TOFp Technical Description

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1 Introduction

The present document describes technical aspects of the "Time-Of-Flight Patch" (TOFp). The detector itself is a single welded Aluminum "tray," filled with plastic scintillators, mesh dynode PMTs, Cockroft-Walton PMT bases, Front End Electronics (FEE), thermocouples, water tubing, and other mechanical and optical pieces. The tray is connected to the STAR platforms via coaxial cables for signals, low voltage cables for the FEE power, thermocouple cables, and two 10bit digital buses for the FEE threshold control/feedback and the PMT base control/feedback. The components on the platform include a CAMAC crate, a NIM bin, commercial electronics (ADCs, TDCs, and logic), and a PC. The technical aspects of each of these components were defined based on four general criteria. The system overall must be safe. The system overall must meet the physics requirements. The detector must impose the minimum possible thickness in terms of interaction and radiation lengths. The detector should not raise the local temperature near its position in STAR by more than a few degrees. In the following, we provide the technical details on each component of the TOFp detector, each of which chosen so as to address these criteria.

Illustrations of the TOFp detector are shown in Figure 1. The tray is welded Aluminum, 50 mil thick, in the shape of a long box. Feet on the bottom of the tray hold it in place on rails attached to the outer field cage of the STAR TPC. Exactly the same trays are presently installed in STAR as the Central Trigger Barrel (CTB). The tray is installed on the east side of STAR in front of the Ring Imaging Cerenkov Detector (RICH), *i.e.* at approximately the 7 o'clock position when looking west from the east side. All tray-interior components must be held firmly in three dimensions with respect to the tray body (such an installation position has the tray nearly upside-down). The tray covers approximately $1/60^{th}$ of the full azimuth and one unit of pseudo-rapidity from $\eta{\sim}0$ to $\eta{\sim}1$. The active elements in the tray are plastic scintillator slats, to which mesh dynode PhotoMultiplier Tubes (PMTs) are glued. The Voltage generation and distribution to the PMT dynodes is performed using Cockroft-Walton bases. The FEE exists as 10 rows of boards spaced along the length of the tray, where each board has 5 channels of leading-edge discriminator. The TOFp discriminators all run at the same threshold, which is remotely controlled from the platform via a 10bit digital bus. The FEE are mounted directly onto Aluminum rails that also run the length of the tray, to which Aluminum tubing is also connected to form a thermal path for heat removal. There are 41 slat assemblies in the TOFp tray, so 82 signal cables pass out the $\eta{\sim}1$ end. The organization of components inside the tray is phi-symmetric. There is one row of 5 slats near $\eta{\sim}0$, then nine rows of 4 slats out to $\eta{\sim}1$. Coaxial cable of the RG-58 family carries the signals to the platform, where commercial CAMAC electronics (PS 708 discriminators, Lecroy 2228A TDC, LeCroy 2249A ADC) do the final processing and digitization. The modules are read out by a CAMAC crate controller into the memory of a Linux PC, and the TOFp data is then made available to the STAR DAQ system via a dedicated ethernet connection to the control room. Thermocouples in the tray, along the cable path, and in the TOFp rack on the platform are connected to termination panel and then to a CAMAC sampling A/D to digitize the temperature information and provide it to the TOFp data stream.

Quite a few of the components inside the TOFp tray are exactly or practically the same as similar components in the (existing) CTB. These include the mechanical structure (aluminum tray plus rigid foam), electrical isolation, and similar active elements (plastic

scintillator plus mesh dynode PMT). The detailed information on the TOFp components that are common to the two detectors are presented in section 2.

The differences between the TOFp and CTB systems fall into three major categories - the PMT Voltage system, the existence of the FEE, and the water/temperature systems. The discussion of these areas in sections 3, 4, and 5, respectively, comprises the majority of this document.

All major pieces of the TOFp system already in hand and have been exercised thoroughly during the so-called TOFp "SysTest-I" at Rice. All of the R&D is completed. The system is by now well understood and performs well, *e.g.* TOFp "stop resolutions" near and below 60 ps for all slats for UV laser events at the far-end of the slat and at $\sim$1 mip of energy deposition. The summary of all of the SysTest-I results, and other details on the TOFp System, can be found in Refs. [1]-[5].

Table 1 provides a general summary of the TOFp System parameters and requirements. Shown in Figures 2 and 3 are schematic overviews of the major connections requirements on the detector side and the platform side, respectively. Table 2 provides a listing of the TOFp cabling and ratings.

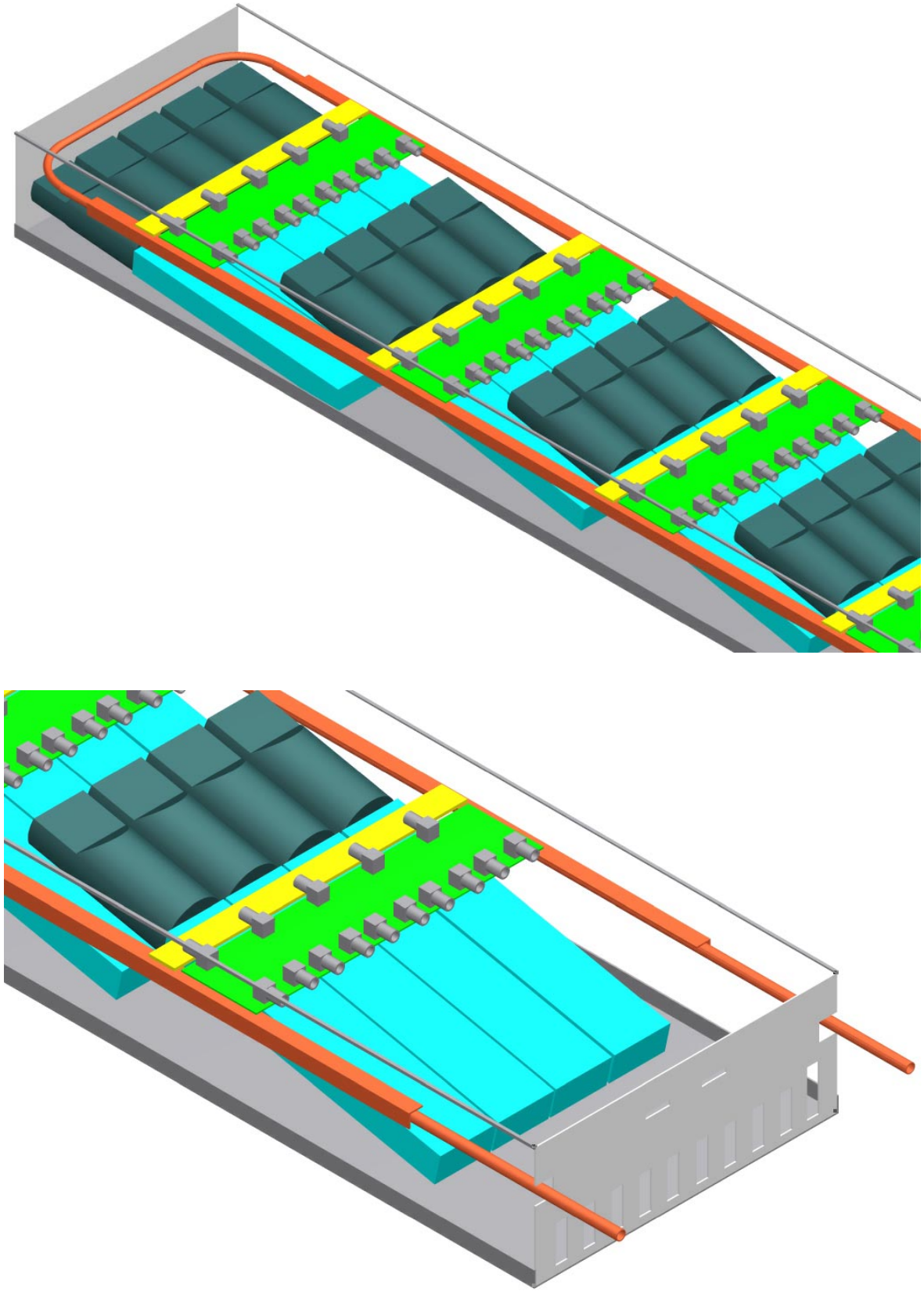


Figure 1: Views of the tray interior. The foam pieces and cabling are not drawn.

Table 1: Executive summary.

Requirement	Specification	Comments
Tray Interior		
Scintillator	41	Bicron BC420, 2×4×20 cm^3
PMTs†	41	Hamamatsu R5946, Mesh Dynode, 1.5"
Cells	41	Cockroft-Walton PMT base, HVSys, Astakhov *et al.*
Tray†	1	welded Aluminum, 50 mil thick walls
Foam†	20 pcs.	Last-A-Foam, density 3 lbs/ft^3
FEE Boards	10	Rice, N. Adams Ver. 5, 1 board/slat row
Thres. Interface Board	1	Rice, mounted on Thres Bus feedthrough connector
Geometry		
Configuration	1×5 + 9×4	number of slat rows in ($\eta\times\phi$)
Slat angle	5.5°-12°	optimized near $\eta\sim0$
Envelope I.R.†	207.75 cm	
Envelope O.R.†	219.5 cm	
Connections		
Signal cables	82	coaxial, no more than 400 ns total delay (∼250')
Max Cable Attn	20 dB/100m @ 200 MHz	
Max Ampl X-talk	0.5%	
Max Time X-talk	20ps	
HVSys Bus	10 cond. ribbon	∼100 ft long, for control/readback of cells
Low voltage	4 conductor	∼100 ft long, for +5 and −5.2 V power to FEE
Thres. bus	15 pair	∼100 ft long, for control/readback of threshold on FEE.
Thermocouples	≤16 pairs	*e.g.* 10 in tray, 3 along cable path, 3 in rack
Heat removal	TPC water, 2 gpm	tray "T's" out of and back into TPC water supply
Digitization		
FEE Time resn.	<20ps	Pulser input (constant pulse height)
FEE Time resn.	<60ps	1 mip-like laser input, far-end hits
ADC/TDC modules	CAMAC	LeCroy 2228A and 2249A
ADC resolution	>10 bits	
TDC resolution	>10 bits	
TDC conversion	≤50 ps/bin	
TDC full scale	100 ns	
Digitization time	≤100 μs	fast clears possible
Power, Bases	4.1W nom., 14.4W max.	nominal 0.1 W/cell for 41 cells
Power, FEE	25W nom.	0.6 W/ch for 41 chs
Power, Total	40W	

† Same as in the STAR-CTB.

