positions T_1 and T_2 as shown in Figure 5.3.1.3. For Header type connectors, T_2 is attached to the Header terminal per Section 5.1.5. All millivolt leads must be no larger than 0.22 mm^2 (24 AWG).
3. Complete the Connector and/or Terminal Cycling procedure per section 5.1.7 if not already performed on the sample set.
4. Measure and record the voltage drop across 150mm of the conductor to be used for the test, using the maximum test current previously determined (Section 5.3.3.3, Step 13) for the combination of that conductor size, insulation type and the TUT. For testing Header type connectors, refer to Section 5.1.5 and measure the millivolt drop across only 75mm of the conductor used.

NOTE: For attachment points exceeding 75 mm per side, the extra wire resistance shall be measured and subtracted per step 10.

5. Assemble the circuit shown in Figure 5.3.3.3 in a draft free enclosure, except use a timer controlled power supply. Set the power supply to provide 45 minutes 'ON' and 15 minutes 'OFF' at the maximum test current previously determined (Section 5.3.3.3, Step 13) for the combination of that conductor size, insulation type and the TUT. Also connect a data logger to the voltage drop and thermocouple leads.
6. Test the set of sample terminal pairs at 23^o C. (Room Temperature). An ambient temperature sensor must be placed on the same plane as the test samples, 30 to 60 cm from the nearest sample.

7. Turn 'ON' the power supply, DMM's, and data logger.
8. After 30 minutes into the first 'ON' cycle, record terminal crimp and interface millivolt drop readings (T_1 to T_2 in Figure 5.3.2.3) as well as thermocouple readings for each terminal pair.
9. Cycle for 1008 hours taking readings at least once daily or as specified by the test request/order, 30 minutes into the 'ON' cycle, and at the conclusion of the test, 30 minutes into the final "on" cycle. mV drop readings should be taken at maximum test current.
10. For each set of data, calculate and record the Total Connection Resistance by subtracting the conductor millivolt drop reading (Step. 4) from the T_1 to T_2 millivolt drop reading (Step 8) and dividing the result by the test current (Step 5).
11. Allow the samples to cool to ambient, then complete the Voltage Drop test section 5.3.2.
12. Verify conformance to the Acceptance Criteria of Section 5.3.4.4.

5.3.4.4 Acceptance Criteria

1. The temperature of any terminal interface must not exceed a 55 °C rise over ambient, or the maximum temperature recommended by the terminal manufacturer, whichever is lower, for any reading during the test.
2. The calculated Total Connection Resistance must not exceed the "After Test" Acceptance Criteria in the table in Section 5.3.2.4 for any data set.

5.4 Connector - Mechanical Tests

5.4.1 Terminal - Connector Insertion/Extraction Force

5.4.1.1 Purpose

This test is to ensure that the Insertion Force of a terminal into its connector cavity is not greater than the column strength of its associated conductor and is also low enough to allow easy and consistent production assembly. Extraction testing is to ensure that the terminal is retained in its housing with sufficient strength to withstand the rigors of the wiring harness and vehicle assembly processes.

5.4.1.2 Equipment

- ⇨ Insertion/Extraction Force Tester with Peak Reading Feature
- ⇨ Temperature/Humidity Chamber capable of 95 to 98% RH at 40ºC

5.4.1.3 Procedure

A. INSERTION FORCE:

Un-sealed Connectors and Sealed Connectors with Individual Cable Seals

1. Prepare 20 (at least 10 male and 10 female) terminal samples per section 5.1.6, Terminal Sample Preparation, using the largest gage size conductor and insulation thickness applicable to the design of the terminal to be tested. For connectors with more than 10 terminal cavities, prepare at least one additional male and one additional female sample for each terminal cavity in excess of 10, so that each terminal cavity in the connector can be tested at least once.
2. Repeat Step 1 using the smallest conductor size and insulation type applicable to the design.
3. Number each connector terminal cavity and, if applicable, each connector.
4. Secure the connector shell in an appropriate fixture.
5. Secure the terminal sample in the force tester by gripping the conductor a minimum of 20mm behind the insulation grip.
6. Adjust the force tester to insert the terminal straight into the connector at a uniform rate not to exceed 50 mm per minute. Upon reaching the forward stop, continue applying force until a minimum 50N of force is exerted or the wire buckles. Use a fresh terminal sample for each insertion and test each terminal cavity in the connector at least once. For connectors with less than 10 cavities, use a new connector after each terminal cavity in the first connector has been tested and continue until at least 10 terminal samples have been used.
7. Record the force required to insert the terminal into the connector for each terminal sample to be tested and verify conformance to the Acceptance Criteria of Section 5.4.1.4.
8. Repeat Steps 4 - 7 using the set of samples with the smallest conductor size and insulation type. It is not necessary to test the forward stop function per step 6 with the small gage samples.

Connectors with Multi-Cavity (Mat) type seals

1. Complete steps 1 – 3 above, except prepare at least one additional set of samples.
2. Complete steps 4 and 5 above.
3. Adjust the force tester to insert the terminal straight into the connector at a uniform rate not to exceed 50 mm per minute. Use a fresh terminal sample for each insertion and test each terminal cavity in the connector at least once. Upon reaching the forward stop, continue applying force until a minimum 50N of force is exerted or the wire buckles. Each test sample lead may be removed after its cavity is tested. This is to prevent possible seal distortion or compression that might affect test results if neighboring seal holes remain filled. For connectors with less than 10 cavities, use a new connector after each terminal cavity in the first connector has been tested and continue until at least 10 terminal samples have been used.

4. Use the extra set of samples prepared in Step 1 above. Using the force tester as in Step 3 above, load each terminal into a separate cavity without removing samples previously inserted. Perform the test in such a sequence that the last cavity to be tested is as centrally located as possible. In addition to the data required in Step 5 below, record the cavity number, the Insertion Force and the order in which the cavities were tested.
5. Record the force required to insert the terminal into the connector for each terminal sample tested and verify conformance to the Acceptance Criteria of Section 5.4.1.4.
6. Repeat Steps 4 - 5 using the set of samples with the smallest conductor size and insulation type appropriate to the design.

B. EXTRACTION FORCE:

1. Prepare 20 (at least 10 male and 10 female) terminal samples per section 5.1.6, Terminal Sample Preparation, using the largest gage size conductor and insulation thickness applicable to the design of the terminal to be tested. Solder may be added to terminal crimps to assure accurate extraction readings. For connectors with more than 10 terminal cavities, prepare at least one additional male and one additional female sample for each terminal cavity in excess of 10, so that each terminal cavity in the connector can be tested at least once. At least 3 connector housings must be used in the test. Each terminal cavity location in the connector must be tested, but these tests may be distributed among the connector housings used. Connectors are to be tested in “dry as molded” condition and should be protected from high humidity and heat levels between the time they are molded and the time they are tested.
2. Number each connector terminal cavity in each connector housing so there are no duplicate cavity numbers among the housings used.
3. Install a terminal sample into each cavity in the connector being tested. For connectors with less than 10 cavities, use a new connector after each terminal cavity has been tested and continue until all 10 terminal samples have been used. Do not install the terminal lock (PLR, TPA, Wedge, etc.).
4. Secure the connector shell in an appropriate fixture.
5. Secure the terminal sample in the force tester by gripping the conductor behind the back edge of the terminal.
6. Adjust the force tester to pull the terminal straight back from the connector. Straight back extraction is critical to avoid side loads and binding which can affect force measurements. Increase the pullout force at a uniform rate not to exceed 50mm/min, until pullout occurs.
7. Record the force required to pull the terminal out of each terminal cavity along with the cavity number and the connector number. If the conductor breaks or pulls out of the terminal grip before the terminal is pulled from the connector, record this force together with a note as to what happened.
8. Verify that the forces obtained in Step 7 above conform to the Acceptance Criteria of Section 5.4.1.4 for each cavity tested.
9. Using new connectors, repeat Steps 1-8 above except install the terminal lock (PLR, TPA, Wedge, etc.).
10. Repeat Step 9 using moisture conditioned parts. Parts are brought to their practical limit of moisture content by exposing “dry as molded parts” to 95-98% Relative Humidity at 40ºC for 6 hours, then within eight hours, completing the extraction test.

5.4.1.4 Acceptance Criteria

Insertion:

1. The maximum Insertion Force for a terminal is 30 Newtons.
2. Neither the conductor nor the terminal may buckle during the test.
3. The forward stop must withstand a push-through force of 50N or the column strength of the largest applicable conductor size, whichever is smallest.

Extraction:

The minimum Extraction Force of a terminal from its cavity shall meet the values shown in the table 5.4.1.4:

			Primary and Secondary Lock * (Newtons) per step 5.4.1.3.-B 9,10.		Primary and Secondary Lock (Newtons) after Temp/Humidity (section 5.6.2)
Terminal Size	Max. Blade Width (mm)	Primary Lock (Newtons)	Before Moisture Conditioning	After Moisture Conditioning	
0.64	1.2	30	75	60	50
1.5	1.8	45	85	70	50
2.8	3.0	60	90	90	50
> 2.8	> 3.0	70	90	90	50

Table 5.4.1.4: Terminal-Connector Minimum Extraction Force

*includes connectors not designed for use with secondary lock

5.4.2 Connector-Connector Mating/Unmating Force (Non-mechanical Assist Connectors)

5.4.2.1 Purpose

This test determines the mating/Un-mating Forces associated with manual mating and un-mating of complete connector assemblies. Mating Forces are an important consideration in determining the suitability of a given connector design for use in production. Un-mating Forces are important in determining serviceability of the design and ensuring the connection will stay mated for the service life of the vehicle.

5.4.2.2 Equipment

⇨ Insertion/Extraction Force Tester.

5.4.2.3 Procedure

A. MATING FORCE

1. Using any applicable conductor size and insulation type, prepare enough samples of male and Female Terminals to fully populate a minimum of 15 connector assemblies per section 5.1.6, Terminal Sample Preparation. (at least 15 male and 15 female halves)
2. Completely assemble (but do not mate) all connector halves (both male and female) using all applicable components such as terminals, wedges, and seals.
3. Number each connector assembly.
4. Secure the connector halves (one male and one female) in the appropriate fixtures of the force tester. Adjust the force tester to insert the Male Connector straight into the Female Connector. Straight-in engagement is critical to avoid side loads and binding which can affect force measurements.

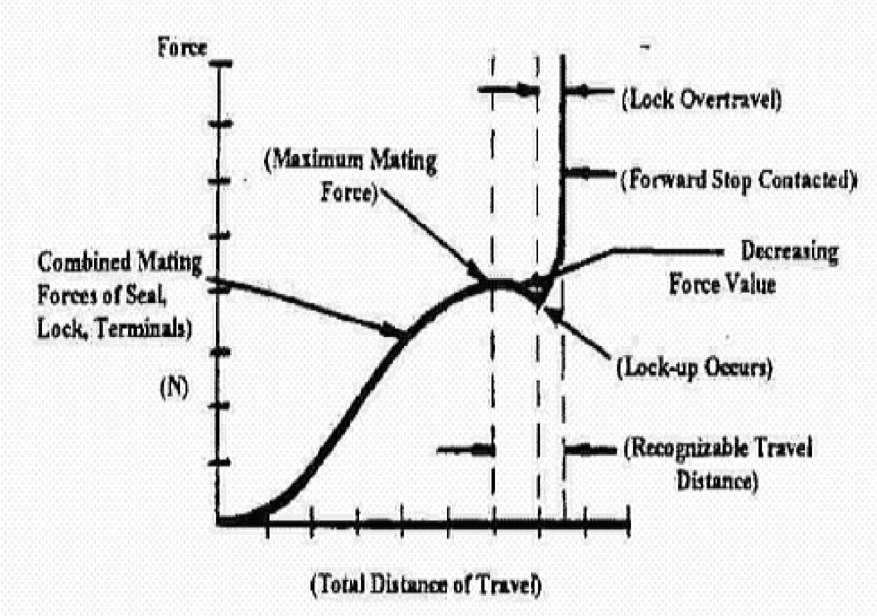


Figure 5.4.2.3: Typical Connector Mating Force Curve

NOTE: If appropriate equipment is available, a continuous graph of applied Mating Force vs. Insertion distance is highly recommended. A properly designed connector (and sealing system where applicable) should produce a graph showing a smooth rise to a single peak force, then a fall off until the connector is fully mated. If the graph shows more than one force peak, the potential for a false lock condition exists.

5. Increase the Mating Force at a uniform rate not to exceed 50mm/min. until complete mating occurs. Test all samples.
6. Record the force required to completely mate each set of connector halves into their locked position and use these values to verify conformance of each connector pair to the Acceptance Criteria of Section 5.4.2.4.

B. UNMATING FORCE

1. This test uses the same samples as in Section 5.4.2.3 Step A above. If the test equipment permits, each sample may be mated and then unmated without removing it from the force tester.
2. Half of the samples (at least 5) are to be tested with the connector primary locking mechanism (without CPA) fully engaged. For this group, completely un-mate the connector halves by applying a uniform force parallel to the centerlines of the fully mated connector halves. The force tester must be configured to apply the Un-mating Force directly to the connector halves, not through the conductor(s). Straight-out un-mating is critical to avoid side loads and binding which can affect force measurements. For connectors with lock arms that protrude above the protective ribs and have no protective bridge, run this test with the lock arm deflected to make it level with the protective ribs.

*** CAUTION ***

The following step will result in sample breakage. Adequate shielding and personnel safeguards must be employed to ensure the safety of persons and property in the vicinity of the test.

3. Increase the Un-mating Force at a uniform rate not to exceed 50mm/min. until complete separation occurs. Test all samples (at least 5) in the first group.
4. Record the force required to completely separate the connector halves and verify conformance to the Acceptance Criteria of Section 5.4.2.4.
5. Repeat Steps 2, 3 and 4 above using the samples (at least 5) from Step A-5 above except completely remove/disable the primary connector locking mechanism(s).
6. For the remaining samples (at least 5) measure the force required to disengage the primary connector lock. This is the force a person would apply to the appropriate point such that the mated connector halves (or a connector mated to a device) could be unmated in the intended manner with no damage to any component. Apply the force perpendicular to the appropriate unlocking surface at a rate not to exceed 50mm/min. Record the force required to displace the lock so it just clears its mating feature. Verify conformance to the appropriate Acceptance Criteria of Section 5.4.2.4.
7. Repeat step 6 with a minimum of 5 additional samples except with the CPA in its fully seated position. Apply only sufficient force to determine if the parts meet the acceptance criteria (5.4.2.5-5)

5.4.2.4 Acceptance Criteria

NOTE: The maximum mating effort is meant to simulate assembly in a vehicle when the assembler's body position and access to the connector being mated is not physically restricted. This specification will cover most operations, but not all conditions of vehicle assembly and connector location can be anticipated.

NOTE: The forces specified in the Acceptance Criteria must be met regardless of the moisture content of the connector housing material. Consult the test request/order to determine if any conditioning of the test samples is required prior to testing.

NOTE: The acceptance criteria of this section varies with the available contact (grip) area of the connector being tested. Reference SAE/USCAR-25 Electrical Connector Assembly Ergonomic Design Criteria for details of the acceptance criteria.

1. Mating (engage) force shall meet the requirements of SAE/USCAR-25.
2. Un-mating Force must be ≤ 75 Newtons with the primary connector lock completely disengaged/disabled.
3. Un-mating Force must be ≥ 110 Newtons with the primary connector lock fully engaged. A CPA device, if provided for, must NOT be engaged during this test.
4. The force to completely disengage the primary connector lock must be > 10N and ≤ 70N without the CPA engaged in its fully seated position.
5. The force to completely disengage the primary connector lock must be >50N with the CPA engaged in its fully seated position.

5.4.3 Connector to Connector Mating and Un-mating Forces (Connectors with Mechanical Assist)

5.4.3.1 Purpose

This test covers mating and un-mating forces for Mechanical Assist connectors such as lever and slide lock. USCAR-25 Ergonomic guidelines should be used as a further reference.

5.4.3.2 Equipment

- ⇨ Force tester
- ⇨ Fixtures for holding connectors as required.

5.4.3.2.1 Samples

Using any applicable conductor size and insulation type, prepare enough samples of male and Female Terminals to fully populate connector assemblies per section 5.1.6, Terminal Sample Preparation.

Prepare connector samples with the full compliment of wires, terminals, and secondary pieces as specified in the design and intended for the production application. A minimum of 10 samples is required to be tested in each section below. Samples may be used for multiple tests.

5.4.3.3 Procedure

A. FORCE TO ENGAGE TO PRE-LOCK POSITION

1. Using the force tester, engage each connector fully to it's pre-lock position.
2. Reverse the direction and measure the force required to un-seat the connector from the pre-lock position.
3. Verify conformance to the acceptance criteria of section 5.4.3.4-1 and 2.

B. FORCE TO RELEASE LATCH FROM SHIPPING POSITION

1. Using the unmated lever connector, place lever or slide in its shipping (open) position.
2. Using the force tester, gradually apply a force of 30N in a direction so as to move the lever toward the lock position.
3. Verify conformance to the acceptance criteria of section 5.4.3.4-3.

C. LEVER ACTUATION/REMOVAL FORCE

1. With the connector in its pre-stage condition, measure the force required to fully actuate and close the lever. Force shall be applied perpendicular with the contact surface of the lever or slide as nearly as possible.
2. For designs with a secondary release mechanism, without disabling or releasing this feature, gradually apply a force of 60N to the lever in the release direction.
3. Disable or release any existing release mechanism (if applicable) and record the force required to move the lever from the locked position to the open position.
4. Verify conformance to the acceptance criteria of section 5.4.3.4-4 and 5.

5.4.3.4 Acceptance Criteria

Note that the acceptance criteria of this section varies with the available contact (grip) area of the connector being tested. Reference SAE/USCAR-25 Electrical Connector Assembly Ergonomic Design Criteria for details of the acceptance criteria.

1. The force to engage the connector to its pre-lock position shall meet the requirements of SAE/USCAR-25.
2. The force required to un-seat the connector from its pre-lock position shall be ≥15 and ≤75.
3. The force required to move the lever or slide from its shipping position while the connector is not in its pre-lock position shall be 30N minimum.
4. The force required to move the lever to and from the locked (engaged) position shall meet the requirements of SAE/USCAR-25.
5. The minimum force to release the assist feature without depressing the release mechanism (if applicable) shall be ≥60N for a fully mated connector

5.4.4 Polarization Feature Effectiveness

5.4.4.1 Purpose

This test ensures that the polarization feature(s) is adequate to meet its intended purpose of preventing incorrect mating of a connector housing with its intended mate, and preventing mating of a connector housing with any unintended mate. It also tests the adequacy of the polarization feature(s) in preventing terminal damage during incorrect assembly attempts. In addition to this objective force test, it is recommended that a jury evaluation be conducted among knowledgeable individuals trying "hands-on" mis-mating.

5.4.4.2 Equipment

⇨ Insertion/Extraction Force Tester with Peak Reading Feature

5.4.4.3 Procedure

1. Two factors must be considered: attempting to incorrectly mate two connector halves, or a connector half and a header, that are supposed to mate if properly oriented, and attempting to mate a connector with an incorrect mate.
2. Sample size varies depending on the number of incorrect orientations tested. Test at least one sample set for each selected mis-orientation or mis-index.
3. No terminals are required for this test of the polarizing feature(s). However, a suitable mechanical or electrical means must be devised to detect penetration of one half of the CUT into the other to a depth sufficient to contact any Male Terminal in any position if that Male Terminal was installed.

4. Orient the CUT with any possible mate in the same family in one or more incorrect orientations chosen by the Authorized Person as most likely to defeat the polarization. The parts should be tested as follows, using a fresh sample of each half for each orientation:
   a. The correct orientation, but with the wrong index
   b. The incorrect orientation
5. Secure the connector halves (or connector and header) (one male and one female) in the appropriate fixtures of the force tester. Adjust the force tester to attempt insertion of the Male Connector into the Female Connector in the orientation selected in Step 3.
6. Engage the connector halves at a uniform rate not to exceed 50mm/min. until the maximum force specified in the part drawing is applied. If no value is specified, apply a maximum force of 220 N. Note the indication of the penetration detection device installed in Step 3.

5.4.4.4 Acceptance Criteria

The minimum mis-mating force that must be resisted by the polarizing feature(s) is the value given on the part drawing. If no value is specified, the minimum value is 220N.

If sufficient mis-mating is achieved to allow contact with any Male Terminal if it were properly installed in any position in its connector housing, the polarizing feature(s) is considered to be inadequate.

5.4.5 Miscellaneous Component Engage/Disengage Force

5.4.5.1 Purpose

This test is to ensure that connector assembly components such as TPAs, PLRs, CPAs, Locator Clips, etc. will be sufficiently retained, yet allow easy and consistent assembly and removal for service where necessary.

5.4.5.2 Equipment

⇨ Insertion/Extraction Force Tester with Peak Reading Feature

5.4.5.3 Procedure

A. ENGAGEMENT FORCE

1. Completely identify and number each component to be tested. A minimum of 10 samples is required to be tested for each of the applicable conditions found in the acceptance criteria. The same samples may be used for various phases of testing.
2. All components to be tested and their mating parts must be fixtured so that proper alignment is maintained during testing. Straight-in engagement and extraction is critical to avoid side loads and binding which can affect force measurements.
3. Engage each component to be tested, with its retaining mechanism(s) in place, at a uniform rate not to exceed 50 mm/min. Test each applicable condition per table 5.4.5.4.
4. Record the force required to completely engage the component with its mating part and use this value to verify conformance to the Acceptance Criteria of Section 5.4.5.4.

B. DISENGAGING FORCE

*** CAUTION ***

The following step may result in sample breakage. Adequate shielding and personnel safeguards must be employed to ensure the safety of persons and property in the vicinity of the test.

1. With the component fully installed and properly fixtured, disengage the component at a uniform rate not to exceed 50mm/min. The force must be applied parallel to the centerline of the component being tested to avoid side loads and binding which can affect force measurements. The direction must be opposite to the direction of normal insertion of the component part. Test each applicable condition per table 5.4.5.4.
2. Record the force required to disengage the component from its mating part and use this value to verify conformance to the Acceptance Criteria of Section 5.4.5.4.
3. For locator clips only, repeat Step 1 above in each of the three directions 90°, 180°, and 270° from the initial insertion direction. Then repeat Step 1 in a direction orthogonal to the plane of the first four tests. Do not exceed a force of 110N for any of these subsequent tests.

5.4.5.4 Acceptance Criteria

Insertion/Extraction Forces shall meet the values indicated on the part print. If no value is specified, the force shall meet the values shown in table 5.4.5.4.

	Force (N)			
	Insertion		Removal	
Device	Insert to lock	Pre-set to lock	Lock to pre-set	Remove
Locator Clip	60 max	N/A	N/A	110 Min (Also see section 5.7.2)
CPA	60 Min (w/connectors un-mated) 22N max w/connectors mated (loose pc. CPA)	60 Min (w/connectors un-mated) 22 Max w/connectors mated	10-30	30 Min
TPA/PLR	60 Max (w/terminals installed)	60 Max (w/terminals installed) 15 Min(w/o terminals)	60 Max 18 Min after initial removal	25 Min

Table 5.4.5.4: Misc. Component Assembly/Dis-assembly Forces

5.4.6 Vibration/Mechanical Shock

5.4.6.1 Purpose

This test subjects a connector system to variable vibration simulating accelerated exposure to actual vehicle conditions. Vibration and shock can cause wear of the terminal interfaces, intermittent electrical contact and failure of mechanical components of the connector system.

Note that two vibration "profiles" are available. One is for components actually mounted on the engine/transmission or on brackets, components, etc. that are directly attached to the engine/transmission and vibrate with it. The other is for components mounted everywhere else on the Sprung portion of the vehicle. Unless a special vibration "profile" is specified in the test request/order, the appropriate profile must be used according to the intended location of the CUT on the vehicle.

Since unsealed connectors are not suitable for use outside the passenger and luggage compartments, they would normally be tested only to the non-engine/transmission profile. Sealed connectors may be used in applications requiring direct attachment to the engine/transmission, so they should normally be qualified to the harsher vibration profile.

NOTE: This section does not apply to components mounted on un-sprung portions of the vehicle, such as the wheel hub. Components mounted on un-sprung portions of the vehicle require special testing to ensure they can survive and function properly in the intended application.

5.4.6.2 Equipment

⇨ Vibration Table
⇨ Vibration Controller
⇨ Accelerometers

5.4.6.3 Procedure

1. Using the largest applicable conductor size and insulation type applicable to the design, prepare enough male and Female Terminals to fully populate a minimum of 10 connector assemblies per section 5.1.6, Terminal Sample Preparation. Prepare each sample by assembling all applicable parts and bundling (with tape, convolute, scroll, etc.) the conductors according to the intended application of the parts being tested. Consult the Authorized Person for details on intended bundling. Refer to Fig. 5.4.6.3 for examples of test mounting arrangements. Mounting position A is for in-line type connectors. Position B is for connectors that will mate to an electrical device. At least 10 samples are required unless otherwise specified in the test request/order.
2. Complete the Connector and/or Terminal Cycling procedure per section 5.1.7 if not already performed on the sample set.
3. Verify conformance of each sample connector assembly to the Acceptance Criteria of the Dry Circuit Resistance test, Section 5.3.1.4. Measure at least 10 terminal pairs randomly distributed among the connector sets.

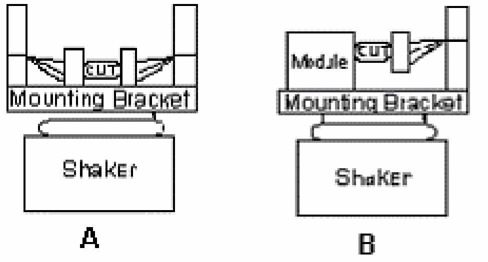


Figure 5.4.6.3: Mounting Positions

NOTE: It is vital to secure the conductors to their respective connector housings. Terminals "float" in their cavities and will wear rapidly if the associated conductors are allowed unrestrained movement relative to the connector housing.

4. Construct a suitable mounting apparatus using the following design criteria:
   a. The mounting apparatus must be constructed and secured to minimize added effects (harmonics, dampening, resonance, etc.).
   b. For In-Line Connectors, mount the mated connector pair directly to the Mounting Bracket using the connector feature provided for mounting. Refer to Figure 5.4.6.3-A. Do not use a "Christmas Tree" or any other type of mounting device. Instead, the Mounting Bracket itself must be constructed so as to include a direct mounting feature to mate with the mounting feature (Dovetail) on the mated connector pair.
   c. For Device Connectors, mount the device directly to the Mounting Bracket. Refer to Figure 5.4.6.3-B. Use the normal device mounting feature(s) used to secure the device in its intended vehicle location. Do not use any intervening bracket or mounting device. Instead, the Mounting Bracket must be fabricated to include any cooperating features necessary to mount the device directly to it.
   d. The conductor attachment points must be 100mm +/-10mm from the rear of the connector body.
5. Should an application arise that does not lend itself to either situation described above, consult the Authorized Person. It is his or her responsibility to devise a suitable method for attaching the CUT as directly and firmly as possible to the Mounting Bracket consistent with the intended vehicle mounting.
6. Securely attach the conductor bundle ends to the mounting fixture such that there is a 10 ± 5 mm sag relative to the bisecting plane of the attachment points. See Figure 5.4.6.3-C.

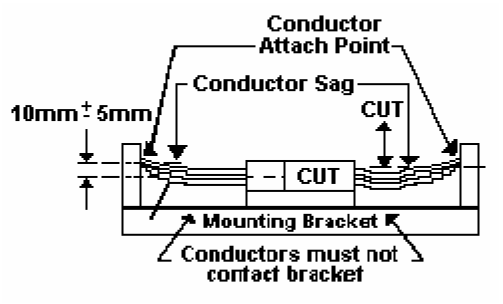


Figure 5.4.6.3-C: Typical Connector Vibration Test Set-up

7. Set up the samples to monitor continuity per section 5.1.9
8. The test fixtures, system layout, and test set-up must be approved by the Authorized Person prior to testing.
9. Subject the CUT to 10 half-sine wave impulses (10 millisecond duration at 35 Gs force) in each of the three mutually perpendicular axes. Mechanical shock and vibration testing may be completed in sequence for each axis before proceeding to the next axis.

10. Unless otherwise specified in the test request/order all CUTs mounted directly to the engine or transmission shall be vibrated for 8 hours in each of the three mutually perpendicular axes (X,Y,Z). Vibrate the CUT using the vibration profile in Fig. 5.4.6.3-D.
11. CUTs mounted anywhere else on the Sprung portions of the vehicle, including the engine compartment (but not directly on or to the engine or transmission) use Figure 5.4.6.3-E. Vibration shall be 8 hours in each of the three mutually perpendicular axes (X,Y,Z) unless otherwise specified in the test request/order.
12. Age the samples for 48 hours at ambient conditions.
13. Record the results, inspect the CUT, and verify conformance to the Acceptance Criteria of Section 5.4.6.4.