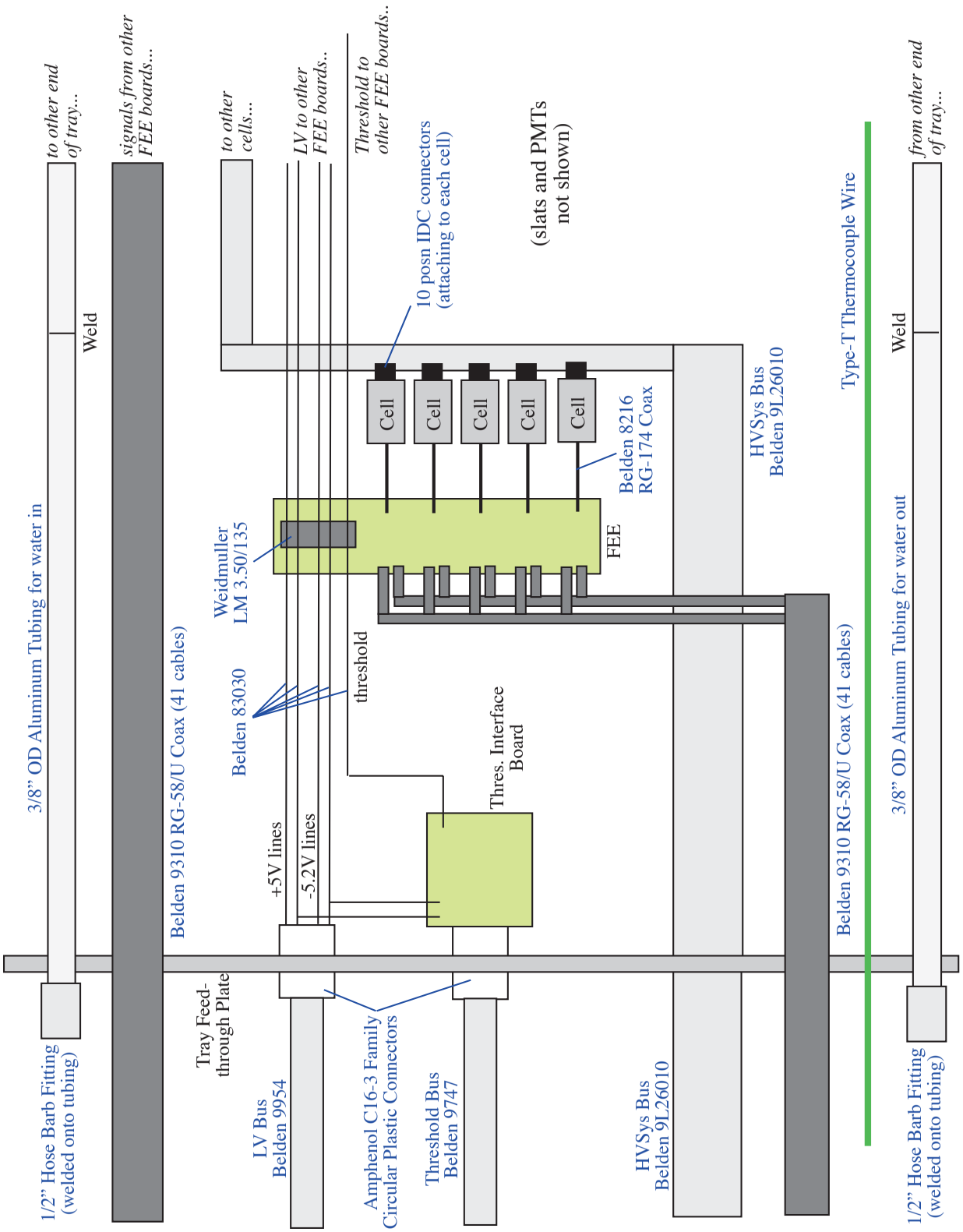


Figure 2: A schematic overview of the TOFp connections on the Detector side.

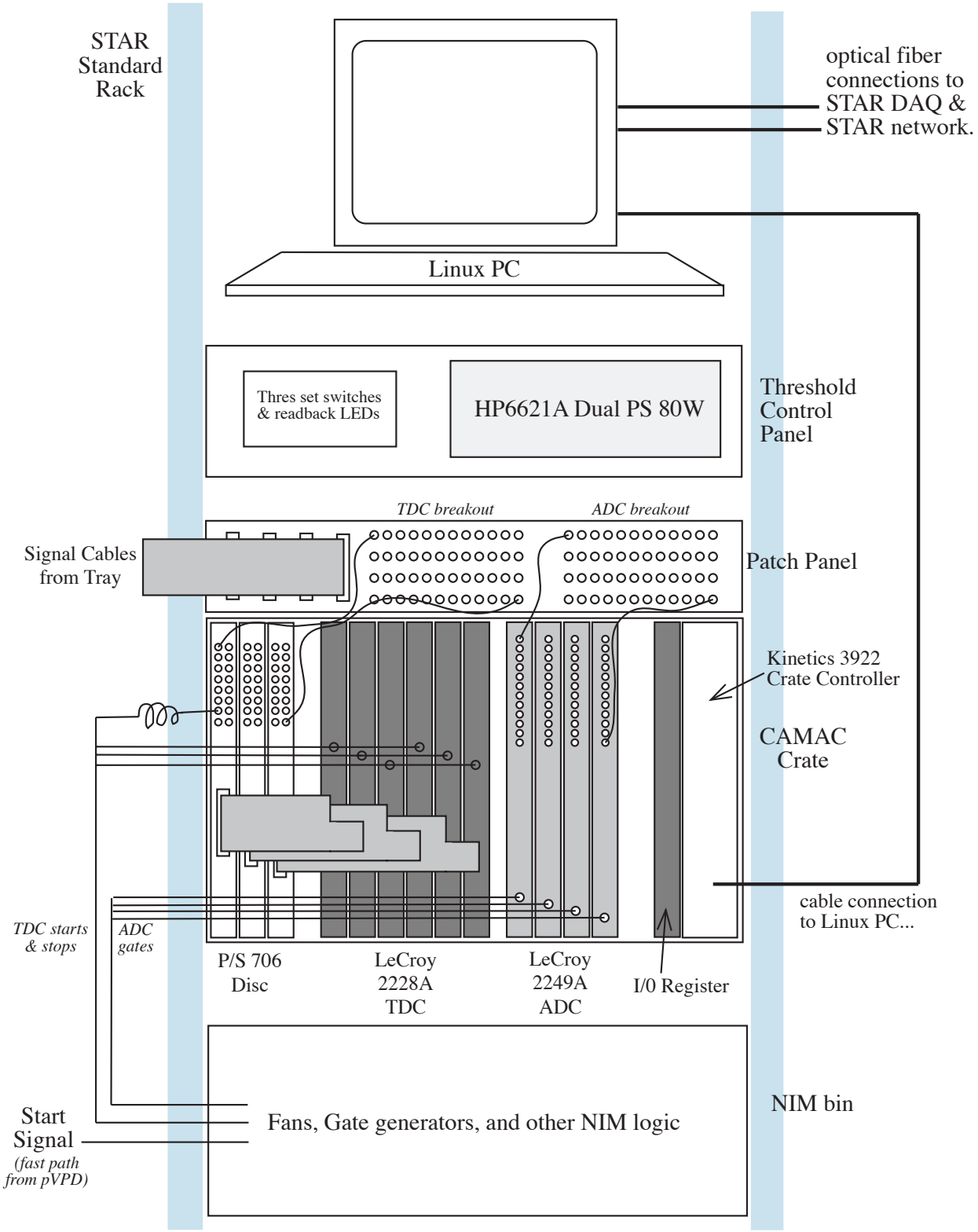


Figure 3: A schematic overview of the TOFp connections on the Platform side.

Table 2: TOFp cable list.

	No.	Type	Product	Voltage (V)		Current (A)		
				Oper.	Rated	Nominal	Fault	Rated
Cables								
Cell output	41	RG-174	Belden 8216	0.8	1100	‡12.5×10^{-6}		
Signal	82	RG-58/U Coaxial	Belden 9310	0.8	300			
HVSys bus	1	10 cond., 26 AWG	Belden 9L26010	200	300	† 0.25	† 1.0	§1.5
Threshold bus	1	12 pair, 18 AWG	Belden 9747	0.5	300	0.01/pair		
Low voltage bus	1	4 cond., 16 AWG	Belden 9954	±5	600	8	10	
Lead wire	5	16 AWG, Teflon	Belden 83030	±5	1000	8	10	
Thermocouples	16	20 AWG, FEP	PMC Type T-20	∼80 °F	400 °F			
Connectors								
FEE→RG-58/U	82	90° Lemo	Lemo	0.8	700			4
HVSys Bus	1	10 pins	Amp LATCH	200	250	†0.25	†1.0	§1.0
LV→tray	1	5+PE cond.	Amp C16-3	±5	400	8		21
LV→FEE	10	5 pin	Weidmuller LM3.50/135	±5	300	8		10
Threshold Bus	1	24 cond. CPC	Amp 737097	0.5		0.01		

‡ Assuming 12.5 nC/hit times 1000 hits/sec.

† Currents are total over all three low voltage lines on the HVSys Bus.

§ Current rating is per conductor.

2 TOFp components in common with CTB

2.1 Discussion

The TOFp tray is more or less a juiced version of a CTB tray. Thus, for many TOFp components, it is possible and correct to use the same materials used in the CTB, which is by now already safety approved, installed, and running in STAR. These components are listed now.

2.2 Components

Name: Tray
Function: Outer shell and main mechanical structure of the TOFp detector.
Material: Aluminum, welded sides and bottom, 50 mil wall thickness.
Manufacturer: Oak's Precision, Houston, TX.
Justification: The same tray material was used in the CTB.
Comments: The tray construction (tray top and tray feet attachment) is the same as for the CTB. The tray is light-tight.

Name: Isolation strips
Function: Forms electrical insulation between TPC rail and the tray, by lining the bottom of the tray and interior surfaces of the tray feet.
Material: Hostalen GUR, UltraHigh Molecular Weight PolyEthylene (UHMW-PE). Additional information is in section 6.1 below.
Manufacturer: Hoechst Celanese, Somerville, NJ, via reseller E&T Plastics, Long Island, NY
Justification: The same isolation strips were used in the CTB.
Comments:

Name: Foam
Function: Three-dimensional mechanical support of the slat assemblies.
Material: Last-A-Foam closed-cell polyurethane, density 3 lbs/ft^3. Additional information is in section 6.2 below.
Manufacturer: General Plastics Manufacturing Company, Tacoma, WA.
Justification: The same foam was used in the CTB.
Comments: Each of the 41 TOFp slats is held in three dimensions and at the proper angles with respect to the tray by 20 separate and specifically shaped pieces of this foam. It is light-weight and workable with machine tools. It mechanically very strong.

Name: Foam Spray
Function: Coats the foam pieces to eliminate foam dust.
Material: Polyurethane Clear Finish, spray can.
Manufacturer: Krylon
Justification: This spray and foam pieces to which it is applied are both polyurethane. Such spray is in general the correct approach to eliminate the foam dust according to the manufacturer.
Comments: The foam pieces used in the CTB were not coated with this spray due to time constraints. No such constraints exist for TOFp, so all TOFp foam pieces will be

coated.

Name: Struts
Function: Mechanical support of the foam pieces.
Material: PVC Type I 90 Deg. Angle, 1-1/2"×3/4"×0.080" wall thickness.
Manufacturer: Rice (custom pieces). Raw material obtained from McMaster-Carr (part number 8659K43).
Justification: These are thin-walled, rigid, low density, and hence provide the optimal mechanical support for the foam pieces.
Comments:

Name: Slats
Function: These are the active element.
Material: BC-420, $4\times2\times20$ cm^3, edges diamond-milled. Additional information may be found in section 6.3.
Manufacturer: Bicron, Newbury, OH.
Justification: This formulation provides the best performance for the physics objectives.
Comments: These slats have been used extensively during SysTest-I and since.

Name: PMT
Function: Optical to electrical transducer.
Material: R5946, 1.5" mesh dynode, 16 stages, 1:10 gain spread, TTS<500ps, RT<2.5ns.
Manufacturer: Hamamatsu USA,
Justification: These are, at present, the only large area and high gain transducers that can operate in a 0.5 T magnetic field.
Comments: This is the PMT model that was used in the CTB. The model to be used in TOFp is the same, but with two additional specifications on the PMT transit time spread (TTS) and rise time (RT). The basic specs are the following: maximum voltage is 2300 V, current amplification at 0.5 T is 4.3×10^5, average anode current is 0.01 mA, dark current typical(maximum) after 30 minutes is 5(30) nA, typical rise time is 1.9 ns and typical electron transit time is 7.2 ns.

Name: Glue
Function: Forms mechanical and optical junction between the PMTs and the slats.
Material: Epotek 301 Spectrally Transparent Epoxy. Additional information may be found in section 6.4.
Manufacturer: Epoxy Technologies
Justification: The same glue was used in the CTB and the E896 TOF System. Its transmission is 100% for wavelengths above 300 nm and is very strong.
Comments: Experience indicates that it is mechanically very strong for forces applied adiabatically, yet is less so for shock forces. This is simply addressed by taking appropriate care during the transport of the TOFp tray from Houston to Upton.

Name: Tyvek
Function: Reflective layer around slats to improve photoelectron performance.

Material: Tyvek Spunbonded Olefin, Style 1060B, unpainted. Additional information may be found in section 6.5.
Manufacturer: Dupont
Justification: The same wrapping was used in the CTB and E896 TOF detectors.
Comments: This material is much softer than aluminum foil and aluminized mylar, is electrically an insulator, yet results in 30-50% (depending on the slat dimensions) more photoelectrons per minimum ionizing particle (mip) hit than aluminum-based reflectors.

Name: Black Plastic
Function: Protects slats and tyvek, and optically seals each slat assembly.
Material: Delta 1 Black Out Cloth, Polyethylene, 6 mil thick.
Manufacturer: CPM Inc., Dallas, TX.
Justification: The same black plastic was used in the CTB.
Comments:

Name: Super 33+
Function: Seals black plastic to make slat assembly light tight
Material: Vinyl, 7 mil thick, temperature rating 220 °F, primary insulation up to 600V.
Manufacturer: Scotch, 3M
Justification: The same tape was used in the CTB and the E896 TOF.
Comments:

Name: Feedthrough plate
Function: Mechanical support for various cables and tubing pass-throughs.
Material: Aluminum, 50 mil thick, or Delrin, 1/8" thick.
Manufacturer: Rice (custom piece). Raw material obtained from McMaster-Carr.
Justification: This plate is needed to close the $\eta\sim1$ end of the tray body and to anchor the TOFp cables at this end.
Comments:

Name: Signal cable
Function: Bring detector analog and logic signals to the TOFp rack with a controlled delay.
Material: 9310 RG-58/U Coaxial cable, 50 Ω, 17.7 dB/100m @ 200 MHz. Additional information may be found in section 6.6.
Manufacturer: Belden, parts obtained from distributor Anixter.
Justification: This cable has the best performance in terms of signal attenuation and rise time attenuation compared to all other cables of the RG-58 family (50 Ω, $v_{signal}\sim0.66c$). The amplitude and timing cross-talk and the temperature coefficients are negligible, which is not the case for coaxial ribbon cables, *e.g.* Amphenol "FlatCoax," which were originally considered for TOFp.
Comments: There are 41 TOFp channels, so there are 82 TOFp signals per event. Each of these 82 cable exist as two cable assemblies that mate some 10' away from the TOFp tray in the STAR cable trays. Each section is composed of Belden 9310 coax. The first assembly is approximately 20 ft long, and it carries the signals from the TOFp FEE boards out to and through the feedthrough plate, and then out some distance through

the magnet coil and along a STAR cable tray. The connectors on this short section are a lemo plug on the FEE end and a BNC socket on the other. The second assembly is longer - no more than ∼250 feet or ∼400 ns total cable delay between the FEE boards and the TOFp rack. The connectors on this cable are BNC plug on the end meeting the short assembly, and BNC socket at the patch panel in the TOFp rack.

3 PMT Voltage System

3.1 Discussion

In the CTB, the PMT voltage system consists of a LeCroy 1440 mainframe delivering high voltage over long cables to simple resistive bases inside the CTB trays. As there are only two PMT's per CTB tray, the high power dissipation of resistive bases ($\sim$1-2 W/base) does not pose a heat problem. For TOFp, there would be twenty times the power dissipation, although this amount would be tolerable given the TOFp water cooling (described below in section 5). The more important problem with delivering high voltage to the TOFp tray involves the excessive cabling requirements. There is simply not enough room, either at the feedthrough plate or inside the tray, to accommodate a HV cable in addition to the two signal cables for each of 41 channels. To reduce the required rack space by eliminating the 1440, the cabling requirements, and the power dissipation inside the TOFp tray, a Cockroft-Walton (CW) PMT base system was desired.

Several such systems were studied during SysTest-I, resulting in the adoption of the "HVSys" system of Astakhov *et al.* The system was exercised thoroughly during SysTest-I and since, and it has met all functional requirements. It consists of "cells " (one per PMT), a 10 conductor bus that is daisy-chained to each cell, and a "System Module" which site on the platform. The cells are very compact and low-density, as they consist of only two small circuit boards perpendicular to the plane of the slat assembly. Their power dissipation is low (more below). The System module on the platform connects only to the bus, to AC power, and to a PC's serial port for the cell control and monitoring. The System module provides over the bus the source voltage (200 V) which drives the CW chains as well as the control and feedback signals. Photographs of cells and System modules can be seen in section 6.7 below.

During SysTest-I, an old-style System module, "SM-255," was used successfully. If permitted by the funding, a new-style System module, SM-512, would be purchased, which is a better more powerful version (details below).[1] The user control over the system is done from the PC, using either a dumb terminal program to send commands directly to the system module, or a DOS-based GUI. The commands recognized by the system include internal monitoring and test procedures. The manufacturers description of this system is included below in section 6.7.

Detailed information on the stability of the HVSys system over periods of months was obtained during SysTest-I and since. A crash of the system was never seen. The fuses in the HVSys System module never blew under running conditions. Cell failures of any kind have not occurred. Undoubtedly, one reason that HVSys failures of any kind were never seen results from the fact that the present implementation is very light compared to the full capabilities of the system. A single old-style(new-style) HVSys System module is capable of driving four buses of up to 64(128) cells per bus, or 256(512) cells maximum per System Module on the 4 buses. In the TOFp implementation, only one bus of the four is used, and on that bus, only 41 cells are connected. The TOFp implementation thus uses, in terms of cell count per bus and total, fractions of the full capabilities of the System module. Given the design of this module, the other three buses are available as a backup should bus 0 in the System module ever fail (such a failure has never been seen).

To decrease the long term effects of humidity and for additional safety, the high voltage

[1] In this case, the older SM-255 we have been using would be retired.

part of the cells is potted (the board of the two containing the CW multiplier chain of capacitors and diodes). The potting compound will be a standard commercial silicon encapsulant, *i.e.* Sylgard 182 or MidSun 570. See section 6.10 for more information on the former.

Features that are intrinsic to the HVSys system include the facts that the range of possible cell output voltages is bounded above and below, and, within those bounds, only a limited number of output voltages can be set on a PMT. For the TOFp cells, the minimum possible cell output voltage is 1150 V, and the maximum possible cell voltage is 2300 V. The user, or the system in some (unknown) failure mode, has no ability to exceed either bound. The user is only able to choose one of 256 different cell output voltages in between the two extreme values ($\sim$4.5 V/step). Typical cell output voltages needed to result in good PMT signals ($\sim$500 mV pulse height) for cosmic mip's the actual TOFp slats and R5946 PMTs are in the range 1600-1900 V. The R5946 PMTs can run up to 2300 V, which is matched by specification to the cell voltage upper limit.

Of the 10 conductors on the HVSys bus, three conductors carry low voltage (one 200 V line, one 6 V line, and one -6 V line), three are power grounds, and four are signal lines for control and feedback (0-5V and very low currents). The power drawn by a single cell under normal operating conditions is 0.1 W typical, 0.35 W maximum. The total power drawn by the 41 TOFp cells in the tray is thus 4.1 W typical, or 14.4 W maximum.

The maximum power on the bus cable would be if the bus has the maximum number of cells connected to it. In this case the typical(maximum) currents on the voltage lines are 0.1(0.5) A on the 200 V line, and 0.25(1.0) A on the $\pm$6 V lines. The TOFp bus thus typically runs at $41/64 = 64\%$ of these currents.

The ribbon cables chosen for this bus are rated to higher voltages and currents than expected for TOFp. The bus cable chosen is Belden 2L26010, which is rated to 300 V and 1.5 A.

To comfortably insure that the 1.5 A current rating of the chosen bus cable is not exceeded, there are on the System module two fuses on the $\pm$6 V lines for every branch. These are 1 A Wickmann fuses obtained from Digi-Key. Shown in Figure 4 is a side view of the System module indicating on the location of these fuses.

The 200 V line on every branch is protected by a current-limiting circuit which insures a maximum current of 0.250 A in case of a short circuit on this line. If the maximum current allowed of 0.25 A is sustained on the 200 V line for more than 10 seconds, the system module will switch off the 200 V line on this particular branch, which shuts down the system.

For insurance against problems (like short circuits) on the cell side, the design prohibits HV currents of more than 2 mA on the last dynode, and 160 μA on the photocathode (which would result in the aforementioned maximum power draw of 0.35 W from supply lines). All of these regimes were tested over long periods by the manufacturer and in previous experiments (see section 6.7). No overheating of the boards was observed under these conditions.

3.2 Components

Name: Cells
Function: Provides voltages to PMT dynodes.
Material: Custom. Additional information may be found in section 6.7.