All Sprung Portions of Vehicle Coupled to Engine

Frequency (hz)	Power Spectral Density (g^2/hz)
60.0	0.00100
200.0	1.50000
210.0	0.10000
1200.0	0.10000
Grms = 12.1	

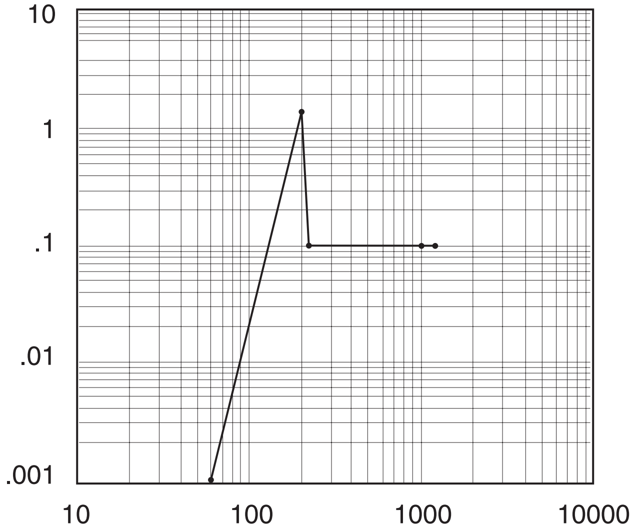


Figure 5.4.6.3-D: For Components Coupled to Engine

All Sprung Portions of Vehicle Not Coupled to Engine

Frequency (hz)	Power Spectral Density (g^2/hz)
5.0	0.00200
12.5	0.24800
77.5	0.00320
145.0	0.00200
200.0	0.01180
230.0	0.00032
1000.0	0.00002
Grms = 1.81	

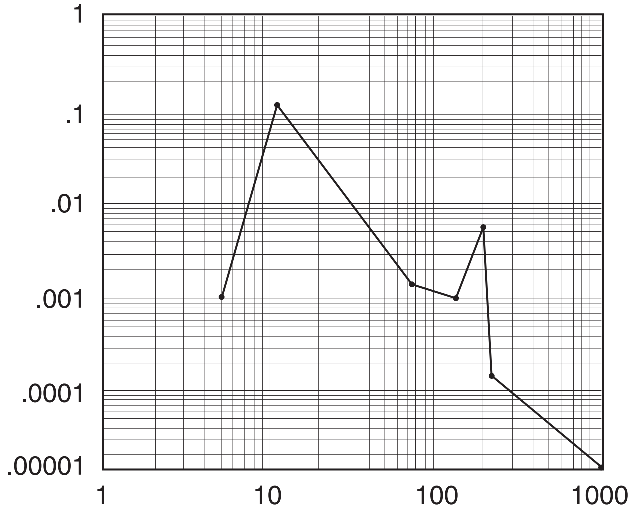


Figure 5.4.6.3-E: For Components Not Coupled to Engine

5.4.6.4 Acceptance Criteria

At the conclusion of the test, verify conformance of each terminal pair and each sample connector assembly, as appropriate, to the Acceptance Criteria of section 5.1.9.4 (Continuity Monitoring) and to the following tests:

1. After 48 hours at ambient conditions, terminals must meet the Acceptance Criteria of the Dry Circuit Resistance test of Section 5.3.1.4. Measure at least 10 terminal pairs randomly distributed among the connector sets.
2. Terminals must meet the Acceptance Criteria of the Voltage Drop test, Section 5.3.2. Check the same terminal pairs as in step 1 above.

3. The connector assembly must not show, with the aid of 10X magnification, any evidence of deterioration, cracks, deformities, etc. that could affect its functionality or severely degrade its appearance.
4. The terminals must not show, with the aid of 10X magnification, any evidence of deterioration, cracks, deformities, excessive plating wear, etc. that could affect their functionality.

5.4.7 Connector-to-Connector Audible Click

5.4.7.1 Purpose

Studies show that assembly plant technicians depend on audible queues that indicate full seating of electrical connectors regardless of background noise. This test measures the level of noise generated when two connectors are mated. Connectors are mated by hand for this test rather than being clamped into a fixture which could dampen or amplify the sound.

5.4.7.2 Equipment

- ⇨ dB meter

5.4.7.3 Procedure

8 sample pairs are required. Samples are to be production intent. All connector cavities shall be filled with wires and terminals of any size appropriate to the CUT. Include all TPA’s, seals, stuffers and auxiliary pieces as applicable.

1. Measure and record the dB (C) level of the ambient sound within the test environment. The ambient noise level must be 60 dB (C) minimum.
2. Locate the sound measuring device or microphone 600+/-50mm from the connector.
3. Mate the connectors by hand and measure the dB (C) level of the sound generated as the lock engages. Do not bias the connectors toward or away from the latch as they are engaged.
4. Repeat Steps 1 through 3 using moisture conditioned parts. Parts are brought to their practical limit of moisture content by exposing “dry as molded parts” to 95-98% Relative Humidity at 40ºC for 6 hours (minimum), then completing the test within 30 minutes.

5.4.7.4 Acceptance Criteria

The minimum sound level required shall be as specified on the part drawing. If no value is specified, the requirement is 7dB above the recorded ambient for un-conditioned parts and 5dB for conditioned parts.

5.4.8 Connector Drop Test

5.4.8.1 Purpose

This test evaluates the ability of the connection to withstand impact due to dropping on a hard surface. This test does not apply to headers or any other connector not designed for use in a wiring harness.

5.4.8.2 Equipment

No specific equipment is required. Alternatively, a rotating drum as described in IEC 68-2-32 may be used. Modifications to this device are required to maintain the 1 meter drop distance.

5.4.8.3 Procedure

1. 3 samples are required. Assemble connectors with all parts to be used in the intended application (CPA, TPA, PLR, etc). Do not insert leads or terminals
2. Drop each sample 3 times (or as agreed upon by the supplier and user) onto a horizontal concrete surface from a height of 1 meter, orienting the sample in various directions each time. The Responsible Engineer may direct specific orientations in order to expose areas of the design that may be vulnerable to damage.

5.4.8.4 Acceptance Criteria

Samples shall meet the Acceptance Criteria of section 5.1.8, Visual Inspection.

5.4.9 Cavity Damage Susceptibility

5.4.9.1 Purpose

This test is intended to demonstrate resistance to damage when the connector TPA/PLR is forcefully inserted on a connector with one or more terminals in the incorrect (un-seated) position. The cavity and other plastic and metal parts must subsequently be able to be assembled correctly and retain full function following such an event.

5.4.9.2 Equipment

Force tester

5.4.9.3 Procedure

1. Samples consist of five connectors with terminal secondary locks in the un-seated position and five leads terminated with each terminal size in the connector.
2. Randomly select one cavity of each terminal type from each sample for testing.
3. Determine the force to be applied to the secondary lock by adding 40N to the maximum force required to seat the device when all terminals are located properly (section 5.4.5.3 A, step 4). The minimum force is 80N.
4. Partially insert a terminated lead into the selected cavity. The terminal should be inserted until it is just short of locking into position. While holding the terminal in this position, apply a force as determined in step 3 to the terminal secondary lock in the direction of normal seating.
5. Remove the force and seat the terminal in its normal position. Seat the secondary lock.

5.4.9.4 Acceptance Criteria

Verify that terminal retention meets the extraction forces in table 5.4.1.4. Moisture conditioning is not required.

5.5 Connector - Electrical Tests

5.5.1 Isolation Resistance

5.5.1.1 Purpose

This test verifies that the electrical resistance between any two cavities in a connector system will be sufficient to prevent detrimental electrical conductivity between the various circuits passing through that connector system. This test is typically done after other environmental stress tests to ensure that any contaminants that may have entered the connector during testing are not sufficient to create an unintended electrical path.

5.5.1.2 Equipment

- ⇨ Megohmeter

5.5.1.3 Procedure

NOTE: This test is typically used only in conjunction with another test that subjects the connector to the chance of some form of moisture or other contaminant intrusion. Test the same samples used for the related test.

NOTE: When samples are to be tested following exposure to moisture or other contaminants, it is important that this Isolation Resistance test be performed on each sample within one hour of concluding the associated test. Otherwise, particularly where samples are exposed to elevated temperatures in the preceding test, any contaminant that might invade the samples may dry to the point of being undetectable by this Isolation Resistance test.

1. If this test is to be performed to check isolation resistance of a new connector housing, prepare cut leads as specified in Section 5.1.6, Terminal Sample Preparation
2. Connect the Megohmeter, set to 500 VDC, to the bared conductor ends as illustrated in Figure 5.5.1.3 so that adjacent cavities have opposite polarization. For special applications, the test voltage may be reduced or increased with the approval of the Authorized Person.
3. Use the Megohmeter to measure the resistance between the adjacent terminals. Apply the test voltage continuously for at least 15 sec. Test both halves of the connector system (if applicable for new connector housings. Test the mated connector assembly for those sample that have been subjected to prior stress testing.
4. Record the minimum resistance measured and verify conformance to the Acceptance Criteria of Section 5.5.1.4

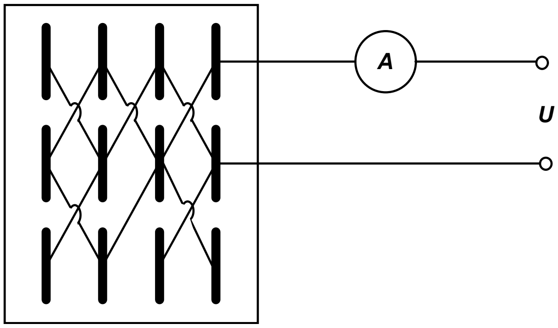


Figure 5.5.1.3: Method of Connecting Leads for Isolation Resistance Test

5. For connectors with Shorting Bars, take the isolation resistance measurement between the two terminals designed to be shorted together by the Shorting Bars (Shorting Bars “open”)

5.5.1.4 Acceptance Criteria

The resistance between every combination of two adjacent terminals in the CUT must exceed 20 MΩ at 500 VDC. This includes terminals that may be separated by one or more vacant terminal cavities.

5.6 Connector Environmental Tests

5.6.1 Thermal Shock

5.6.1.1 Purpose

This test subjects the connector assembly to extreme temperature cycles that cause expansion and contraction of the various materials used in the connector system. This is intended to produce accelerated wear at the terminal-to-terminal interface.

5.6.1.2 Equipment

⇨ Temp. Chamber(s) (-40° C to +175° C *)

* As required by the Temperature Class selected from Figure 5.1.4.

5.6.1.3 Procedure

1. Using leads prepared per section 5.1.6, assemble a minimum of 10 pairs of fully populated connectors (at least 10 male and 10 Female Connector halves). Leads may be of any size and insulation type appropriate to the TUT. Assemblies must include all applicable Wedges (TPAs, PLRs, etc.), Seals, etc. Number each mated connector pair.
2. Complete the Connector and/or Terminal Cycling procedure per section 5.1.7 if not already performed on the sample set.
3. Verify conformance of each sample connector assembly to the Acceptance Criteria of the Dry Circuit Resistance test, Section 5.3.1.4. Measure at least 10 terminal pairs randomly distributed among the connector sets.
4. Set up the samples to monitor continuity per section 5.1.9
5. Place the samples in the chamber so that there is no substantial obstruction to air flow across and around the samples, and the samples are not touching each other.
6. Determine the Temperature Class for the intended application of the connector system from Figure 5.1.4. Then set the Temperature chamber to the minimum ambient temperature for that class. Allow the chamber to stabilize, then cold Soak the samples an additional 30 min.
7. At the conclusion of the 30 minute cold Soak, transfer the samples to another chamber set to the maximum ambient temperature for the Temperature Class selected in Step 6. It is important to complete the transfer of all samples from the cold to hot chamber (or, optionally, to transition one chamber from the coldest to the hottest extreme) in less than 30 seconds. Allow the samples to heat Soak for 30 minutes.
8. At the conclusion of the 30 minute heat Soak, transfer the samples to another chamber set to the minimum ambient temperature for the Temperature Class selected in Step 6. It is important to complete the transfer of all samples from the hot to cold chamber in less than 30 seconds. Allow the samples to cold Soak for 30 minutes.
9. Repeat Steps 7 and 8 ninety nine (99) more times.
10. Measure the Dry Circuit resistance (section 5.3.1) of the same terminal pairs selected in step 3. Do not use monitored circuits for Dry Circuit measurements
11. Measure the voltage drop per section 5.3.2. At least 10 terminal pairs must be measured.

Verify conformance to the Acceptance Criteria of Section 5.6.1.4

5.6.1.4 Acceptance Criteria

At the conclusion of the test, verify conformance of each terminal pair and each sample connector assembly, as appropriate, to the Acceptance Criteria of section 5.1.9.4 (continuity Monitoring) and to the following tests:

First, the Dry Circuit Resistance test, Section 5.3.1.4.

Second, the Voltage Drop test, Section 5.3.2.4.

NOTE: If samples are to be subjected to further testing (for example as part of the test sequence shown in Section 5.9.6), the following steps may be deferred until the sequence is complete.

The connector assemblies must not show, with the aid of 10X magnification, any evidence of deterioration, cracks, deformities, etc. that could affect their fit or function, or distort their appearance.

5.6.2 Temperature/Humidity Cycling

5.6.2.1 Purpose

This test simulates actual operating conditions using temperature and humidity variations as aging mechanisms for evaluation of a connector system's electrical durability. High humidity and temperature can promote galvanic and electrolytic corrosion of the terminals which may cause electrical and mechanical degradation. Temperature cycling promotes relative movement of the contact surfaces that can cause wear and fretting corrosion. Certain plastic materials may also degrade.

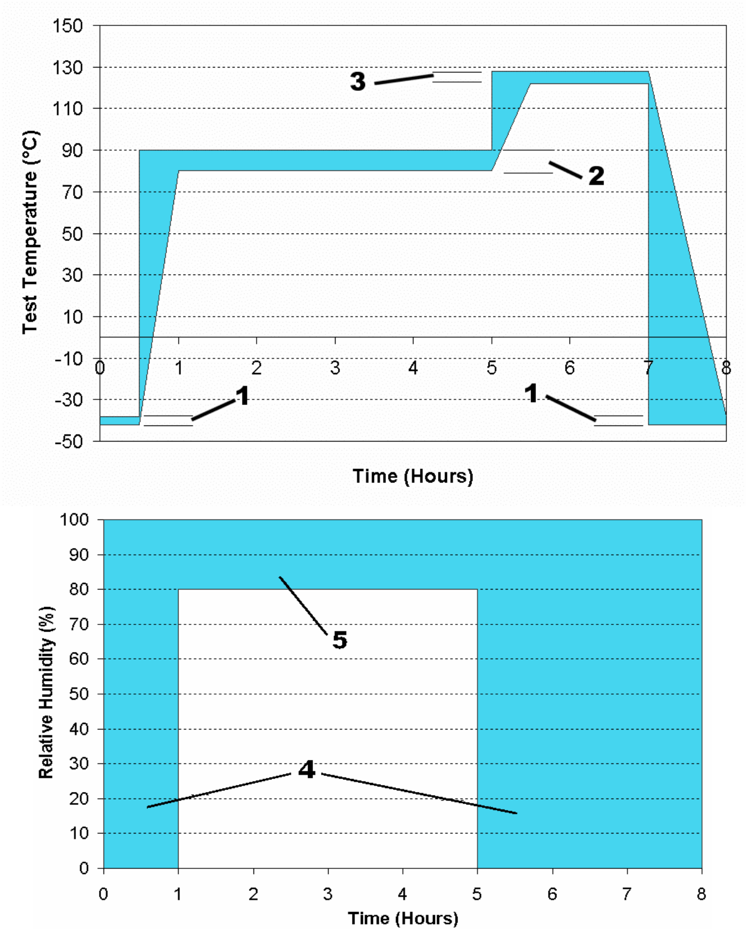
5.6.2.2 Equipment

- ⇨ Data Logger
- ⇨ Temperature Chamber(s) (-40° C to +175° C *, 0%-95% Relative Humidity)

* As required by the Temperature Class selected from Figure 5.1.4.

5.6.2.3 Procedure

1. Using leads prepared per section 5.1.6, assemble a minimum of 10 pairs of fully populated connectors (at least 10 male and 10 Female Connector halves). Leads may be of any size and insulation type appropriate to the application. Assembly must include all applicable Wedges (TPAs, PLRs, etc.), Seals, etc. Number each mated connector pair.
2. Complete the Connector and/or Terminal Cycling procedure per section 5.1.7 if not already performed on the sample set.
3. Verify conformance of each sample connector assembly to the following Acceptance Criteria:
    a. First, the Dry Circuit Resistance test, Section 5.3.1.4, when this test is performed stand-alone. Measure at least 10 terminal pairs randomly distributed among the connector sets.
    b. The Isolation Resistance test, Section 5.5.1.4.
4. The test fixtures, system layout, and test set-up must be approved by the Authorized Person prior to testing.
5. Place the samples in the chamber so that there is no substantial obstruction to air flow across and around the samples, and the samples are not touching each other.
6. Determine the Temperature Class for the intended application of the connector system from Figure 5.1.4. Then set the Temperature chamber to the minimum temperature for that class. Allow the chamber to stabilize before proceeding.
7. Cycle the test samples 40 times using the cycling schedule shown in Figure 5.6.2.3. Extended transition times may be used as long as the dwell times at temperature are maintained. The cycle begins with the sample at –40°C and un-controlled relative humidity. Completion of the schedule shown in Figure 5.6.2.3 will constitute one cycle. Use the Maximum Ambient Temperature for hours 5 through 7 as determined from Figure 5.1.4 in Step 6 above.