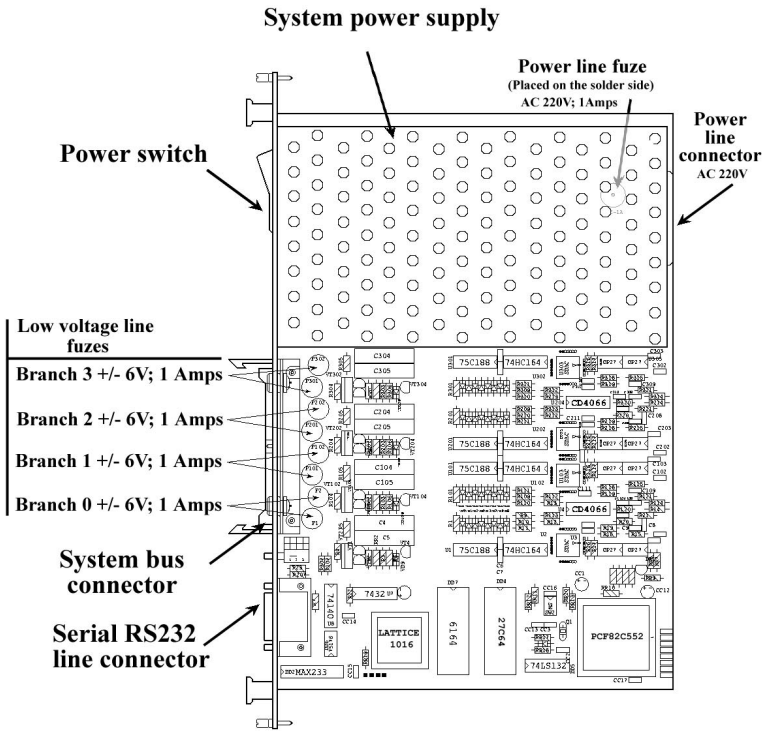


Figure 4: The HVSys "System Module" schematic, indicating the fusing.

Manufacturer: V. Astakhov *et al.*, JINR-Dubna.
Justification: These are low size and low power, stable, and hence the most appropriate.
Comments: These were used extensively during and since SysTest-I.

Name: HVSys Bus, platform to feedthrough plate
Function: Connects HVSys System Module to tray for cell control and feedback.
Material: Belden 9L26010, gray ribbon cable, .050" Pitch, 26 AWG, 10 Conductors, ∼100' long. Additional information may be found in section 6.8 and in Table 2.
Manufacturer: Belden.
Justification: This 10ch wide ribbon cable type meets the HVSys requirement and is rated to 300 V, while the maximum voltage on a conductor is 200 V. This cable is rated to 1.5 A, while the System module is fused so as to insure the maximum current on this bus is 1 A in some (unknown) failure mode.
Comments: This cable has been used extensively during SysTest-I and since.

Name: HVSys Bus, tray interior

Function: Same as the previous component, but inside the tray. Connects to each cell as a daisy-chain. Additional information may be found in section 6.8 and in Table 2.
Material: Belden 9L26010, gray ribbon cable, .050" Pitch, 26 AWG, 10 Conductors, ∼20' long
Manufacturer: Belden.
Justification: See previous component.
Comments: This cable has been used extensively during SysTest-I and since. This cable can in fact be the same as the cable used from the platform to feedthrough plate (no feedthrough connector at the $\eta\sim1$ end).

Name: HVSys Bus Feedthrough Connector
Function: In case single contiguous cable is not used for the HVSys bus, this connects the HVSys outside the tray to the HVSys bus inside the tray. Additional information may be found in section 6.9 and in Table 2.
Material: AMP-LATCH Series, 10 posn, with mating polarization and strain relief.
Manufacturer: Amphenol
Justification:
Comments:

4 Front End Electronics

4.1 Discussion

One FEE board is positioned close to each row of cells. There are thus ten FEE boards: one with all 5 channels used and nine with 4 out of the 5 channels used (41 ch total). The function of each channel is first to buffer the PMT anode signal after a ∼6" long RG-174 coaxial cable exiting each cell, so as to provide the a copy of the full PMT signal to each of two paths on the board. The first path is a straight 50 Ω trace to a board-mounted lemo socket connector. The second path includes a custom leading-edge discriminator, which forms a NIM-standard logic signal also output using a board-mounted lemo socket. The former path is used for pulse area measurements, while the latter path is used for time measurements. The discrimination of the signal close to the PMT produces a very fast rise time signal to be propagated over the long RG-58/U signal cables and rediscriminated on the platform. The rediscriminated logic signals are sent to CAMAC TDCs, while the analog signals are sent to CAMAC ADCs, in the TOF rack on the platform.

During SysTest-I, version 4 of this board was tested exhaustively. The leading-edge discriminator parts of the version 4 board are just the repackaging of the discriminator circa version 2. In version 4, the rise time of the logic signal was 600 ps, which should be compared to 2-3 ns rise times from commercial 300 MHz discriminators. The time resolution for pulser events was ∼15 ps, and for 1 mip-sized pulses obtained from an attenuated UV laser for real slats and PMTs ranged from 40-60 ps over the length of the slat. The design of the components of the FEE bearing on the physics performance were thus frozen at the (2 layer) version 4 design. However, certain important safety and stability features were lacking in this version.

Version 5 boards are now in hand and are being tested, while Version 6 is presently under construction (see Fig. 50). On this 4 layer ∼2"×8" board, five copies of the version 4 leading-edge discriminator circuit exist side by side. The board mounts directly to the Aluminum rails for mechanical stability and to form a good thermal path and the water tubing loop (see section 5 below). Unlike the version 4 board though, each version 5 board includes proper low voltage distribution, fusing, and remote threshold control. Each of these new features are now described.

A dual low voltage power supply (see section 6.13) on the platform in the TOFp rack supplies +5 V and -5.2 V to be used in the tray by the FEE. The -2 V line needed by the FEE is simply derived from the -5.2 V line inside the tray on each FEE board. The currents drawn by each channel of TOFp FEE are the following: 50 mA on the +5 V line, and 170 mA on the -5.2 V line. The 170 mA current per channel on the -5.2 V line includes the current drawn by the derived -2 V line. The voltages and currents on the long LV bus and the LV lead wires are thus 50 mA on the +5 V line, 170 mA on the -5.2 V line. The low voltage cables from the power supply to the tray was thus chosen to be Belden 9954, while Belden 83030 lead wires daisy-chain the LV lines to each board in the tray (see Figure 2). The voltage supply is the Hewlett-Packard 6621A dual power supply, where each output is 0-7 V and 0-10 A.

Each channel of FEE draws 0.6 W of power under full running conditions. For ten boards of TOFp FEE, in which 41 channels total are stuffed, there would be a total FEE power draw of 41*0.6 W, or 25 W, inside the tray.

The version 5 FEE board includes fuses on the ±5 V lines. The nominal current draw

per channel from the -5.2 V line is 170 mA, so each board as a whole draws 850 mA on this line. The nominal current draw for 5 FEE channels on the +5 V line is 250 mA. Thus, the fuses installed in each version 5 FEE board are 1.5 A on the +5 V line and 3 A on the -5.2 V line. These are Picofuse UL-284-14 fuses.

The threshold used on each board is controlled from the platform over a digital bus. A small panel in the TOFp rack allows the user to thumb-switch to the desired threshold. Components on this panel convert this value to a digital number, which is transferred over a 100' long 12-pair cable to a small interface board inside the tray. The voltages and currents on this threshold bus are 0.5 V and 0.01 A on each pair (differential). The threshold interface board inside the tray takes the digital information and the ± 5 V lines from the low voltage bus to produce the threshold as a -100 mV or so level then used as the discriminator threshold on each FEE board. This threshold travels by Belden 83030 lead wire to the same connectors on the FEE boards that accept the ± 5 V lines (see Figure 2).

Redundant DACs are used with a comparator on this board to allow a failsafe condition. The comparator makes a loose check on the threshold converted from each DAC. If the two values are different, the comparator assumes one of the two DACs has failed. In this case, the discriminator threshold (for all channels) goes automatically to -100 mV. This would be a perfectly reasonable threshold in general and would allow good timing data to be obtained even given the possibility that a threshold DAC fails.

A unit composed of large resistors was built to simulate the current draw corresponding to nine TOFp FEE boards in a row. The performance of the existing version 5 board is thus being studied under conditions where the power supply is being asked to provide the full currents that will be needed from the entire system (ten FEE boards in a row inside the tray).

4.2 Components

Name: FEE Board
Function: Split PMT signal, discriminate one of these, and provide analog and logic signals to output cables.
Material: four-layer custom printed circuit board, Rice version 5, five channels. Additional information on the version 4 board can be found in section 6.11.
Manufacturer: Rice (custom board)
Justification: The version 5 board meets all requirements, as well as the proper low voltage conditioning, fusing on the low voltage inputs, and remote threshold control.
Comments:

Name: Low Voltage Power Supply
Function: Provide +5 V and -5.2 V power used by the FEE.
Material: Model 6621A Dual Power Supply. Additional information can be found in section 6.13.
Manufacturer: Hewlett-Packard
Justification: The model provides the necessary functionality at the lowest cost. Each of the two channels is 0-7 V and 0-10 A, which is safely in excess of the expected $\sim$5V and $\sim$8 A total draws from the FEE boards.

Comments: Mounts in TOF rack on platform alongside the Threshold Control Panel.

Name: Low Voltage Distribution (Platform to Tray)
Function: Brings +5 V and -5.2 V lines from the platform to the feedthrough plate.
Material: Belden 9954, multiconductor nonpaired, braid shield, 16 AWG, 4 Conductors. Additional information can be found in section 6.14 and in Table 2.
Manufacturer: Belden
Justification: Low voltage is needed to power the FEE boards. This cable is rated to 600 V, well above the $\pm$5 V on this cable. The largest nominal current on the -5.2 V lines is expected to be $\sim$8 A.
Comments:

Name: Low Voltage Feedthrough Connectors
Function: Pass low voltage lines from outside the tray to inside the tray.
Material: Amphenol C16-3 Family, panel mounting, Shell Style 2, 5+PE contacts, 4 mm^2 wire gauge. Additional information can be found in section 6.15 and in Table 2.
Manufacturer: Amphenol
Justification: This connector is rated to 400 V and 21 A, well in excess of the $\pm$5 V and $\sim$8 A that is expected nominal values.
Comments:

Name: Threshold Control Panel
Function: Push-button control of threshold setting, convert to digital and send to tray for decoding by Threshold Interface board, with readback. LEDs used to display actual threshold value.
Material: Rack mounting plate onto which the Low Voltage Power Supply and the threshold control dials and readback LEDs are mounted.
Manufacturer: Rice (custom board).
Justification: Needed to control and readback the threshold value.
Comments:

Name: Threshold Control Bus
Function: Provide digital information on desired discriminator threshold.
Material: Belden 9747, multiconductor, unshielded, 22 AWG, 12 twisted pairs. Additional information can be found in section 6.16 and in Table 2.
Manufacturer: Belden.
Justification: Needed to control and readback the threshold value.
Comments:

Name: Threshold Bus Feedthrough Connector
Function: Passes threshold bus through feedthrough plate.
Material: CPC 737097, panel mount, 24 conductor, thermoplastic housing. Additional information can be found in section 6.17 and in Table 2.
Manufacturer: Amphenol.
Justification: This is needed to as the feedthrough for the threshold bus.