Key:
1 (-40)°C
2 (80 – 90)°C
3 Test temperature, see Figure 5.1.4 (Class 3 shown for illustration only)
4 Relative humidity, uncontrolled. Do not vent chamber at hour 5
5 (80 – 100)% Relative humidity

Figure 5.6.2.3: Temperature/Humidity Cycling Schedule

8. Using the separate set of samples designated for that purpose, complete the Connector/Terminal Extraction Force Test (Section 5.4.1.3-B, Steps 4-8, except do not increase the force above 50N.
9. Verify conformance to the Acceptance Criteria of Section 5.6.2.4.

5.6.2.4 Acceptance Criteria

1. At the conclusion of the test, verify conformance of each terminal pair and each sample connector assembly, as appropriate, to the Acceptance Criteria of the following tests:
   a. First, the Dry Circuit Resistance test, Section 5.3.1.4. Measure at least 10 terminal pairs randomly distributed among the connector sets.
   b. Second, Voltage Drop test, Section 5.3.2.4. Measure at least 10 terminal pairs randomly distributed among the connector sets.
   c. Finally, the Isolation Resistance test, Section 5.5.1.
   d. Pull test samples shall meet the connector/terminal Extraction Force test requirements of section 5.4.1.4

NOTE: If samples are to be subjected to further testing (for example as part of the test sequence shown in Section 5.9.6). The following steps may be deferred until the sequence is complete.

2. The connector assemblies must not show, with the aid of 10X magnification, any evidence of deterioration, cracks, deformities, etc. that could affect their functionality or distort their appearance.

5.6.3 High Temperature Exposure

5.6.3.1 Purpose

This test evaluates the effects of long-term exposure to elevated temperature on connector assembly components. Thermal aging may cause changes in metal and plastic materials, including stress relaxation in important flexing members of the terminal or its connector. These changes may be detrimental to electrical and physical performance.

5.6.3.2 Equipment

⇨ Temperature Chamber(s) (+175^{o} C *)

* As required by the Temperature Class selected from Figure 5.1.4.

5.6.3.3 Procedure

1. Using leads prepared per section 5.1.6, assemble a minimum of 10 pairs of fully populated connectors (at least 10 male and 10 Female Connector halves) Leads may be of any size and insulation type appropriate to the application. The assembly must include all applicable Wedges (TPAs, PLRs, etc.), seals, etc. Number each mated connector pair.
2. Complete the Connector and/or Terminal Cycling procedure per section 5.1.7 if not already performed on the sample set.
3. Verify the performance of each sample connector assembly to the Acceptance Criteria of the Dry Circuit Resistance test, Section 5.3.1.4. Measure at least 10 terminal pairs randomly distributed among the connector sets.
4. The test fixtures, system layout, and test set-up must be approved by the Authorized Person prior to testing.
5. Determine the Temperature Class for the intended application of the connector system from Figure 5.1.4. Then set the temperature chamber to the maximum ambient temperature for that class. Allow the chamber to stabilize before proceeding.
6. Place the samples in the chamber, set to the maximum ambient temperature, so that there is no substantial obstruction to air flow across and around the samples, and the samples are not touching each other. Leave the samples in the chamber for 1008 hours.
7. Sample evaluation is required only at the beginning and end of the test, but additional measurement intervals may be requested by the Authorized Person.
8. At the conclusion of the test, verify conformance to the Acceptance Criteria of Section 5.6.3.4.

5.6.3.4 Acceptance Criteria

At the conclusion of the test, verify conformance of each terminal pair and each sample connector assembly, as appropriate, to the Acceptance Criteria of the following tests, in the order shown:

a. The Dry Circuit Resistance test, Section 5.3.1.4. Measure at least 10 terminal pairs randomly distributed among the connector sets.
b. The Voltage Drop test, Section 5.3.2.4. Measure at least 10 terminal pairs randomly distributed among the connector sets.

NOTE: If samples are to be subjected to further testing (for example as part of the test sequence shown in Section 5.9.6) do not perform any steps beyond this point.

c. The visual inspection, section 5.1.8.4

5.6.4 Fluid Resistance

NOTE: This test is to be used for sealed connector systems only.

5.6.4.1 Purpose

This test evaluates the sealing capability and material compatibility of a sealed connector system when immersed in various fluids commonly found in and around road vehicles.
Since the same materials are commonly used for numerous connection systems, the use of surrogate data is acceptable for this test. If surrogate data is used, all references to the original test(s) shall be included in the test report.

5.6.4.2 Equipment

- ⇨ Laboratory Fume Hood
- ⇨ Stainless steel tanks or Pyrex beakers
- ⇨ Explosion-proof Heat Chamber

5.6.4.3 Procedure

1. Using leads prepared per section 5.1.6, assemble a minimum of 8 pairs of fully populated connectors. Use leads of the smallest conductor size and insulation type appropriate to the terminals and connector being tested. Assembly must include all applicable Wedges (TPAs, PLRs, etc.), Seals, etc. Number each mated connector pair.
2. Verify conformance of each mated sample connector assembly to the Isolation Resistance test, Section 5.5.1. This establishes a reference for the concluding Isolation Resistance test.
3. Completely submerse at least 1 test sample in each fluid listed in table 5.6.4.3 for 30 minutes. Fluids are to be stabilized at the temperatures indicated. A fresh sample is to be used for each fluid and each sample is to be submersed in one fluid only, unless otherwise requested by the Authorized Person.

CAUTION: Follow all Federal, state, and local safety regulations, standards, and procedures when performing this test.

Fluid	Specification*	Test temp.°C
Gasoline	ISO1817, liquid C	23 ± 5
Diesel fuel	90% ISO 1817, Oil No. 3 + 10% p-xylene	23 ± 5
Engine oil	ISO 1817, Oil No. 2	50 ± 3
Ethanol	85% Ethanol + 15% ISO 1817 liquid C	23 ± 5
Power steering fluid	ISO 1817, Oil No. 3	50 ± 3
Automatic transmission fluid	Dexron III	50 ± 3
Engine coolant	50 % ethylene glycol + 50 % distilled water	50 ± 3
Brake Fluid	SAE RM66xx**	50 ± 3

*Solutions are determined as percent by volume
**Use latest available SAE reference fluid
See appendix A for fluid source list

Table 5.6.4.3: Fluid Test

1. At the conclusion of the submersion period, remove the sample from the fluid. Do NOT shake off any excess fluid. Use care not to splash any fluid on unintended surfaces. Leave the samples "wet" and store them in a suitable container or area for one week. Do not allow samples submersed in different fluids to touch each other and do not allow any dissimilar fluid drippings to intermingle.
2. At the conclusion of the storage period, samples may be dried sufficiently to allow inspection and to avoid contamination of test apparatus.
3. Verify conformance of each test sample to the Acceptance Criteria of Section 5.6.4.4.

5.6.4.4 Acceptance Criteria

1. Each mated terminal pair in every test sample must meet the Acceptance Criteria of the Isolation Resistance test, Section 5.5.1.4. In the case of single cavity connectors, apply the test voltage between a ground plane foil wrap and one of the conductors from the test sample.
2. There must be no visible degradation, swelling*, cracking, or loss of mechanical function evident on any test sample, examined with the aid of a 10X magnifying glass.

*Swelling of cable and connector and cable seals is permissible.

5.6.5 Submersion

NOTE: This test is to be used for sealed connector systems only.

5.6.5.1 Purpose

This test is an accelerated simulation of the "breathing" that may occur in a sealed connector system when it is heated and suddenly cooled by submersion in a cooler liquid. Salt water is used as the liquid to facilitate detection of any leakage into the connector. As a further aid to detecting any leakage that may occur, it is recommended that a suitable ultraviolet dye be added to the salt water solution.

5.6.5.2 Equipment

⇨ Stainless steel tanks or Pyrex beakers
⇨ Megohmeter
⇨ Temperature Chamber (-40^{o} C to +175^{o} C*)

*As required by the Temperature Class selected from Figure 5.1.4.

5.6.5.3 Procedure

1. Using leads prepared per section 5.1.6 assemble a minimum of 10 pairs of fully populated connectors. Use leads of the smallest conductor size and insulation type appropriate to the terminals and connector being tested. The assembly must include all applicable Wedges (TPAs, PLRs, etc.), Seals, etc. Number each mated connector pair.
2. For multiple conductor (mat) type seals only, select 10 cavities at random among the sample set and record the connector and cavity numbers. Remove and re-insert the terminals in the selected cavities. The purpose of this step is to ensure the terminal does not damage the seal during service operations.
3. Complete the Connector and/or Terminal Cycling procedure per section 5.1.7 if not already performed on the sample set
4. Verify conformance of each mated sample connector assembly to the Isolation Resistance test, Section 5.5.1.4. This establishes a reference for the concluding Isolation Resistance test.
5. Place the samples in the chamber such that there is no substantial obstruction to air flow across and around the samples, and the samples are not touching each other.
6. Determine the Temperature Class of the connector system from Figure 5.1.4 and set the chamber to the Maximum Ambient Temperature for that class. Allow the chamber to stabilize before proceeding. Heat Soak the samples at the elevated temperature of the chamber for 2 hours. If the internal temperature of a representative sample of the parts to be tested can be shown to stabilize at oven temperature in less than two hours, the shorter time may be used. The demonstration sample may not be used as an actual test sample.

7. Prepare enough salt water solution to completely submerse the samples. Use tap water and 15-16 grams of table salt per liter. Then add 10 ml of liquid dish washing soap per liter. Mix well before adding to test apparatus. It is recommended that an appropriate ultraviolet dye be added to assist in visual inspection for any ingress of solution into the test samples.
8. Remove the samples from the chamber. Within 30 seconds, submerse them in the Room Temperature salt water solution to a depth of 30 - 40 cm. The samples shall remain submersed at this depth for a period of 30 minutes.
9. At the end of the 30 minute submersion, remove the samples from the salt water solution, shake off the excess solution, then carefully dry the exterior surfaces of the samples. Immediately perform the Isolation Resistance test of Section 5.5.1 on each sample.
10. Repeat Steps 6, 8, and 9 four (4) more times, except do not repeat when this test is done on samples that have completed the Temperature/Humidity Cycling test of Section 5.6.2 or the High Temperature Exposure Test of Section 5.6.3.
11. Immediately upon concluding the test, verify conformance of each sample to the Acceptance Criteria of Section 5.6.5.4.
12. SPECIAL TEST for connectors with multi-cavity (mat) type conductor seals. This test is not applicable to single cavity connector designs. This is an <u>additional</u> test and requires use of new samples. Its purpose is to check for seal distortion from extremes of conductor size that may produce a leak.
    a. Repeat Step 1, except prepare one male and one female terminal (smallest conductor size) for each connector pair to be tested.
    b. Repeat Step 1 except use the largest conductor size and insulation type for the terminals to be used in the intended application. Prepare only enough terminal samples to fully populate all connector pairs, less one cavity for each connector half.
    c. Prepare a minimum of 10 connector pairs so that all but one randomly selected cavity in each connector half is populated with a terminal crimped to the largest conductor size, prepared in Step b above. Then fill the remaining cavity in each connector half with the appropriate terminal crimped to the smallest conductor size, prepared in Step a above. Number each connector pair.
    d. Repeat Steps 3, 4, 5, 6, 8, 9, 10, and 11 using the samples prepared in Step C above.
13. At the conclusion of the test, disconnect each mated sample pair and perform the Visual Inspection test of Section 5.1.6. When disconnecting the samples, use care not to allow any residual solution to enter the interior of any connector half. Careful examination is required to detect any trace of fluid leakage that escaped detection by the Isolation Resistance test. Use of a dye in the solution, as recommended in Step 7 above, will aid in this inspection.

5.6.5.4 Acceptance Criteria

1. There should be no trace of fluid ingress in any connector at the conclusion of this test.
2. Samples shall meet the Acceptance Criteria of the Isolation resistance Test, Section 5.5.1.4.

5.6.6 Pressure/Vacuum Leak

5.6.6.1 Purpose

This test evaluates the sealing capability of a sealed connector system when subjected to a specified pressure differential between the inside and outside of the sealed area.

5.6.6.2 Equipment

⇨ Pressure/Vacuum Source (Regulated)
⇨ Container (for sample immersion)
⇨ Temperature Chamber (-40^{o} C to +175^{o} C *)

* As required by the Temperature Class selected from Figure 5.1.4.

5.6.6.3 Procedure

NOTE: When using samples that have been subjected to any prior testing that includes the Temperature/Humidity Cycling test, Section 5.6.2 or High Temperature Exposure test, section 5.6.3, proceed directly to Step 18. This assumes that the samples have already been prepared with vacuum tubes per steps 1 through 17.

1. Refer to section 5.1.6 and prepare leads using the smallest conductor size and insulation type appropriate to the terminal and connector under test. Crimp enough samples of male and Female Terminals to assemble a minimum of 10 pairs of connector assemblies, less one cavity for each connector pair. Crimp both the conductor and insulation grips.
2. For convenience, and to minimize loose conductor ends, conductor lengths may be terminated on both ends and looped between samples.
3. Using the terminals prepared in Step 1, assemble a minimum of 10 pairs of fully populated connectors, leaving one conveniently located cavity open in each connector pair. Determination of which connector half has the vacant cavity will have been determined in Step 1. Assembly must include all applicable Wedges (TPAs, PLRs, seals, etc). Number each mated connector pair.
4. For multiple conductor (mat) type seals only, select 10 cavities at random among the sample set and record the connector and cavity numbers. Remove and re-insert the terminals in the selected cavities. The purpose of this step is to ensure the terminal does not damage the seal during service operations. (Not required if previously done on this sample set.)
5. Into the one open cavity in each connector pair, insert a tube of sufficient diameter and wall strength to ensure that there is not a possible leak path between the outer tube surface and the conductor seal. Be sure the tube is inserted far enough to engage the full sealing capability of the conductor seal. After completing Steps 6 and 7 below, connect the free end of the tube to a regulated pressure source. Alternative methods of adding a pressure/vacuum port are acceptable as long as the integrity of the part is not compromised.

6. Complete the Connector and/or Terminal Cycling procedure per section 5.1.7 if not already performed on the sample set
7. Verify conformance of each mated sample connector assembly to the Isolation Resistance test, Section 5.5.1.4. This establishes a reference for the concluding Isolation Resistance test.
8. Prepare enough salt water solution to completely submerse all samples to a depth of 30-40 cm below the surface. Use tap water and 15-16 grams of table salt per liter. 10 ml of liquid dish washing soap per liter of water may be added. Mix well before adding to test apparatus. It is recommended that an appropriate ultraviolet dye be added to assist in visual inspection for any ingress of solution into the test samples.
9. Bend all conductors in the same direction, 90° to the back of each sample connector half and secure them in this position, using actual conductor dress shields if available. This is to simulate dressing of the conductors as they exit the connector and is intended to stress the conductor seal(s) as in actual applications. If actual production dress shields are not available, simulate production application intent as closely as possible. Ensure that the tube is not kinked, squeezed shut or otherwise obstructed. The tube should be left out of the 90^0 bend if feasible. Seal all loose conductor ends to eliminate possible Leakage through the conductor strands.
10. Completely submerse all samples into a container of the Room Temperature salt water solution prepared in Step 8 above. Use care to avoid submersing any wire ends or the open end of the tube.
11. Slowly increase the air pressure of the regulated pressure source supplying the tube in each sample until the gage reads 48 KPa (7psig).
12. Observe samples for 15 seconds and verify that there are no air bubbles.
13. Switch the regulated source from pressure to vacuum and slowly apply 48 KPa (7psig) of vacuum to the samples for 15 seconds.
14. Remove the samples from the salt water solution, shake off excess fluid and then carefully dry all exterior surfaces of the sample.
15. Strip 10 mm of insulation from the conductor ends of each terminal in one connector half and perform the Isolation Resistance test of Section 5.5.1.
16. Disconnect each mated sample pair and perform the Visual Inspection test of Section 5.1.6. When disconnecting the samples, use care not to allow any residual solution to enter the interior of any connector half. Careful examination is required to detect any trace of fluid leakage that escaped detection by the Isolation Resistance test.
17. Re-connect each sample to its original mate and re-seal all conductor ends. Place the samples in a temperature chamber stabilized at the maximum ambient temperature for the Temperature Class selected from Figure 5.1.4 for the CUT. Heat Soak all samples for 70 hours.
18. After the heat Soak, remove the samples from the chamber and allow the samples to cool to Room Temperature, then repeat steps 9 - 15, except limit pressure in Step 11, and vacuum in Step 13, to 28 KPa (4 psig).
19. Verify conformance of all test samples to the Acceptance Criteria of Section 5.6.6.4.

20. SPECIAL TEST for connectors with multi-cavity (mat) type conductor seals. This test is not applicable to single cavity connector designs. This is an additional test and requires use of new samples. Its purpose is to check for seal distortion from extremes of conductor size that may produce a leak.
    a. Repeat Step 1, except prepare one male and one Female Terminal (smallest conductor size) for each connection pair to be tested.
    b. Repeat Step 1 except use the largest conductor size and insulation type for the terminals to be used in the intended application. Prepare only enough terminal samples to fully populate all connector pairs, less one cavity for each connector half and less the one cavity left open for the pressure/vacuum tube.
    c. Prepare a minimum of 10 connector pairs so that all but one randomly selected cavity in each connector half is populated with a terminal crimped to the largest conductor size, prepared in Step b above. Leave one cavity in each connector pair open for the pressure/vacuum tube, as directed in Step 1. Then fill the remaining cavity in each connector half with the appropriate terminal crimped to the smallest conductor size, prepared in Step a above. Unless the size of the connector makes it impossible, do not place the smallest conductor in a cavity adjacent to the pressure/vacuum tube. Number each connector pair.
    d. Repeat Steps 4 through 19 using the samples prepared in Step c above.

5.6.6.4 Acceptance Criteria

1. When samples are subjected to positive pressure, there must be no loss in the applied pressure and no bubbles visible exiting any test sample.
2. After samples are subjected to negative pressure (vacuum), all must meet the Acceptance Criteria of the Isolation Resistance test, Section 5.5.1.4.
3. At the conclusion of the test, all samples must meet the Acceptance Criteria of the Visual Inspection test, Section 5.1.8.4. When disconnecting the samples, use care not to allow any residual solution to enter the interior of any connector half. Careful examination is required to detect any trace of fluid Leakage that escaped detection by the Isolation Resistance test. There should be no trace of fluid ingress in the connector at the conclusion of this test.

5.7 Special Tests

5.7.1 Header Pin Retention

5.7.1.1 Purpose

The terminal push-out test is used to determine the retention of the Male Terminal in certain stitched or insert molded Header Connectors. It may also be used to test the attachment of male pins when staked or soldered directly to circuit boards. Proper pin retention assures that the terminal will not be displaced by forces associated with normal engagement and disengagement of the mating connector. These requirements apply to finished devices only and not to “in-process” products such as pin blocks or other sub-assemblies. The module and/or connector suppliers need to determine at what stage of the process these requirements will be tested and verified.

5.7.1.2 Equipment

- ⇨ Insertion/Extraction Force tester with peak reading feature
- ⇨ Appropriate fixtures to hold the connector
- ⇨ Collets, mandrels, or jaws to grip the terminal or pin in a longitudinal direction as needed

5.7.1.3 Procedure

NOTE: Samples are to be production intent. For designs where pins are closely spaced, pins or terminals may need to be selectively removed or cut to allow space for attachment of jaws, collets or mandrels. Pins may be shortened if necessary to allow for gripping and fixturing. All pin locations for a given design shall be tested and in no case less than 10 pins.

1. Moisture condition samples by exposing “dry as molded parts” to 95-98% Relative Humidity at 40ºC for 6 hours, then immediately complete the extraction test.
2. Measurements shall be taken in both directions if possible, i.e. force to push the pin longitudinally through the connector, and to pull it out as if removing a female plug from the header. Depending on individual design, “pushing” or “pulling” may be reversed in order to get the proper reading. It may also be appropriate to apply the loads from the back of the connector on certain designs. Pressure or tension must be applied parallel with the axis of the pin to achieve accurate results.
3. Secure the connector body to the appropriate fixture.
4. Using the force tester, apply a ramping pressure to the terminal pin. Note and record the force at which the pin begins to be displaced within the plastic housing or board attachment. Repeat for each pin location. Where resultant damage to the connector housing would affect readings on adjacent cavities, move to an undamaged pin or use a fresh connector.
5. Using fresh samples as needed, reverse force direction and repeat step 3.

5.7.1.4 Acceptance Criteria

The minimum force required to displace the pin longitudinally in either direction shall meet the values specified in table 5.7.1.

Terminal Family	Minimum Displacement Force
</=0.64	15N
>0.64<1.5	24N
1.5	50N
2.8	60N
>2,8	70N

Table 5.7.1: Minimum Header Pin Displacement Force

NOTE: Values for terminal sizes falling between the table values are calculated by interpolation.

5.7.2 Connector Mounting Feature Mechanical Strength

5.7.2.1 Purpose

This test is designed to test the mechanical strength of clip slots and other designed-in mounting features for electrical connectors. Such features must withstand mechanical stresses (pulling, pushing, etc.) expected in the vehicle including vehicle assembly, service and repair without functional damage to the housing.

5.7.2.2 Equipment

⇨ Force Tester

5.7.2.3 Procedure

1. Test a minimum of 20 connectors (five in each direction).
2. One non-mounting (mating) connector may be used to test all connectors.
3. Secure a virgin connector with the designed-in mounting feature to a bracket with a fixture simulating the coordinating mounting feature (see Figure 5.7.2.3-A). No additional reinforcement of the connector slot is permitted.
4. With the connector assembly attached to the bracket, apply a downward force with a probe (at a rate of 50 mm/min) to the non-mounted mating connector in direction F1 until breakage of the mounting feature or until the force specified in the Acceptance Criteria of section 5.7.2.4 is reached. The force shall be applied 5 mm from the rear and side of the connector to affect the greatest moment arm (see Figures 5.7.3.2-B, C & D).
5. Remove the connector from the fixture.
6. Repeat steps 2 – 5 with four additional connectors.
7. Repeat steps 2 – 6 in the other three directions (F2, F3, & F4 - 90 degrees apart, each perpendicular to the direction of mating of the mounting feature). The same samples may be used for testing various force directions if not damaged.

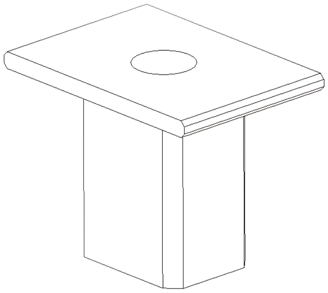


Figure 5.7.2.3-A: Mounting Fixture - Example

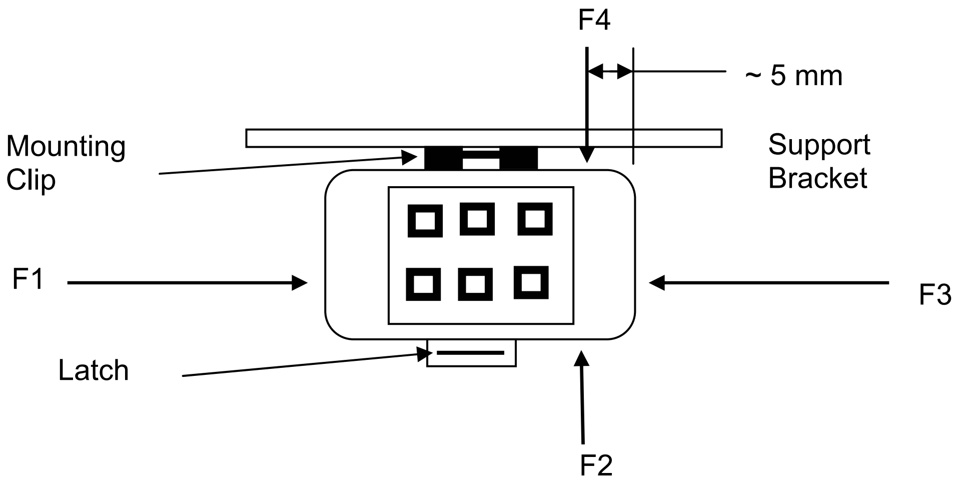


Figure 5.7.2.3-B: Test Set-up, End View

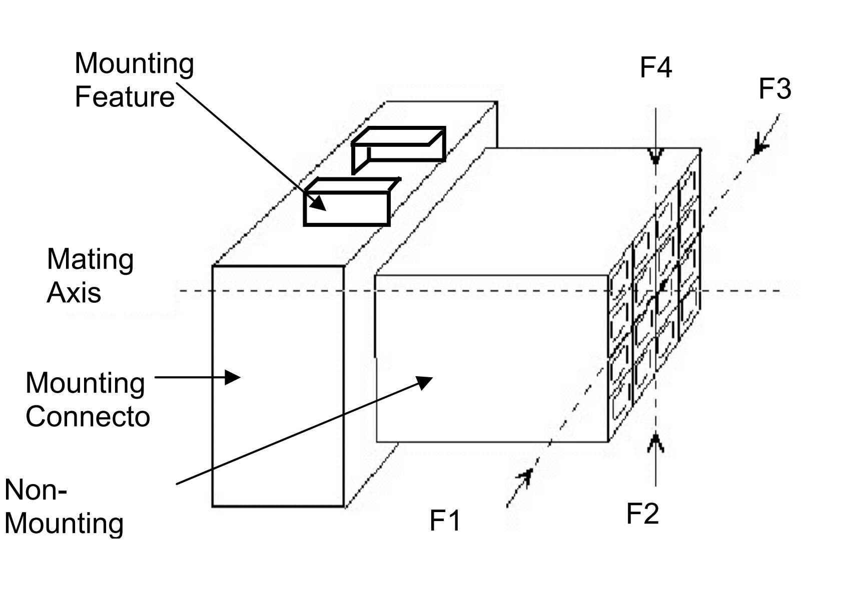


Figure 5.7.2.3-C (3d View)

NOTE: Arrows indicate direction of applied force, not location of probe.

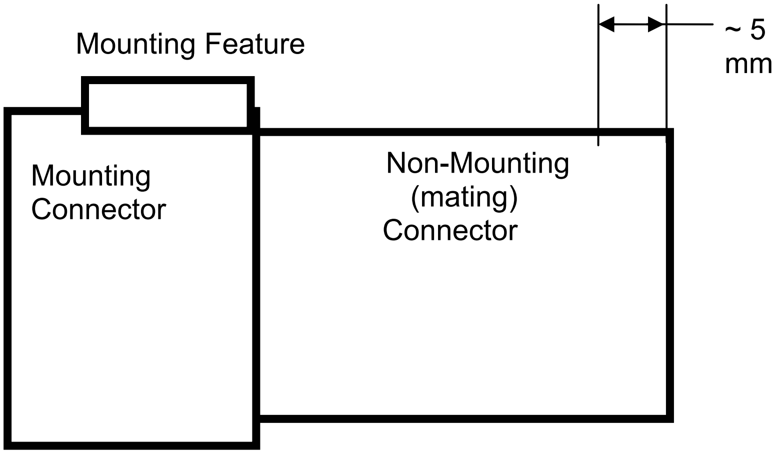


Figure 5.7.2.3-D (Side View)

5.7.2.4 Acceptance Criteria

The minimum force required to break the mounting feature shall be > 50 N.

5.7.3 Forced Fretting Test

5.7.3.1 Purpose

This test creates fretting in terminals systems by controlled micro-motion. This test can be used for comparing normal forces, coatings, lubricants, and other variables in the design of connection systems. Only one direction of motion (axial) is considered. Forced fretting is therefore considered a development test and not a requirement for validation. No field correlation is currently available.

5.7.3.2 Equipment

- ⇨ Cycling Fixture - Various forms of equipment are acceptable. Cycling equipment is usually custom built. One set-up is described in Figure 5.7.3.2
- ⇨ Dry Circuit Monitoring Equipment

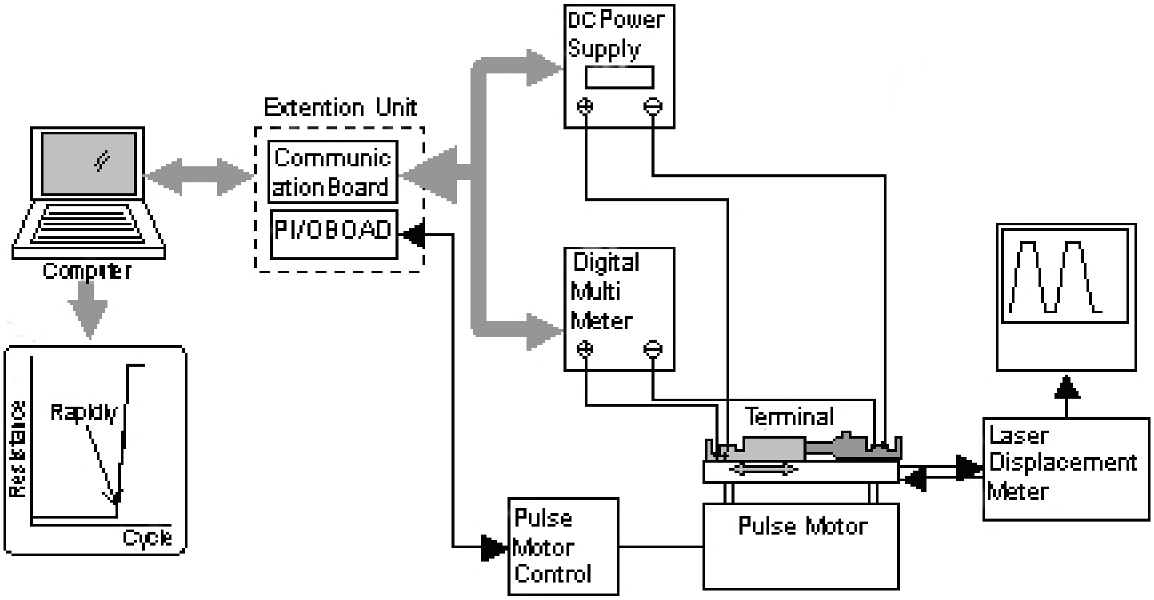


Figure 5.7.3.2: Forced Fretting Test Set-up (Example)

5.7.3.3 Procedure

1. At least 8 samples of male and Female Terminal should be tested. Set up the terminal holding device so that there is at least 1.0mm of over-travel from the end of the Male Terminal lead-in past the contact point of the Female Terminal. Terminals must be positioned so that testing begins at the nominal contact point of the interface.
2. Record initial Dry Circuit Resistance of each sample. Contact resistance data must be taken throughout the procedure.
3. Set the equipment to the following:
   Stroke – 50 µm
   Frequency – 1 Hz. Higher frequencies are permissible depending on equipment capability.
   Cycles – 100K or sufficient to reach a defined failure (total cycles depends on the system being evaluated)
   Alternative settings and equipment may be determined by the test requestor. Frequency and stroke can have major effects on the outcome of the test.
4. Turn on the equipment and complete the test cycle.
5. Plot the resistance vs. fretting cycles for each sample. (ref. figure 5.7.3.4)
6. Following the test cycle, measure the Dry Circuit resistance of each interface.
7. Visual examination of the interface may be requested. If so, photograph and document the wear characteristics of the interface including SEM analysis if applicable.