Comments: The voltages and currents on any conductor of this connector are nominally 0.5 V and 10 mA on pairs (differential).

Name: Low Voltage & Threshold Distribution (In-tray)
Function: Brings +5 V and -5.2 V lines to each FEE board.
Material: Belden 83030, Lead wire, TFE Teflon, 16 AWG. Additional information can be found in section 6.18 and in Table 2.
Manufacturer: Belden
Justification: Low voltage is needed to power the FEE boards, and the threshold is needed for the leading-edge discriminators to work.
Comments:

Name: Threshold Interface Board
Function: Derive from the -5.2 V low voltage line inside the tray the negative level used as the FEE discriminator threshold for all channels.
Material: Custom printed circuit board.
Manufacturer: Rice (custom board).
Justification: Needed for precise control of the in-tray discriminator level from the platform over ~100' cables.
Comments: Has redundancy to allow a failsafe mode if a DAC fails.

Name: Low Voltage Board Connect
Function: Bring low voltage lines and threshold line to the appropriate traces on the FEE boards.
Material: Weidmuller LM 3.50/135 Terminal Block, Polyimide.
Manufacturer: Weidmuller
Justification: This is the most space efficient means to appropriately attach the LV and threshold wires to each FEE board. These connectors are rated to 10 A and 300 V, which is in exceeds the expected ~5V and ~8 A total draws through this connector in the worst case (*i.e.* at the first FEE board in the chain of 10 along the tray). The last connector in the LV/threshold daisy-chain sees ~5V and <1 A.
Comments: These are presently being used on the v5 FEE boards. They mount underneath the board.

Name: Optical fiber pigtail (on slats)
Function: Laser light input through wrapping to each slat for slat/FEE testing with a laser after transport but before before installation in STAR.
Material: Fiber Optic Cable, Plastic, 1000 μm diameter
Manufacturer: Rice (custom pieces). Raw material obtained from Newark (part number 87F6287).
Justification: Needed to run SysTest-II.
Comments: Used to allow laser-testing of each slat+PMT+Cell+FEE channel chain when tray is in its full-constructed final configuration but not yet installed.

5 Water & Temperature Systems

5.1 Discussion

As discussed in the two previous sections, the power draw inside the tray is at most 15 W from the cells and 25 W from the FEE. The total power dissipated inside the tray is thus ∼40 W, or a total of ∼ 1 W per channel. While no significant dependence of the FEE performance on the board's temperature was seen in specific tests in SysTest-I, heat removal is prudent if for nothing other than to enhance the long-term stability of the system.

This heat removal is performed by installing an Aluminum tube inside the tray that is bent into the shape of a long "U." This tube carries water from the TPC water system in on one side of the feedthrough plate, all the way to the $\eta\sim0$ end along this side, turns around in two 90 degree bends, then travels all the way back along the other side of the tray and exits through the feedthrough plate. There are no tubing connectors inside the tray, the loop is a single contiguous (but welded) tube. This tubing loop is attached permanently to two ∼8' long aluminum angles, "rails," which have threaded holes for mounting semi-permanently to the walls of the TOFp tray body. The FEE boards and slat supports (plastic angles and shaped foam) also mount off of these rails, providing solid support for holding the various structural pieces in place, as well as a good thermal path between the electronics boards and the heat removal water tube.

Bench tests were done in 1995 to measure the effectiveness of this design for heat removal from an actual tray. At this time, it was thought the power generation of TOF trays would be 2-4 W per channel for a 50 channel tray. A full size tray was outfitted with the cooling loops attached to the angle aluminum rails, to which a 1/16 inch thick aluminum plate was also attached running the entire length of the tray. Twenty-four resistors were epoxied to this plate evenly along to length to generate a total power of 210 W. Water was brought to and from the cooling loop via 1/8" I.D. hose. The flow rate at the exit of the second 1/8" ID hose was measured with a calibrated beaker and a watch. With a manometer, it was found a pressure of 2.6 psig was required to produce a flow rate of 0.1 gpm. The flow resistance was due almost entirely to the 1/8" tubing that was used in this test before and after the cooling loop. After some hours for the tray to reach thermal equilibrium at 210 W, the temperatures inside the tray were measured with thermocouples and the exit water temperature was measured with a thermometer. For an input water temperature of 65.3 °F and an ambient temperature of 73 °F, the exit water temperature was 77 °F. The temperatures measured inside the tray ranged from 81 to 93 °F depending on the location of the thermocouple on on the resistor plate. Thus 210 W of power (w/ 0.1 gpm flow and ∼65 °F input water) raises the internal temperature of the tray to ∼20 °F above the ambient temperature, and the increase in the water temperature is about 8 °F. Note the heat sources for this test are more like a series of point sources than is likely with the actual electronics, leading to larger thermal gradients in this test than would be expected in the real environment. Note also that the present tray is expected to draw ∼40 W, or 1/5 of the power assumed for this test.

An alternate estimate for TOF heat loads and temperature rises is available in Ref. [6]. Here it was assumed that the power per tray was 525 W plus 20 W to account for heating of the TOFp by the magnet through the EMC, or 545 W total per tray. In this case a flow rate of 0.8 gpm results in a temperature rise of 5 °F. The total power per

TOFp tray is expected to be 1/10 of the assumed power, while the expected actual TOFp flow rate of 2 gpm is 2.5 times higher than the assumed flow rate. For both reasons the TOFp temperature rise should be $\ll$5 °F.

Note also that the TPC rails onto which the TOFp is mounted is itself cooled as a regular part of the TPC's water flow on the outer field cage. There is this a cooled aluminum plate between the TOFp and TPC.

The present system thus has quite modest requirements on the cooling water that is supplied by the TPC water system. The requirements are indeed low enough to allow the necessary cooling path to be simply "T'd" into the existing water system for the TPC. The flow rate and temperature at the input to the TOFp tray are 2 gpm and 75 °F, respectively. [7]

The in-tray tubing is Aluminum 6061, which is according to the manufacturer the most versatile of all heat-treatable aluminum alloys, featuring good strength, weldability, and corrosion resistance. Its temperature range is 40° to +400° F. Meets Fed. Spec. WW-T-700/6 and ASTM B210. The tube is ∼17' long, 3/8" O.D., 0.305" I.D., with a maximum rated pressure at 72° F of 1736 psi. This ∼17' tube is produced by welding three 6' sections (McMaster-Carr part number 89965K45). A simple 3/8" pipe bender is used to form the two 90 degree bends at the $\eta\sim0$ end. The radius of curvature for each bend of 2" is more than 5 times the (3/8") diameter of the tubing.

On the two ends of the tubing loop which extend to outside of the feedthrough plate, aluminum hose barb connectors (also McMaster-Carr) are welded. These are then connected (outside the tray) to two pieces of 1/2" vinyl braided hose, which carry the TOFp water to and from the TPC water system. The vinyl hose and flowmeter are already in hand, and the actual connection of the TOFp loop to the TPC system will be done by A. Lebedev of the TPC group. [8]

For leak detection, TraceTek cables are installed at this hose barb to hose connection. As the tray interior tubing is a single (welded) tube without connectors inside the tray, TraceTek cabling inside the tray is not required. [9]

Specific pressure tests will be performed after the loop is constructed and before installation. It will be necessary [9] to show the TOFp tubing assembly is leakless for water pressures up to 1.5 times the pump operating pressure, or 90 psig maximum for TPC water.

During Systest-I the temperature dependence of the performance of the PMT+Cell+FEE chain was studied. These components were placed in an oven, the UV laser was used to input ∼1 mip-like light pulses, and the ambient temperature was measured with a thermocouple. Over a temperature range from 70 to 110 °F and over ∼5 hours, no variation of the time resolution with the temperature of more than 5 ps was observed. Also measured during SysTest-I was the temperature dependence of the attenuation profiles (attenuation in dB versus frequency in MHz) for RG-58 style coaxial cables and for coaxial ribbon cables such as Amphenol FlatCoax. The attenuation in the RG-58 cable did not depend on the temperature in the range from 22 to 52 °C, while the attenuation in the Flat Coax did show a temperature dependence (an increase) of ∼0.1 dB per 10 °C. This and other aspects (amplitude and timing cross-talk) of the FlatCoax cable ruled out its use for TOFp. So, in direct tests including the actual PMT+Cell+FEE assemblies and long RG-58 cables, we expect no significant temperature dependences. However, slight temperature dependences of the timing offsets (*i.e.* the actual delay in any given signal cable), and possibly in the signal digitization in the ADC and TDC modules, are not

ruled out. Thus, the temperatures inside the tray, along the cable path, and in the TOFp rack on the platform will be monitored continuously by a thermocouple system.

Up to 16 thermocouples are connected to a Kinetics 1992 Thermocouple Termination panel. There would be ten thermocouples inside the tray (1 per FEE board), three along the cable path (one outside the tray but inside the coil, one just outside the coil, and one in the cable trays), and three at the TOFp rack (all three in and near the CAMAC crate). The Thermocouple Termination panel is connected to a Kinetics 3514 12bit 16ch Scanning A/D Converter for the conversion of the thermocouple voltages to digital data. The cold-junction compensation is done by the Termination panel. The Scanning A/D is read out over the CAMAC backplane into the standard TOFp data stream. Thermocouple information is thus saved for every experiment event. Due to its good temperature resolution for room temperature-like environments, Type T thermocouple wire is used. Additional information on this wire can be found in section 6.19 below.

5.2 Components

Name: Cooling loop
Function: Water path through tray for heat removal.
Material: 3/8" O.D. Aluminum tubing, fabricated by welding 6' sections end-to-end.
Manufacturer: unknown, three 6' tubing sections obtained from McMaster-Carr (part no. 89965K45).
Justification: Needed for long-term stability of FEE and cells.
Comments: Design of this loop approved by TPC water system experts.

Name: TraceTek cables
Function: Leak detection at feedthrough plate
Material: TraceTek cable
Manufacturer: Provided and connected by STAR Facilities experts.
Justification: Needed to indicate failure of hose to hose-barb connections (outside of tray).
Comments:

Name: Water Hose
Function: Water path to/from TPC water system
Material: 1/2" Vinyl Braided Hose
Manufacturer: Harrington Plastics
Justification: Specified by TPC water system experts
Comments:

Name: Thermocouple Wire
Function: Monitor local temperatures inside tray, along cable path, and at TOF rack.
Material: Type T thermocouple wire. Additional information may be found in section 6.19 below.
Manufacturer: PMC Wire Inc.
Justification: Needed for small corrections if FEE or cable experience significant tem-

perature variations.
Comments:

Name: Thermocouple Termination Panel
Function: Interface between thermocouple wires and Scanning A/D
Material: Kinetics 1992 Thermocouple Termination Panel, 32 ch.
Manufacturer: Kinetics
Justification: Needed for proper thermocouple connection to the Scanning A/D.
Comments: Includes cold junction compensation. Rack mounting, 1-U wide.