5.7.3.4 Acceptance Criteria

1. The test requestor may determine the Dry Circuit resistance Acceptance Criteria as well as any additional Acceptance Criteria such as visual examination of the interface.

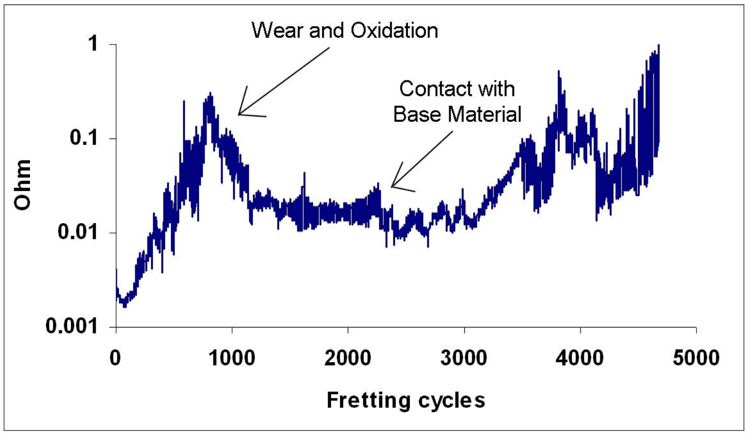


Figure 5.7.3.4: Example Forced Fretting Resistance Curve of a Tin Contact

5.8 Severe Duty Tests

The following test procedures are optional and are intended for use when, in the judgment of the Authorized Person, additional testing is needed to demonstrate acceptability of the connection system for severe duty applications. Because these situations are unique, the procedures may have to be modified according to data gathered from prototype vehicles or field experience. These procedures and acceptance criteria are not required for general validation, but rather are intended to lend consistency to the test procedures when such tests are deemed necessary.

Special design provisions will likely be needed for connectors required to pass these tests.

5.8.1 High Pressure Spray

5.8.1.1 Purpose

The purpose of this test is to determine the ability of sealed connection systems to withstand high pressure spray during use. Such conditions may be encountered where there is direct road splash or in cases where high-pressure washing may be expected. This test is optional at the discretion of the Authorized Person and may be specified in addition to the Water Submersion and Pressure/Vacuum Leak Tests (sections 5.6.5 and 5.6.6). Perform this test for sealed connectors only.

A vacuum of minimum 48 kPa (7psi) may be added to the high pressure spray to simulate rapid cooling of the interior of the connector due to the water spray. The level of vacuum may have to be adjusted depending on the application. Document any such adjustments or other test modifications in the test report.

This test and the associated equipment are intended to conform to ISO16750, with a 9K degree of protection.

5.8.1.2 Equipment

- ⇨ Fan jet nozzle
- ⇨ Device holder
- ⇨ Swiveling table

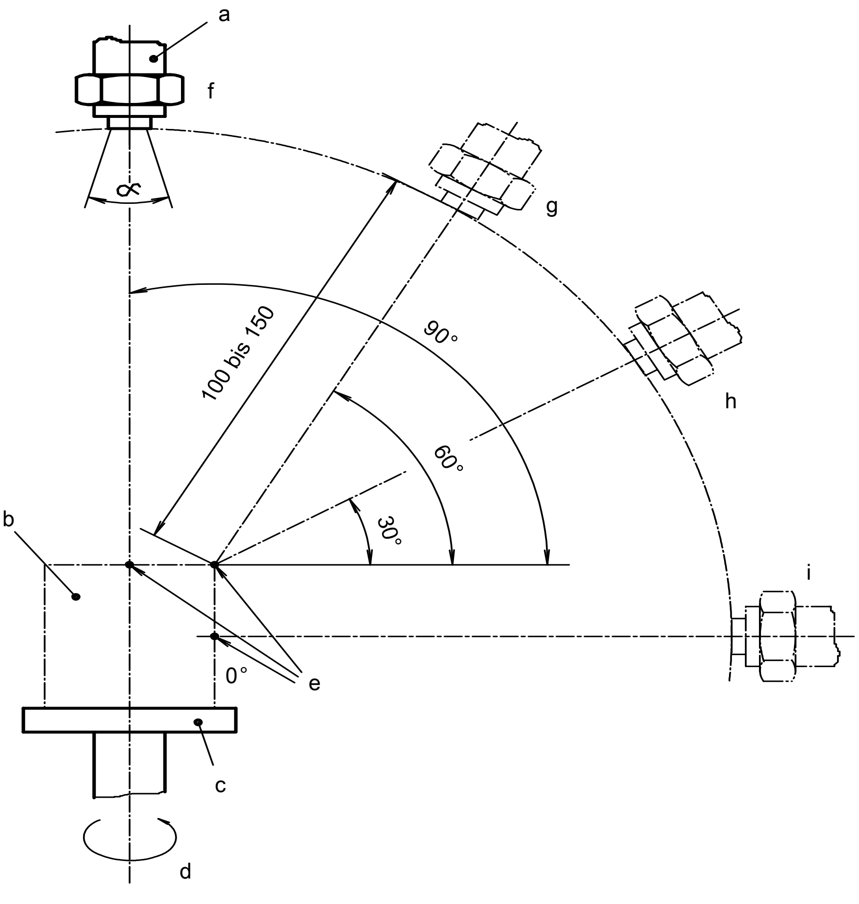


Figure 5.8.1.2: Spray Nozzle and Table Arrangement

Equipment	Spray Requirements	Water flow rate	Water Pressure	Water temperature	Exposure Time
Fan jet nozzle	Turntable Speed of (5±1) rpm Position Angle of (0°, 30°, 60°, 90°)±5° Distance of (100 to 150) mm	14 to 16 l/min	Approx. (8000 to 10000) kPa	(20±5) °C (Deviating temperatures may be agreed)	30s / position of spray angle

Table 5.8.1.3: Specification for High Pressure Spray Testing

5.8.1.3 Procedure

1. A minimum of 10 mated connector pairs are required for this test. Use the smallest gage wire and insulation appropriate to the application and prepare leads per section 5.1.6. Prepare complete connector samples fitted with all terminals, seals, TPA's and grommets or shields intended for the production application. For mat type cable seals, Select and mark 10 leads at random. Remove and reinsert the selected leads.
2. If specified, attach a vacuum port to the connector or connector mating device so that a vacuum can be pulled on the interior of the connection system. The vacuum port must be completely sealed and must not affect the normal sealing system of the connector. Vacuum tubes may also be inserted through the cable seals per section 5.6.6.3, step 5.
3. Complete the Visual Examination per section 5.1.6.
4. Complete the Isolation Resistance test per section 5.5.1
5. Mount the connector under test onto the device holder such that the connector lays flush against the turntable.
6. If specified in the test request, expose the connection system to a 48 kPa (7 psig) vacuum, Position the sprayer at a 0° and initiate spray and turntable rotation.
7. With the table rotating, spray the connector under test for 30s. Repeat at each of the spray angles specified in table 5.8.1.3.
8. Complete the Isolation Resistance per section 5.5.1.
9. Condition samples at ambient conditions for 168 hours.
10. Complete the Visual Examination of section 5.1.8. Dis-assemble each connector pair and examine for any water intrusion or corrosion.

5.8.1.4 Acceptance Criteria

1. All parts shall meet the isolation resistance acceptance criteria specified in section 5.5.1.4.
2. Upon examination of the interior of the connection system, no water or corrosion products shall be visible inside the connector.
3. All parts shall meet the visual examination acceptance criteria specified in section 5.1.8.4.

5.8.2 Severe Vibration

5.8.2.1 Purpose

The vibration test method specified is applicable to in-line and Header Connectors. It considers extreme vibration levels applicable to connector systems that are mounted directly to the drive train. Severe vibration testing should be considered for sealed connection systems only. This test is optional at the discretion of the Authorized Person.

This test has two components: Sinusoidal vibration which results from the unbalanced mass of rotating parts and random vibration due to various engine mechanics like closing of valves. The sine component of the schedule is intended to duplicate vibration profiles of both <5 cylinder and ≥5 cylinder engines.

The vibration profiles contained in this procedure are very severe and are not representative of all situations. Actual measurement may need to be taken to determine a vibration and temperature profile for each application. In any case, vibration profiles used for validation of connection systems must never be accelerated. This results in non-representative failure modes such as severe terminal wear and cable failure.

5.8.2.2 Equipment

- ⇨ Vibration Table with temperature control capability (-40^{o}C to Class Ambient)
- ⇨ Vibration Controller
- ⇨ Temperature Control Unit
- ⇨ Accelerometers

5.8.2.3 Procedure

The sine and random components of this test may be run concurrently or separately. A temperature cycling component (Figure 5.8.2.3-A, Table 5.8.2.3-A) is also included and is to be run simultaneously with all vibration schedules.

1. Prepare samples and monitoring set-up per section 5.4.6.3.
2. Construct a suitable mounting apparatus using the following design criteria:
   a. The mounting apparatus must be constructed to minimize added effects (harmonics, dampening, resonance, etc.).
   b. For In-Line Connectors, mount the mated connector pair directly to the Mounting Bracket with a metallic clamp such that the connector lays flush against the cube or vibration table.
   c. For Device Connectors, mount the device directly to the Mounting Bracket. Refer to Figure 5.4.6.3-B. Use the normal device mounting feature(s) used to secure the device in its intended vehicle location. The mounting method(s) used shall be noted in the test report.

   d. The conductor attachment points must be 100mm +/-10mm from the rear of the connector body.
   e. When only one conductor attachment point is specified, as when testing the connection to a device, the distance between the vertical centerline of the electrical receptacle portion of the device and the attachment point is 100 mm.
3. Set up the samples to monitor continuity per section 5.1.9.
4. Complete the sine (Table 5.8.2.3-B) and random (Table 5.8.2.3-C) or combined sine and random profiles concurrently with temperature cycling (Figure 5.8.2.3-A). Carry out the frequency variation by logarithmic sweeping of 1 octave/min for sinusoidal tests.
5. Unless otherwise specified in the test request/order all CUTs mounted directly to the engine or transmission shall be vibrated for 22 hours in each of the three mutually perpendicular axes (X,Y,Z) for each vibration profile (sine and random) or 22 hours for the combined sine and random.
6. Without un-mating the connectors, condition samples for 48 hours @ ambient conditions.
7. Verify conformance of each sample to the Acceptance Criteria of Section 5.8.2.4.

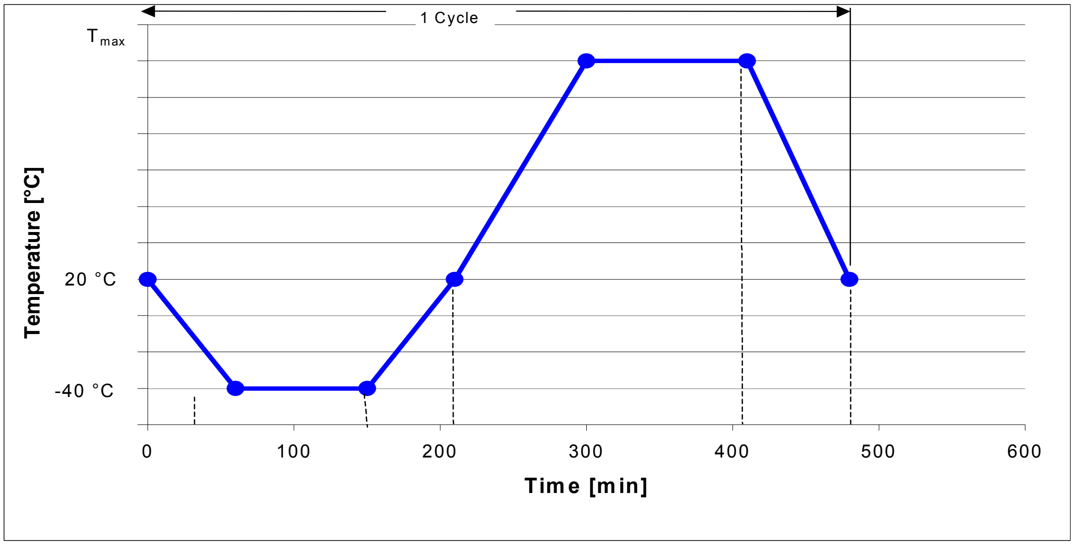


Figure 5.8.2.3-A: Temperature profile

Duration Min	Temperature °C
0	20
60	-40
150	-40
210	20
300	T_{max} *
410	T_{max} *
480	20

Table 5.8.2.3-A: Temperature vs. time

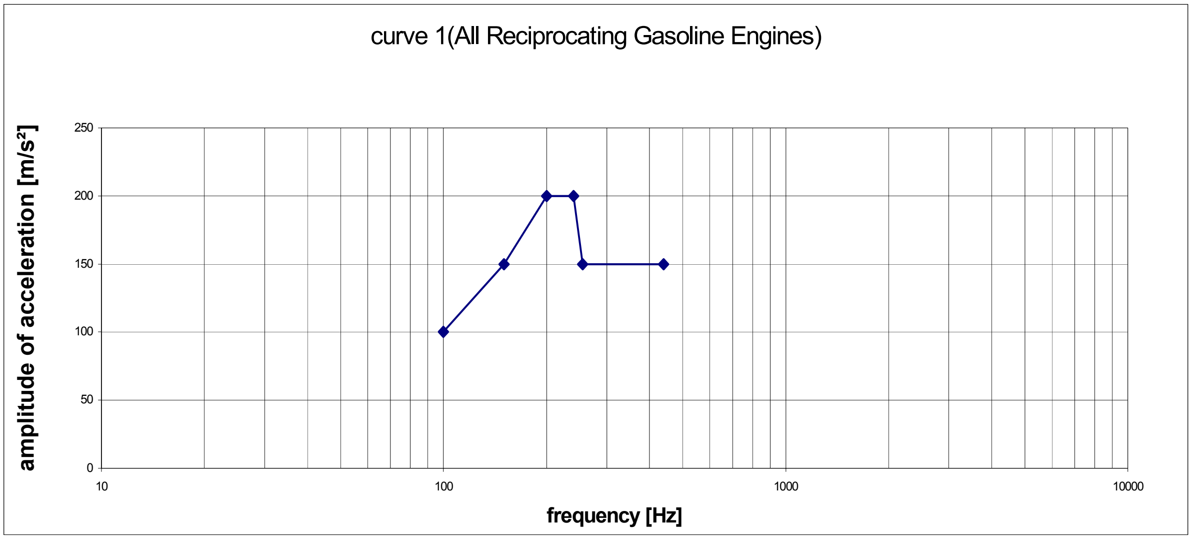


Figure 5.8.2.3-B: Sine Vibration Schedule

Frequency Hz	Amplitude of acceleration m/s²
100	100
150	150
200	200
240	200
255	150
440	150

Table 5.8.2.3-B: Sine Vibration Schedule

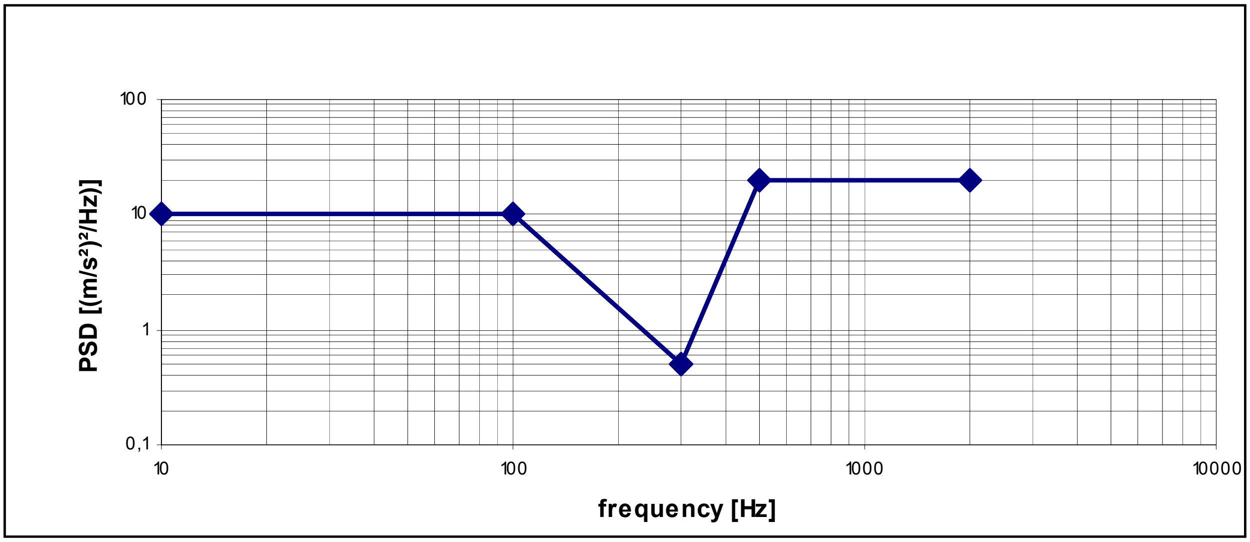


Figure 5.8.2.3-C: Random Vibration - Power density of acceleration vs. frequency

NOTE: The PSD-values (random vibration) are reduced in the frequency range of the sinusoidal vibration test.

Frequency Hz	Power spectral density (m/s²)²/Hz
10	10
100	10
300	0.51
500	20
2000	20

Table 5.8.2.3-C: Random Vibration – Values for Frequency and Power Spectral Density

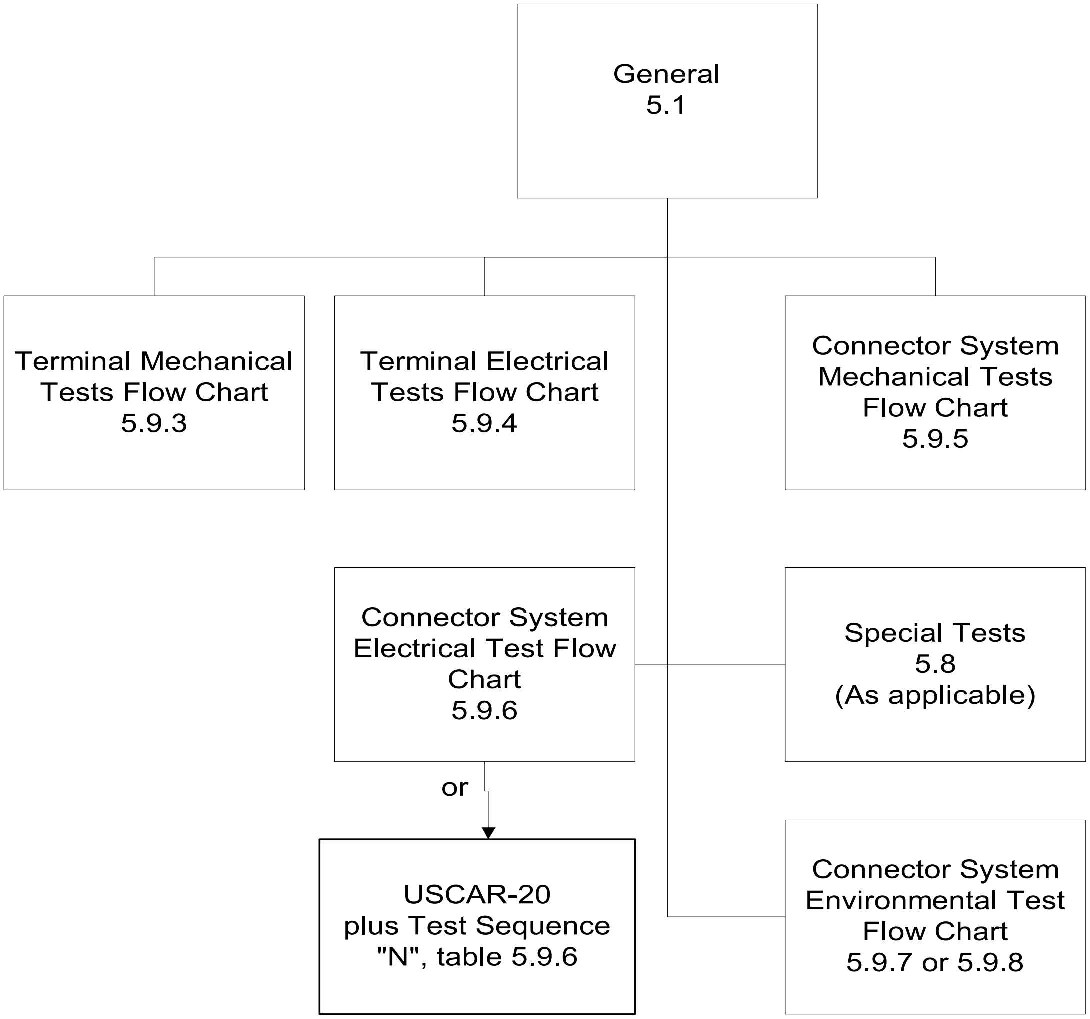
5.8.2.4 Acceptance Criteria

Refer to section 5.4.6.4 for Acceptance Criteria.

5.9 Test Sequence

5.9.1 General Notes

1. Test sequence is the order in which tests are performed. The sequence should be logical and interrelated in order to accurately establish the performance characteristics of the component or assembly.
2. Numbers in the body of charts 5.9.3-5.9.8 indicate the order in which the tests or conditioning procedures are performed. Where there are duplicate numbers in the same column, the procedures are performed concurrently.
3. Destructive tests should be performed only on samples that are not intended for use in further test sequences.
4. The Dry Circuit Resistance test (Section 5.3.1) should always be performed before any other electrical test and prior to sample movement.
5. Fixtures and test set-ups should be reviewed by the Authorized Person prior to the start of testing.
6. The sequential test tables in section 5.9 are base sequences and may be altered according to the Authorized Person's request.
7. The total number of test samples needed for sequential tests is shown at the top of each column. It is important to note that, where parallel test paths are shown, a separate set of samples is required for each path. The same set of samples is never run through one path and then used again for a parallel test path unless specifically required in the test request/order. Exceptions are noted in each flow chart.



Section 5.9.2: General Test Flow Chart

	Flow Chart	5.9.3		5.9.4	5.9.5								
	Test	Term. - Term. Engage/Disengage Force	Terminal Bend Resistance	Maximum Current/Current Cycling	Term.-Conn. Insertion/Extraction	Misc. Component Engage/Disengage	Audible Click	Conn. Conn Mating/Un-mating	Polarization Effectiveness	Drop	Cavity Damage	Header Pin Retention	Mounting Feature Mech Strength
	Sequence ID	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**
	Sample Size (Refer to individual procedures)	10	15/30	10/30	10	10(1)	8	15	(2)	3	5	20	20
5.1	General	1	1	1	1	1	1	1	1	1	1	1	1
5.1.8	Visual Inspection	2, 4	2, 4	2, 5	2, 4	2, 4	2, 4	2, 4	2, 4	2, 4	2, 4	2, 4	2, 4
5.2.1	Terminal to Terminal Engage/Disengage Force	3											
5.2.2	Terminal Bend Resistance		3										
5.3.3	Maximum Test Current Capability			3									
5.3.4	1008 Hour Current Cycling			4									
5.4.1	Terminal - Connector Insertion/Extraction Force				3								
5.4.2	Connector-Connector Mating/Unmating Force (Non-mechanical Assist Connectors)							3					
5.4.3	Connector to Connector Mating and Unmating forces (Connectors with Mechanical Assist							3					
5.4.4	Polarization Feature Effectiveness								3				
5.4.5	Miscellaneous Component Engage/Disengage Force					3							
5.4.7	Connector-to-Connector Audible Click						3						
5.4.8	Connector Drop Test									3			
5.4.9	Cavity Damage										3		
5.7.1	Header Pin Retention											3	
5.7.2	Connector Mounting Feature Mechanical Strength												3

Notes:

(1) 10 samples for each applicable Misc. Component Engage/Disengage Force test.

(2) Sample size for Polarization Effectiveness is determined by the procedure.

**Tables 5.9.3: Terminal Mechanical 5.9.4 Terminal Electrical,
and 5.9.5 Connector System Mechanical Test Sequences**

	Flow Chart	5.9.6$^{(2)}$				5.9.7$^{(4)}$					5.9.8	
	Test	Vibration	Thermal Shock	Temp./Humidity	High Temp Exposure	Fluid Resistance	Temp/Humidity-Submersion	Temp/Humidity-PV Leak	High Temp Exposure-Submersion	High Temp Exposure-PV Leak	Temp/Humidity$^{(10)}$	Pressure/Vacuum Stand Alone
	Sequence ID	**M**	**N**	**O**	**P**	**Q**	**R**	**S**	**T**	**U**	**V**	**W**
	Sample Size (Refer to individual procedures)	10	10	10	10	8	10	10	10	10	10	10
5.1	General	1	1	1	1	1	1	1	1	1	1	1
5.1.8	Visual Inspection	2, 8$^{(1)}$	2, 8$^{(1)}$	2, 10$^{(1)}$	2, 8$^{(1)}$	2, 6	2,10	2,10	2, 9	2, 9	2, 7	2,5
5.1.7	Connector Cycling	3$^{(1)}$	3$^{(1)}$	3$^{(1)}$	3$^{(1)}$		3	3	3	3		3
5.1.9	Circuit Continuity Monitoring	5	5									
5.3.1	Dry Circuit Resistance	4, 6	4, 6	4, 6	4, 6							
5.3.2	Voltage Drop	7	7	7	7							
5.4.1	Terminal-Connector Extraction Force			9			9	9			6	
5.4.6	Vibration/Mechanical Shock	5										
5.5.1	Isolation Resistance			8$^{(3, 11)}$		3, 5	4, 6, 8	4, 6, 8	4, 6, 8	4, 6, 8	3, 5$^{(3)}$	
5.6.1	Thermal Shock		5									
5.6.2	Temperature/Humidity Cycling			5			5$^{(8,7)}$	5$^{(8,7)}$			4	
5.6.3	High Temperature Exposure				5				5$^{(8,7)}$	5$^{(8,7)}$		
5.6.4	Fluid Resistance					4						
5.6.5	Submersion						7$^{(6,8,9)}$		7$^{(6,8,9)}$			
5.6.6	Pressure/Vacuum Leak							7$^{(5,8,9)}$		7$^{(5,8,9)}$		4

Notes:

(1) For connectors with Shorting bars, complete Dry Circuit Test on shorted contacts prior to connector mating and after final connector un-mating.

(2) Optionally, Section 5.9.6 Connector Sys. Electrical Table may be omitted when performing SAE/USCAR-20 Field Correlated Life Test and the Thermal Shock sequence (5.6.1 – sequence N of Table 5.9.6) of USCAR-2). (See USCAR-20)

(3) Isolation Resistance (5.5.1) required only if 5.9.7 is not performed (un-sealed connectors)

(4) This test sequence is for sealed systems only.

(5) Use reduced pressure/vacuum of 28 kPa (4 psig) following High Temp. Exposure test (5.6.3) and Temperature/Humidity Cycling test (5.6.2).

(6) Submersion test 5.6.5 reduced to one (1) cycle following High Temperature Exposure Test 5.6.3, and Temperature/ Humidity Cycling Test (5.6.2).

(7) When Temperature/Humidity cycling or High Temperature Exposure are done as part of this table, complete the conditioning procedure only. Dry Circuit/voltage drop readings and monitoring are not required.

(8) In order to reduce sample size, the Pressure/Vacuum Leak (5.6.6) and Submersion (5.6.5) may be run in series. This allows Sequences R and S to be combined and T and U to be combined. When tests are done in series, do not open the connectors as directed in section 5.6.5.4 and 5.6.6.4. Isolation resistance must be run between the PV Leak and Submersion tests.

(9) Mat seal terminal insertion per section 5.6.5.3-2, 5.6.6.3-4 may be done prior to beginning the table sequence, or may be done prior to Submersion or P/V Leak.

(10) Must be performed for sealed and un-sealed systems if section 5.9.6 is omitted for USCAR-20. (also see note 2)

(11) It is permissible to use separate sample sets for Dry Circuit/Voltage Drop and Isolation Resistance due to differences in sample preparation methods.

Section 5.9.6 Connector System Electrical, 5.9.7 Sealed Connector System Environmental, and 5.9.8 Un-sealed Connector System Environmental Test Sequences

APPENDIX A: DEFINITIONS

Acceptance Criteria:

Generally the final section in each test description. It specifies the requirements that all test samples must meet during or at the conclusion of that test.

Authorized Person:

One person will be responsible as the final authority for releasing a given part for production and/or for testing that part. Such person may delegate authority for testing that part, or may retain the authority. The Authorized Person, as used in the Specification, is the person with authority for making the final decision as to any question arising during testing to this Specification or for any deviations from any requirement of this Specification. Such Authorized Person is responsible for documenting any deviation he/she authorizes from this Specification. This documentation must be included in the final test report.

Benchmark:

Performance measurements of a specific design which serve as a standard by which the performance of other connector systems and terminals can be compared.

Bulk Resistance:

That part of total connection resistance attributed to the terminal body. Bulk resistance does not include crimp resistance or interface resistance.

Critical Dimension:

Any dimension noted on the part drawing or otherwise specified that can adversely affect the performance or function of the part or assembly if it exceeds the applicable tolerance.

Device Connector:

An electrical connector that mates with the electrical interface of a device (e.g. headlamp, switch, horn, etc.).

Due Care:

The proper use of sound engineering judgment to assure a part is fit for its intended use and meets all applicable FMVSS requirements. The assurance that design specifications and test plans satisfy all applicable FMVSS requirements. Use of sound, accepted engineering and laboratory practice to safeguard the integrity of all data and to ensure that no degradation of any sample occurs in any fashion except as specified in actual testing.