Name: Thermocouple A/D
Function: Digitize the thermocouple voltages and provide data to CAMAC backplane.
Material: Kinetics 3514 Scanning A/D Converter, 12 bit, 16 ch.
Manufacturer: Kinetics
Justification: Needed to digitize the thermocouple information and insert these data into TOFp data stream.
Comments:

References

[1] TOFp Proposal, available from http://bonner-mac8.rice.edu/~TOF/default.html (Nov. 17, 1998).

[2] TOFp Implementation Plan, available from http://bonner-mac8.rice.edu/~TOF/default.html (Oct. 5, 1999).

[3] W.J. Llope for the STAR TOFp Group, STAR Collaboration Meeting, plenary session, BNL, January, 1999. Transparencies available from http://bonner-mac8.rice.edu/~TOF/default.html.

[4] W.J. Llope for the STAR TOFp Group, STAR Collaboration Meeting, plenary session, BNL, August, 1999. Transparencies available from http://bonner-mac8.rice.edu/~TOF/default.html.

[5] W.J. Llope for the STAR TOFp Group, STAR Review II, October 7, 1999. Transparencies available from http://bonner-mac8.rice.edu/~TOF/default.html.

[6] W. Christie, "Cooling and Dehumidifying Requirements for the STAR Detector System at RHIC." Feb. 7, 1995.

[7] B. Stringfellow, private communication.

[8] A. Lebedev, private communication.

[9] R. Brown, private communication.

6 MSDSs & Manufacturer's Descriptions

The following pages provide more detailed technical and safety information on various TOFp components. These include both general product information pages obtained from the manufacturer and Materials Safety Data Sheets (MSDSs), as labelled. Each page is also labelled with its source as the URL at the bottom.

6.1 Isolation Strips

CORNELL PDC Planning Design & Construction

Material Safety Data Sheets

DOD Hazardous Material Information
July, 1998
For Cornell University Convenience Only

UHMW/POLYETHYLENE

FSC: 6850
NIIN: 00F009255
NSN: 685000F0092555
MANUFACTURERS CAGE: 5H407
PART NO INDICATOR: A
PART NUMBER TRADE NAME: UHMW/POLYETHYLENE

General Information

ITEM NAME: POLYOLEFINS PLASTICS
MANUFACTURERS NAME: LUSK PLASTICS
MANUFACTURERS STREET: 26575 CORPORATE AVENUE
MANUFACTURERS P O BOX: N/K
MANUFACTURERS CITY: HAYWARD
MANUFACTURERS STATE: CA
MANUFACTURERS COUNTRY:
MANUFACTURERS ZIP CODE: 94545
MANUFACTURERS EMERG PH: (415) 785-6452
MANUFACTURERS INFO PH: (415) 785-6452
DISTRIBUTOR VENDOR 1:
DISTRIBUTOR VENDOR 1 CAGE:
DISTRIBUTOR VENDOR 2:
DISTRIBUTOR VENDOR 2 CAGE:
DISTRIBUTOR VENDOR 3:
DISTRIBUTOR VENDOR 3 CAGE:
DISTRIBUTOR VENDOR 4:
DISTRIBUTOR VENDOR 4 CAGE:
SAFETY DATA ACTION CODE:
SAFETY FOCAL POINT: F
RECORD NO FOR SAFETY ENTRY: 001
TOT SAFETY ENTRIES THIS STK: 001
STATUS:
DATE MSDS PREPARED: 06JUN88
SAFETY DATA REVIEW DATE: 29AUG89
SUPPLY ITEM MANAGER:
MSDS PREPARERS NAME:
PREPARERS COMPANY: LUSK PLASTICS
PREPARERS ST OR P O BOX: 26575 CORPORATE AVENUE
PREPARERS CITY: HAYWARD
PREPARERS STATE: CA
PREPARERS ZIP CODE: 94545
OTHER MSDS NUMBER:
MSDS SERIAL NUMBER: BGZQQ
SPECIFICATION NUMBER:
SPEC TYPE GRADE CLASS:
HAZARD CHARACTERISTIC CODE:
UNIT OF ISSUE:
UNIT OF ISSUE CONTAINER QTY:
TYPE OF CONTAINER:
NET UNIT WEIGHT:

Figure 5: Ultra High Molecular Weight (UHMW) Polyethelyene MSDS page 1.

NRC STATE LICENSE NUMBER:
NET EXPLOSIVE WEIGHT:
NET PROPELLANT WEIGHT AMMO:
COAST GUARD AMMUNITION CODE:

Physical & Chemical Characteristics

APPEARANCE AND ODOR: SOLID SHAPES, NATURAL TO BLACK, SLIGHT ODOR.
BOILING POINT: N/R
MELTING POINT: N/R
VAPOR PRESSURE MM HG 70 F: N/R
VAPOR DENSITY AIR 1: N/R
SPECIFIC GRAVITY: .7 - 2.20
DECOMPOSITION TEMPERATURE: N/R
EVAPORATION RATE AND REF: N/R
SOLUBILITY IN WATER: NIL
PERCENT VOLATILES BY VOLUME: N/R
VISCOSITY:
PH: N/R
RADIOACTIVITY:
FORM RADIOACTIVE MATL:
MAGNETISM MILLIGAUSS:
CORROSION RATE IPY: N/R
AUTOIGNITION TEMPERATURE:

Fire and Explosion Hazard Data

FLASH POINT: N/R
FLASH POINT METHOD: N/P
LOWER EXPLOSIVE LIMIT: N/R
UPPER EXPLOSIVE LIMIT: N/R
EXTINGUISHING MEDIA: CO2, WATER, FOAM, DRY CHEMICALS
SPECIAL FIRE FIGHTING PROC: NONE
UNUSUAL FIRE AND EXPL HAZRDS: SMALL CHIPS, FINE TURNINGS, & DUST MAY IGNITE READILY.

Reactivity Data

STABILITY: YES
COND TO AVOID (STABILITY): EXCESSIVE HEAT DURING STORAGE.
MATERIALS TO AVOID: N/R
HAZARDOUS DECOMP PRODUCTS: N/R
HAZARDOUS POLY OCCUR: NO
CONDITIONS TO AVOID POLY: N/R

Health Hazard Data

LD50 LC50 MIXTURE: N/K
ROUTE OF ENTRY INHALATION: YES
ROUTE OF ENTRY SKIN: YES
ROUTE OF ENTRY INGESTION: YES
HEALTH HAZ ACUTE AND CHRONIC: FOR STANDARD OPERATIONS (E.G. CUTTING/ MACHINING/GRINDING) PLASTICS PRESENT A LOW HEALTH RISK/ARE USUALLY CONSIDERED A NUISANCE DUST WHEN PARTICULATE IS <15 MG/CUM. EYES: IRRITATION. SKIN: MOLTEN POLYMER CAUSE THERMAL BURNS. DON'T ATTEMPT TO PEEL POLYMER. INGESTION: CAN RESULT IN RESPIRATORY TRACT IRRITATION/NAUSEA.
CARCINOGENICITY NTP: NO
CARCINOGENICITY IARC: NO
CARCINOGENICITY OSHA: NO
EXPLANATION CARCINOGENICITY: INGREDIENTS MAY BE CONSIDERED HAZARDOUS/ PRESENT CARCINOGINIC/HEALTH CONCERNS DUE TO CHEMICAL CONCENTRATIONS OF FORM.
SIGNS SYMPTOMS OF OVEREXP: EYES: IRRITATION. SKIN: MOLTEN POLYMER CAUSES THERMAL BURNS. IF MOLTEN POLYMER CONTACTS THE SKIN, COOL RAPIDLY W/ COOL WATER. DON'T ATTEMPT TO PEEL POLYMER. OBTAIN MEDICAL HELP FOR THERMAL BURN. INHALATION: CAN RESULT IN RESPIRATORY TRACT IRRITATION & NAUSEA.
MED COND AGGRAVATED BY EXP: N/K
EMERGENCY FIRST AID PROC: SKIN: REMOVE PARTICLES THOROUGHLY BY WASHING W/SOAP & WATER. EYES: FLUSH THOROUGHLY W/WATER. IF IRRITATION PERSISTS, CALL PHYSICIAN.

Figure 6: Ultra High Molecular Weight (UHMW) Polyethelyene MSDS page 2.

CORNELL PDC Material Safety Data Sheets
Planning Design & Construction

DOD Hazardous Material Information
July, 1998
For Cornell University Convenience Only

UHMW/POLYETHYLENE

FSC: 6850
NIIN: 00F009255
NSN: 685000F0092555
MANUFACTURERS CAGE: 5H407
PART NO INDICATOR: A
PART NUMBER TRADE NAME: UHMW/POLYETHYLENE

General Information

ITEM NAME: POLYOLEFINS PLASTICS
MANUFACTURERS NAME: LUSK PLASTICS
MANUFACTURERS STREET: 26575 CORPORATE AVENUE
MANUFACTURERS P O BOX: N/K
MANUFACTURERS CITY: HAYWARD
MANUFACTURERS STATE: CA
MANUFACTURERS COUNTRY:
MANUFACTURERS ZIP CODE: 94545
MANUFACTURERS EMERG PH: (415) 785-6452
MANUFACTURERS INFO PH: (415) 785-6452
DISTRIBUTOR VENDOR 1:
DISTRIBUTOR VENDOR 1 CAGE:
DISTRIBUTOR VENDOR 2:
DISTRIBUTOR VENDOR 2 CAGE:
DISTRIBUTOR VENDOR 3:
DISTRIBUTOR VENDOR 3 CAGE:
DISTRIBUTOR VENDOR 4:
DISTRIBUTOR VENDOR 4 CAGE:
SAFETY DATA ACTION CODE:
SAFETY FOCAL POINT: F
RECORD NO FOR SAFETY ENTRY: 001
TOT SAFETY ENTRIES THIS STK: 001
STATUS:
DATE MSDS PREPARED: 06JUN88
SAFETY DATA REVIEW DATE: 29AUG89
SUPPLY ITEM MANAGER:
MSDS PREPARERS NAME:
PREPARERS COMPANY: LUSK PLASTICS
PREPARERS ST OR P O BOX: 26575 CORPORATE AVENUE
PREPARERS CITY: HAYWARD
PREPARERS STATE: CA
PREPARERS ZIP CODE: 94545
OTHER MSDS NUMBER:
MSDS SERIAL NUMBER: BGZQQ
SPECIFICATION NUMBER:
SPEC TYPE GRADE CLASS:
HAZARD CHARACTERISTIC CODE:
UNIT OF ISSUE:
UNIT OF ISSUE CONTAINER QTY:
TYPE OF CONTAINER:
NET UNIT WEIGHT:

Figure 7: Ultra High Molecular Weight (UHMW) Polyethelyene MSDS page 3.

Precautions for Safe Handling and Use

STEPS IF MATL RELEASED SPILL: N/R
NEUTRALIZING AGENT: N/R
WASTE DISPOSAL METHOD: FOLLOW FEDERAL, STATE & LOCAL REGULATIONS REGARDING DISPOSAL.
PRECAUTIONS HANDLING STORING: USE GOOD HOUSEKEEPING PRACTICES TO PREVENT ACCUMULATION OF DUST & TO KEEP AIRBORNE DUST TO A MINIMUM.
OTHER PRECAUTIONS: N/R

Control Measures

RESPIRATORY PROTECTION: NIOSH APPROVED DUST RESPIRATOR SHOULD BE USED DURING FABRICATION, CUTTING/MACHINING.
VENTILATION: USUALLY CONSIDERED A NUISANCE DUST WHEN PARTICULATE IS <15 MG/CUM.
PROTECTIVE GLOVES: PROTECTIVE
EYE PROTECTION: SAFETY GLASSES
OTHER PROTECTIVE EQUIPMENT: PROTECTIVE FOOTWEAR & CLOTHING FOR WELDING, CUTTING/BURNING.
WORK HYGIENIC PRACTICES: USE GOOD HOUSEKEEPING PRACTICES TO PREVENT ACCUMULATIO OF DUST & TO KEEP AIRBORNE DUST TO A MINIMUM.
SUPPL SAFETY HEALTH DATA: N/K

Transportation Data

TRANSPORTATION ACTION CODE:
TRANSPORTATION FOCAL POINT:
TRANS DATA REVIEW DATE:
DOT PSN CODE:
DOT SYMBOL:
DOT PROPER SHIPPING NAME:
DOT CLASS:
DOT ID NUMBER:
DOT PACK GROUP:
DOT LABEL:
DOT DOD EXEMPTION NUMBER:
IMO PSN CODE:
IMO PROPER SHIPPING NAME:
IMO REG PAGE NUMBER:
IMO UN NUMBER:
IMO UN CLASS:
IMO SUBSID RISK LABEL:
IATA PSN CODE:
IATA UN ID NUMBER:
IATA PROPER SHIP NAME:
IATA UN CLASS:
IATA SUBSID RISK CLASS:
IATA LABEL:
AFI PSN CODE:
AFI SYMBOLS:
AFI PROP SHIPPING NAME:
AFI CLASS:
AFI ID NUMBER:
AFI PACK GROUP:
AFI LABEL:
AFI SPECIAL PROV:
AFI BASIC PAC REF:
MMAC CODE:
N O S SHIPPING NAME:
ADDITIONAL TRANS DATA:

Disposal Data

DISPOSAL DATA ACTION CODE:
DISPOSAL DATA FOCAL POINT:
DISPOSAL DATA REVIEW DATE:
RECNUM FOR THIS DISP ENTR:
TOT DISP ENTRIES PER NSN:
LANDFILL BAN ITEM:
DISPOSAL SUPPLEMENTAL DAT:
EPAHAZWST 1ST CODE NEW:

Figure 8: Ultra High Molecular Weight (UHMW) Polyethelyene MSDS page 4.

6.2 Foam

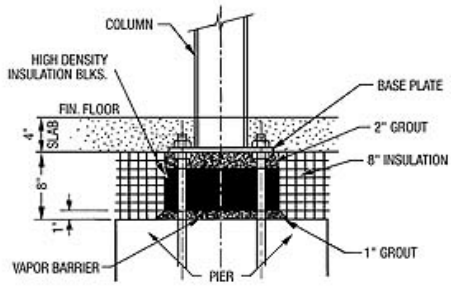
LAST-A-FOAM®

ENGINEERED HIGH DENSITY RIGID POLYURETHANE FOAMS

LAST-A-FOAM® CFC-free rigid foam products are flame-resistant, versatile, and available in a wide range of densities, sheet thicknesses and sizes. **LAST-A-FOAM®** products are made using polyether polyurethane resins, and exhibit great uniformity and consistency in all properties. They are dimensionally stable, chemically inert, and resistant to most solvents and resins. Strong and durable, **LAST-A-FOAM®** can replace wood and other materials in many applications.

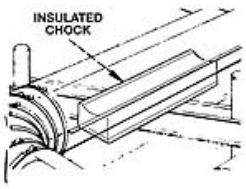
LAST-A-FOAM® FR-6700 is a CFC-free, rigid, closed-cell, flame-retardant polyurethane foam available in densities ranging from 3 to 40 pounds per cubic foot. It exhibits a high strength-to-weight ratio due to its cellular structure and cross-linked resin. Also, because of its closed-cell structure, **LAST-A-FOAM® FR-6700** has great resistance to water absorption, and will not swell, crack, or split on exposure to water. **LAST-A-FOAM® FR-6700** is stable, inert, and is resistant to most chemicals and solvents. It is easily worked with common tools, and performs well as a primary or replacement for many materials in a variety of applications. The last two digits of product numbers describe foam density in pounds per cubic foot.

CONSTRUCTION: **LAST-A-FOAM®** in sheet form is used for insulation and structural applications in commercial and industrial applications. A very useful application of our R-9330 (30 lbs/cubic foot) foam is in column-bearing blocks in cold-storage building applications, replacing oak blocks. This product resists compressive loads of 1000 psi with less than 2% deflection. Since **LAST-A-FOAM®** will not absorb water, nor will it rot, it retains its structural integrity over the life of the building.



Typical **LAST-A-FOAM®** R-9330 Column-bearing block installation in cold-storage building, replacing rot-prone oak blocks with a closed-cell insulating structural foam.

Because **LAST-A-FOAM® FR-6700** has outstanding insulation value and a high strength-to-weight ratio, it performs very well in pipe-support applications for both hot and cold lines, where it is important to isolate the line from ambient conditions.



LAST-A-FOAM® FR-6700 was used extensively in the Alaska oil pipeline project.

LAST-A-FOAM® FR-6700 is also used in making laminated, insulated panels for emergency shelters and other temporary structures, as well as walk-in freezers and coolers, and dry-kilns. **LAST-A-FOAM® FR-6700** has been used for insulating core in sports flooring over ice, as used in the

MARINE: **LAST-A-FOAM® FR-6700** and **R-3300** are used in marine applications where resistance to moisture, rot and decay, and compatibility with fiberglass resins are important factors.

LAST-A-FOAM® FR-6700 is used in marine construction for hull stringers, motor mounts, and for boat transoms, as well as in superstructure applications. Most structural applications use foams in densities from 6 to 40 lbs/cubic foot.

LAST-A-FOAM® R-3300 is a hydrostatic-pressure resistant foam that has outstanding (up to 500 psi) resistance to penetration by water and other liquids. It is available in densities from 10 to 18 lbs/cubic foot. It also provides permanent flotation in semi-deep submersible craft.

NUCLEAR: **LAST-A-FOAM® FR-6700** is used in insulating and isolating radioactive nuclear materials from shock, impact, and fire damage in crash situations. It has been specifically formulated to produce an insulating char in fire situations, which keeps excessive heat from dangerous cargoes.

Another nuclear industry application for **LAST-A-FOAM® FR-6700** is for safety blocks placed under nuclear reactor components to be moved during plant dismantling. The special impact-absorbing properties of **LAST-A-FOAM®** prevent the release of nuclear material by keeping components from shattering or bursting if dropped.

MODELS, PROTOTYPES, AND CNC-PROOFING STOCK: Lightweight, strong, dimensionally stable, uniform, and grainless, **LAST-A-FOAM® FR-7300** works extremely well for making models, prototypes, and tooling. Available in densities from 7 to 30 lbs/cubic foot, this material offers a wide range of possibilities for matching the right material to the job.

If you machine parts on CNC equipment, **LAST-A-FOAM® FR-7300** allows you to confirm the accuracy of a part-cutting program using a low-cost material that will not damage expensive cutting tools. By selecting the right density, you can maintain exacting tolerances while proving your cutter paths.

LAST-A-FOAM® FR-7300 can be finished or painted with ease, using virtually any materials you wish. Unaffected by solvents and resins, **FR-7300** can be made to look like anything you please. That may be why it is used extensively in Hollywood and at amusement parks to produce many familiar items and characters.

SIGN-FOAM®, a special grade of **LAST-A-FOAM®** , is used throughout the United States and the world for both indoor and outdoor signs. Whether it is routed, carved, sandblasted or machined, **SIGN-FOAM®** has become the sign-maker's substrate of choice.

SIGN-FOAM® is marketed and distributed exclusively by SIGN ARTS PRODUCTS, INC.

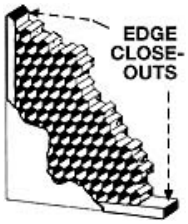
Figure 9: “Last-A-Foam” FR6700 manufacturer’s description page 1.

LAST-A-FOAM®

ENGINEERED HIGH DENSITY RIGID POLYURETHANE FOAMS

LAST-A-FOAM ® FR-6700 is qualified to Boeing Material Specification BMS 8-133, McDonnell-Douglas Material Specification DMS-1937, Federal Aviation Regulation FAR 25.853 (a) and (b), and numerous other aircraft, aerospace, defense contractor, and MIL-specifications. A high-performance product, **LAST-A-FOAM ® FR-10100**, also meets the requirements of some of these specifications.

AIRCRAFT: **LAST-A-FOAM ® FR-6700** is used extensively as high-strength, light-weight flame resistant composite core material and as "edge-close-out" for honeycomb structures in:



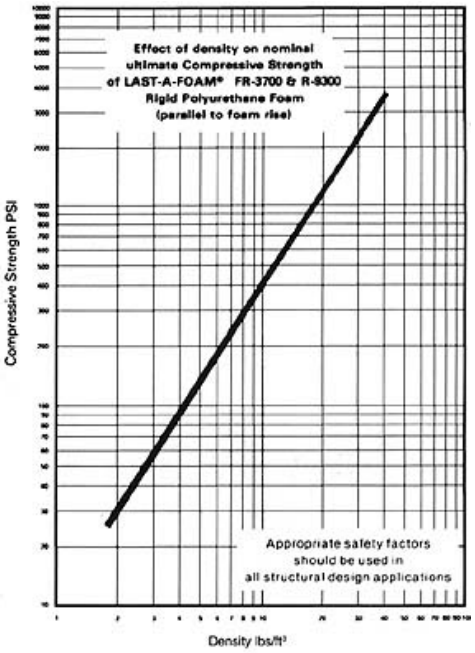
- passenger cabin walls and ceilings
- overhead stow bins
- class divider partitions
- food-service galleys and lavatory walls

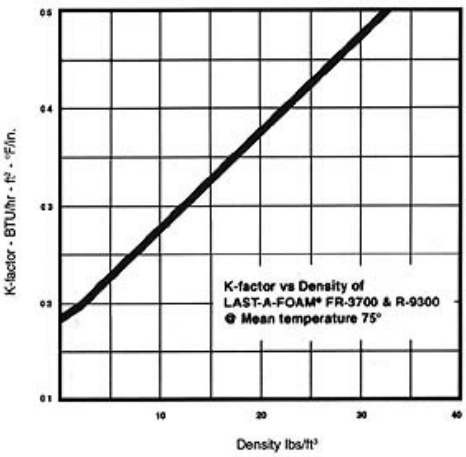
LAST-A-FOAM ® FR-10100 foams are isocyanurate formulations with greater resistance to high-temperature conditions, with reduced flame-spread and smoke-development in fire applications. **FR-10100** foams are produced in densities from 6 to 20 lbs/cubic foot, and offer the user another choice for core material in autoclave, hot press, and RTM applications where temperature and pressure exceed the limits of **FR-6700** properties.