Dry Circuit:

Circuit that operates continuously below a level of 20mV open circuit voltage and 100 mA current limit.

Edgeboard Connector:
A connector system that utilizes the edge of a printed circuit board for an electrical interface.

Engaging Force:
The force required to mate a separate pair of contacts (terminals) or a contact and mating test gage.

Extraction Force:
The force required to completely remove an individual contact (terminal) from its cavity in a connector.

Female Connector:
The connector that houses the Female Terminal(s).

Female Terminal:
The electrical receptacle that receives the male blade or pin.

Header Connector:
A connector system that utilizes one or more fixed Male Terminals inserted into a housing. The non-mating ends of the terminals are usually soldered to a printed circuit board or connect internally to the device.

In-Line Connector:
A system using male and Female Terminals, each contained in an appropriate housing, to electrically connect two or more conductors.

Insertion Force:
The force required to insert an individual contact (terminal) into its cavity in a connector.

Leakage:
Refers to current passage between two or more conductors separated by a normally non-conductive medium when sufficient voltage potential exists between the conductors. By increasing the potential to 500 volts DC or more, the current flow, or Leakage, becomes measurable even though at a micro or nanoampere scale. Leakage measured at a known voltage is useful in estimating contact air gap and detecting contaminants without specimen disassembly.

Male Connector:
The connector that houses the Male Terminal(s).

Male Terminal:
The metal blade or pin that inserts into the Female Terminal.

Mating Force:
The force required to mate male and Female Connector halves or to completely seat a connector in a device Header or receptacle.

Maximum Current Capability:

The maximum current carrying capability at Room Temperature of the specific combination of terminal size, conductor gage, insulation type, etc. as determined in Section 5.3.3. This value must be derated for actual conditions in the expected application.

Mechanical Assist:

A means of minimizing the operator effort required to mate two connector halves or a connector to a header. Typical means are a bolt, cam, or lever.

Power Circuit:

Any electrical circuit expected to carry in excess of 5A continuously for more than one minute.

Retention Force:

The maximum force that can be exerted on an individual contact (terminal) without dislodging it from its proper position in its connector cavity. This force may have two different values; one with the associated Wedge (TPA, PLK, etc.) installed and a second value without such assistance.

Room Temperature:

23°C ± 5°C.

Separating Force:

The force required to disengage a mated pair of contacts (terminals) or a contact and a mating test gage.

Signal Circuit:

Any electrical circuit expected to carry 5A or less at all times.

Soak:

Refers to a time period during which the device under test is exposed to stated environmental conditions, such as temperature, humidity, current flow, etc. This exposure may be for the purpose of conditioning the sample prior to another test, or may itself form part of a given test.

Special Tool:

A tool specifically designed to mate and/or unmate a connector, or to insert and/or remove a connector terminal or other component.

Sprung :

(Adj.) Describes any portion or component of a motor vehicle that is supported by the suspension system. Sprung components do not include tires, wheels, hubs, or outboard disc. or drum brake assemblies.

Shorting Bar:

A mechanical device within a connector designed to electrically short two or more circuits together when the connectors are not mated. Shorting Bars may act to overcome the effects of static electricity or to act as a means of detecting when connectors are disconnected.

Steady State:

A condition of environment or current flow that remains stable for 1 minute or more.

Total Connection Resistance:

Electrical resistance of one terminal to terminal interface plus the resistance of the conductor to terminal grip for each terminal. For Header type connections, only the resistance of the one conductor to terminal grip is included. Included is the "bulk resistance" of the terminal material itself.

Unmating Force:

The force required to unmate male and Female Connector halves or a connector from a device Header or receptacle.

Un-sprung:

(Adj) Describes any component of a motor vehicle that is not supported by the suspension system. (see Sprung)

APPENDIX B: GLOSSARY OF TERMS

AIAG	Automotive Industry Action Group. Contact at AIAG, Box 77000, Detroit, Michigan 48277-0839. Phone (248) 358-3570. website www.aiag.org
CPA	Connector Position Assurance. Essentially a lock on the lock that holds the two halves of a connector together or holds a connector to an electrical device. Usually an optional device. It prevents accidental release of the connector lock and serves as an indicator of full connector mating.
CT	Continuity Tester. A made-up test device composed of a data analyzer and a continuity monitor.
CUT	Component Under Test
DMM	Digital Multimeter
DVP&R	Design Verification Plan and Report
EWCAP	Electrical Wiring Component Applications Partnership. One of several sub-groups of USCAR. Has the task of commonizing electrical components and interfaces.
FMEA	Failure Mode and Effects Analysis
FMVSS	Federal Motor Vehicle Safety Standard
FS	Full Scale
GD&T	Geometric Dimensioning and Tolerancing. A method required by the USCAR Companies for representing dimensions and their tolerances on all part drawings.
IACS	International Annealed Copper Standard
IDC	Insulation Displacement Connection. A means of attaching a terminal to a conductor where projections on the terminal pierce the conductor insulation to make electrical contact, rather than requiring the insulation to be removed.
MVD	Millivolt Drop.
MVSS	Motor Vehicle Safety Standard.

PLR	Positive Latch Reinforcement. Also known as a Wedge, Spacer or Terminal Position Assurance (TPA) feature. It is installed or seated after the terminals are inserted into their housing to assure that the terminals are properly positioned. It either reinforces the primary terminal locking mechanism or provides a separate redundant terminal lock.
PPAP	Production Part Approval Process.
RH	Relative Humidity.
TPA	Terminal Position Assurance. See PLR.
TUT	Terminal Under Test.
USCAR	United States Council for Automotive Research. A consortium of representatives from Ford, General Motors and DaimlerChrysler to promote joint research in non-competitive areas that can strengthen the US automotive industry.

APPENDIX C: TESTS RECOMMENDED FOR NEW TOOLING, TOOL TRANSFER, OR MATERIAL CHANGE

Ford, GM and DaimlerChrysler have jointly published a booklet entitled Production Part Approval Process (PPAP), which is available through the AIAG whose address can be found in Appendix B of this Specification. Section II of the PPAP booklet, "When Submission Is Required", outlines the agreed upon conditions necessitating initial or resubmission of production parts for engineering approval. Among the "Requirements For Part Approval", given in Section III of the booklet, is listed "Material, performance and durability test results as specified on the design record."

This table shows the recommended performance and durability tests for several of the Section II situations.

The Authorized Person is the final authority as to which, if any, tests are required in any given situation.

Requirements are generally listed in a "Control Plan" or similar document. Recommendations in this table are intended only as suggestions based on the past experiences of the USCAR/EWCAP team.

Test Seq.	USCAR/EWCAP SAE/USCAR-2 Test Name	Tool Transfer			New/Capacity Tooling			Material Change (1)			
									Connector		
		Terminal	Connector	Seal	Terminal	Connector	Seal	Terminal(2)	Sealed	Un-sealed	Seal(3)(4)
A	Terminal to Terminal Engage/Disengage Force	X			X			X			
B	Terminal Bend Resistance				X			X			
C	Maximum/Current Cycling							X			
D	Terminal-Connector Insertion/Extraction		X		X	X			X	X	X(5)
E	Miscellaneous Component Engage/ Disengage Force		X			X			X	X	
F	Audible Click								X	X	
G	Connector- Connector Mating/Unmating		X			X			X	X	X
H	Polarization Effectiveness								X	X	
I	Drop								X	X	
J	Cavity Damage								X	X	
K	Header Pin Retention								X	X	
L	Mounting Feature Mech. Strength								X	X	
M	Vibration/ Mechanical Shock							(2)	X	X	
N	Thermal Shock							(2)	X	X	
O	Temperature / Humidity Cycling							(2)	X	X	
P	High Temperature Exposure							(2)	X	X	
Q	Fluid Resistance								X		
R	Temp./Humidity - Submersion								X		X
S	Temp./Humidity – PV Leak								X		X
T	High Temp Exposure - Submersion								X		X
U	High Temp. Exposure – P/V Leak								X		X
V	Temp./Humidity								X	X	
W	P/V Leak (Stand-alone)		X	X		X	X				X(4)

"X" indicates recommended tests to be performed on at least the minimum sample size of production parts for each test from the affected tooling.

(1) “Material Change” includes the following:
Terminal: Base material, hardness, plating, process and/or electrical lubricant.
Connector: Base material/composition
Seal: Base material, properties or process
(2) All terminal material changes: perform 5.8.6 or USCAR-20
(3) Seal durometer change: perform 5.4.1-A (Terminal-Connector Insertion) and Test Sequence W (Pressure Vacuum Leak) only
(4) Seal color change: perform Test Sequence W, Pressure/Vacuum Leak only.
(5) Insertion only

Table 8: Recommended Performance and Durablilty Tests

APPENDIX D: TESTS FOR NEW/EXISTING TERMINAL OR CONNECTOR DESIGNS

Test seq	SAE/USCAR-2 Test Name	New Design			Existing Connector with more or less cavities		Existing Connector , New Polarization	New Cable Seal/Application
		Terminal	Sealed Connector	Unsealed Connector	Sealed	Unsealed		
A	Term. - Term. Engage/Disengage Force	X						
B	Terminal Bend Resistance	X						
C	Maximum Current/Current Cycling	X						
D	Term.-Conn. Insertion/Extraction		X	X				
E	Misc. Component Engage/Disengage		X	X				
F	Audible Click		X	X	X	X		
G	Conn. Conn Mating/Un-mating		X	X	X	X		
H	Polarization Effectiveness		X	X	X	X	X	
I	Drop		X	X				
J	Cavity Damage		X	X				
K	Header Pin Retention		X	X				
L	Mounting Feature Mech Strength		X	X				
M	Vibration	X	X	X				
N	Thermal Shock	X	X	X				
O	Temp./Humidity	X	X	X				
P	High Temp Exposure	X	X	X				
Q	Fluid Resistance		X					
R	Temp/Humidity-Submersion		X					
S	Temp/Humidity-PV Leak		X					
T	High Temp Exposure-Submersion		X					
U	High Temp Exposure- PV Leak		X		X			
V	Temp/Humidity(2)		X	X				
W	Pressure/Vacuum Stand Alone	X (1)						X

(1) For terminals intended for sealed applications only

(2) Must be performed for sealed and un-sealed systems if section 5.9.6 is omitted.

APPENDIX E: SOURCE LIST

Reference material	Supplier
Engine Oil ASTM D471, IRM 902 Oil ISO 1817, Oil No. 2 & Power Steering ASTM D471, IRM 903 Oil ISO 1817, Oil No. 3	R. E. Carroll, Inc. P. O. Box 5806 Trenton, NJ 08638-0806 Phone: +1 800-257-9365 Fax: +1 609-695-0102 URL: http://www.recarroll.com
	Penreco 4426 East Washington Blvd. Los Angeles, CA 90023 Phone: +1 888-227-5448 Fax: +1 323-268-7972 URL: http://www.penreco.com
	Swedish National Testing and Research Institute Box 857 SE-501 15 Borås Sweden Phone: +46 33 16 50 00 Fax: +46 33 10 33 88 http://www.sp.se/eng/default.htm
Automatic Trans Fluid SAE J311, Dexron III Citgo Part No. 33123	Citgo Petroleum 699 Heights Rd. Lake Orion, MI 48362 Phone: +1 800-331-4068 URL: http://www.citgo.com
Brake Fluid SAERM-66XX	SAE Automotive Headquarters 400 Commonwealth Dr. Warrendale, PA. 15096-0001 www.sae.org or www.sae.org/servlets/otherProduct?Prod_CD=RM-6605&PROD_TYP=RM

Table 10: Materials and Sources

APPENDIX F: DESIGN NOTES

Regarding maximum current rating:

NOTE: The “Maximum Test Current Capability” (ref. section 5.3.3) test detailed in this document is only conducted to establish test parameters. The value obtained in this procedure is used to limit the current in the “1008 hr. current cycling test”. Data collected during this test can also be used to compare various terminals tested to the same specification. This test cannot establish the Maximum Current Capability of a specific terminal application. For specific applications, several factors other than current load must be considered. All of the following have an effect on the maximum current load that can be passed through a terminal grip and interface over the life of the vehicle.

- Wire size: Larger wire sizes can sink heat away from a terminal, into the harness and reduce the terminal operating temperature. The opposite is true for smaller wire sizes.
- Devices: Some devices can create heat while some can sink heat away from an interface. This can have a dramatic effect on the maximum current capability of a terminal system.
- Terminal location within a connector: Terminals carrying current loads located next to other terminals carrying current loads can cause hot spots or heat build up in a localized area within a connector and lead to terminal failure. At a given current load, terminals located in the corner connector cavities will run cooler than terminals in the center of the field.
- Sealed connectors: Sealed connectors can trap heat and cause terminals to run hotter than the same terminal at the same load in an unsealed connector.
- Ambient temperature: Terminals running in elevated temperature environments, such as engine compartments will have lower Maximum Current Capability than the same terminal/wire combination running in lower temperature locations.

Terminals operating at cooler temperatures tend to exhibit less stress relaxation in the contact beams and less degradation to the coating and plating on their contact surfaces when compared to the same terminals operating at elevated temperatures. These factors have an effect on the maximum current load over the usable life span of a terminal system.

APPENDIX G: REVISIONS

This specification was approved by USCAR/EWCAP in December 1999.

Any revisions since that date have been incorporated into the specification. Revisions that altered the content of the specification are recorded below:

DATE	SECTION	SUMMARY OF CHANGES MADE *	NOTES
12/6/99	all	Signed off by EWCAP team	"Draft" removed
12/14/00	all	Changes made and signed off by EWCAP team	
1-10-01	p.2-21	Some figure references were corrected, but no technical content was affected.	Current draft will now differ from SAE published draft 3 but NOT in technical content.
1/14/04	5.1.6	Added terminal crimp preparation section	
	5.3.1, 5.1.7, 5.5.1, 5.9.6	Added requirements for Shorting Bars	
	3.2	Deleted drawing legal notice	
	5.1.7	Created separate procedure for 10 mate-un-mate conditioning	
	5.4.7	Added Audible Click Requirement	
	5.4.8	Drop Test added	
	5.6.2	Revised Temp./Humidity profile to conform with ISO cable proposal	
	5.4.9	Added Cavity Damage Susceptibility	
	All	Changed "Standard" to "specification"	
	5.7.1	Added requirement for header pin retention	
	5.4.3	Added connector Mechanical Assist requirements	
	5.6.4 & Appendix E	Revised fluids list and added source reference	
	5.8.1	High Pressure Spray added	
	5.8.2	Severe Vibration added	
	5.7.3	Optional Forced Fretting Section added	
	5.2.2.	Bend test procedure revised	
	5.4.1	Separate section added for mat seals for clarification. No change to procedure	
	5.1.9	Consolidated Continuity Monitoring for all conditioning procedures into one section	
	5.4.2	Added graph. Added deflection requirement for connectors with protective ribs.	
	5.7.2	Added Connector Mounting Feature, Mechanical Strength Test,	
	11	Appendix F added "Design Notes"	
	5.6.5.3, 5.6.6.3	Revised procedure for testing mat seals	
	5.1.7	Created separate procedure Connector/Terminal Cycling Section	
	Appendix C & D	Revised test requirements	
	5.4.1.4	Revised terminal pull-out requirements	
	5.4.6.3-1	Conductor size was "Any"	
	5.6.4.1	Surrogate data allowed	
	5.6.5.3	Revised Insertion/Removal for MAT seals	
	5.9	Revised	