Under development is **LAST-A-FOAM ®** FR-10300, a further improvement in our polyurethane material technology. **LAST-A-FOAM ®** FR-10300 will conform to the more stringent flammability and heat-release requirements of FAR 25.853 while maintaining other important foam physical properties.

LAST-A-FOAM ® FR-6718 scored with a patented design under BMS 8-133, to allow escape of volatile gases evolved in composite cure cycle. This enhancement has cut panel rejection rates virtually to zero.

Graphs show how compressive strength and K-factor vary with foam density.





http://www.generalplastics.com/PAGE3.html

Figure 10: "Last-A-Foam" FR6700 manufacturer's description page 2.

GENERAL PLASTICS MFG -- FRL-6700 LAST-A-FOAM PART A
MATERIAL SAFETY DATA SHEET
NSN: 933000F049008
Manufacturer's CAGE: 28014
Part No. Indicator: A
Part Number/Trade Name: FRL-6700 LAST-A-FOAM PART A

==========

General Information

==========

Company's Name: GENERAL PLASTICS MFG CO
Company's Street: 4910 BURLINGTON WAY
Company's P. O. Box: 9097
Company's City: TACOMA
Company's State: WA
Company's Country: US
Company's Zip Code: 98409-2833
Company's Emerg Ph #: 206-473-5000
Company's Info Ph #: 206-473-5000
Record No. For Safety Entry: 001
Tot Safety Entries This Stk#: 002
Status: KE
Date MSDS Prepared: 13MAR96
Safety Data Review Date: 17JUL96
Preparer's Company: GENERAL PLASTICS MFG CO
Preparer's St Or P. O. Box: 4910 BURLINGTON WAY
Preparer's City: TACOMA
Preparer's State: WA
Preparer's Zip Code: 98409-2833
MSDS Serial Number: BZVFX
Hazard Characteristic Code: N1

==========

Ingredients/Identity Information

==========

Proprietary: NO
Ingredient: DIPHENYLMETHANEDIISOCYANATE (MDI), METHYLENE BIS
(PHENYLISOCYANATE), 4,4 DIPHENYLMETHANE DIISOCYANATE (MDI)
Ingredient Sequence Number: 01
Percent: 50
NIOSH (RTECS) Number: NQ9350000
CAS Number: 101-68-8
OSHA PEL: 0.02 PPM
ACGIH TLV: 0.051 MG/CUM
Other Recommended Limit: 0.005 PPM

Proprietary: NO
Ingredient: HIGHER OLIGOMERS OF MDI, POLYMETHYLENE POLYPHENYLENE
POLYISOCYANATE
Ingredient Sequence Number: 02
Percent: 50
NIOSH (RTECS) Number: TR0350000
CAS Number: 9016-87-9

==========

Physical/Chemical Characteristics

==========

Appearance And Odor: DARK BROWN LIQUID W/A SLIGHT MUSTY ODOR
Boiling Point: 406F
Vapor Pressure (MM Hg/70 F): <0.0001
Vapor Density (Air=1): 8.5
Specific Gravity: 1.24
Solubility In Water: INSOLUBLE

==========

Fire and Explosion Hazard Data

==========

Flash Point: 425F
Flash Point Method: COC
Extinguishing Media: DRY CHEMICAL, CO2, FOAM, EXTENSIVE WATER SPRAY.
Special Fire Fighting Proc: DURING A FIRE, 4.4-DEPHENYLMETHANE-
DIISOCYANATE VAPORS & OTHER IRRITATING &/HIGHLY TOXIC VAPORS MAY BE
PRESENT. SCBA & FULL PROTECTIVE GEAR MUST BE USED.
Unusual Fire And Expl Hazrds: AT TEMPS GREATER THAN 400F THIS MATERIAL CAN
REACT &/DECOMPOSE WHICH CAN CAUSE PRESSURE BUILDUP IN CLOSED CONTAINERS &
EXPLOSIVE RUPTURE IS POSSIBLE.

==========

Reactivity Data

==========

Stability: YES
Cond To Avoid (Stability): MOISTURE
Materials To Avoid: WATER, ALCOHOL, AMMONIA, BASES & ACIDS, ALKALINE
MATERIALS & SOME METAL COMPOUNDS.
Hazardous Decomp Products: TEMPS >400F.
Hazardous Poly Occur: NO

==========

Health Hazard Data

==========

LD50-LC50 Mixture: ORAL LD50(RAT): 10 G/KG
Route Of Entry - Inhalation: YES

Figure 11: "Last-A-Foam" FR6700 Part A MSDS page 1.

Route Of Entry - Skin: NO
Route Of Entry - Ingestion: YES
Health Haz Acute And Chronic: INGESTION: IRRITATON OF THE MOUTH, PHARYNX, DERMATITIS & SENSITIZATION CAN DEVELOP AFTER REPEATED/PROLONGED CONTACT. INHALATION: VAPORS & AEROSOLS CAN IRRITATE EYES, NOSE, RESPIRATORY PASSAGES & CAN RESULT IN PERMANENT DECREASE IN LUNG FUNCTION.
Carcinogenicity - NTP: NO
Carcinogenicity - IARC: NO
Carcinogenicity - OSHA: NO
Explanation Carcinogenicity: NONE
Signs/Symptoms Of Overexp: IRRITATION.
Med Cond Aggravated By Exp: ASTHMA, BRONCHITIS, EMPHYSEMA, SKIN ALLERGIES & ECZEMA & ASTHMA LIKE RESPIRATORY SENSITIZATION.
Emergency/First Aid Proc: SKIN: REMOVE W/SOAP & WATER. EYES: IMMEDIATELY FLUSH W/PLENTY OF WATER FOR 15 MINS. INGESTION: GIVE 1/2 GLASSES OF WATER TO DRINK. DON'T INDUCE VOMITING. INHALATION: REMOVE TO FRESH AIR. OBTAIN MEDICAL ATTENTION IN ALL CASES.

Precautions for Safe Handling and Use

Steps If Matl Released/Spill: WEAR PROTECTIVE EQUIPMENT & RESPIRATORY PROTECTION DURING CLEANUP. MIX W/AN ABSORBENT & TREAT W/A DECONTAMINATION SOLUTION. DISSOLVE & MIX THE ABSORBED AREA W/THE SOLUTION TO OBTAIN A WET TO DAMP SLURRY, ALLOW IT TO REACT FOR AN HOUR. (SEE SUPP)
Neutralizing Agent: DECONTAMINATED SOLUTION: 3-8% AMMONIA IN WATER. 5-10 SODIUM CARBONATE.
Waste Disposal Method: DISPOSE OF IAW/FEDERAL, STATE & LOCAL REGULATIONS. SOLID NOR THE LIQUID PORTION IS A HAZARDOUS WASTE UNDER RCRA 40.
Precautions-Handling/Storing: STORE IN TIGHTLY SEALED CONTAINER TO PROTECT FROM ATMOSPHERIC MOISTURE. NEVER SEAL A CONTAINER THAT MAY BE CONTAMINATED.
Other Precautions: REACTION W/WATER WILL PRODUCE CO2 WHICH WILL PRESSURIZE CONTAINERS. PREVENT SKIN & EYE CONTACT. AVOID BREATHING VAPORS/AEROSOLS.

Control Measures

Respiratory Protection: IF NECESSARY, USE A NIOSH APPROVED POSITIVE PRESSURE SUPPLIED AIR RESPIRATOR. FOR EMERGENCIES USE A SCBA.
Ventilation: IS SUFFICIENT TO KEEP VAPORS BELOW THE TLV AT ROOM TEMPS.
Protective Gloves: IMPERVIOUS
Eye Protection: SAFETY GLASSES/GOGGLES/FULL FACE SHIELD
Other Protective Equipment: PROTECTIVE APRONS, EYE WASH STATION.
Suppl. Safety & Health Data: KEY1:N1. SHOVEL MIX TO AN OPEN CONTAINER. DON'T SEAL THE CONTAINER, ALLOW THE REACTION TO GO TO COMPLETION OVER 48 HOURS/MORE. CO2 WILL BE EVOLVED, LEAVING INSOLUBLE POLYUREAS. THIS PHYSICAL PROPERTIES IS FOR 4.4 DEPHENYLMETHANE-DIISOCYANATE.

Transportation Data

Disposal Data

Label Data

Label Required: YES
Label Status: G
Common Name: FRL-6700 LAST-A-FOAM PART A
Special Hazard Precautions: INGESTION: IRRITATON OF THE MOUTH, PHARYNX, DERMATITIS & SENSITIZATION CAN DEVELOP AFTER REPEATED/PROLONGED CONTACT. INHALATION: VAPORS & AEROSOLS CAN IRRITATE EYES, NOSE, RESPIRATORY PASSAGES & CAN RESULT IN PERMANENT DECREASE IN LUNG FUNCTION.IRRITATION.
Label Name: GENERAL PLASTICS MFG CO
Label Street: 4910 BURLINGTON WAY
Label P.O. Box: 9097
Label City: TACOMA
Label State: WA
Label Zip Code: 98409-2833
Label Country: US
Label Emergency Number: 206-473-5000

Figure 12: "Last-A-Foam" FR6700 Part A MSDS page 2.

GENERAL PLASTICS MFG -- FRL-6700 LAST-A-FOAM PART B
MATERIAL SAFETY DATA SHEET
NSN: 933000F049008
Manufacturer's CAGE: 28014
Part No. Indicator: B
Part Number/Trade Name: FRL-6700 LAST-A-FOAM PART B

==========

General Information

==========

Company's Name: GENERAL PLASTICS MFG CO
Company's Street: 4910 BURLINGTON WAY
Company's P. O. Box: 9097
Company's City: TACOMA
Company's State: WA
Company's Country: US
Company's Zip Code: 98409-2833
Company's Emerg Ph #: 206-473-5000
Company's Info Ph #: 206-473-5000
Record No. For Safety Entry: 002
Tot Safety Entries This Stk#: 002
Status: KE
Date MSDS Prepared: 13MAR96
Safety Data Review Date: 17JUL96
Preparer's Company: GENERAL PLASTICS MFG CO
Preparer's St Or P. O. Box: 4910 BURLINGTON WAY
Preparer's City: TACOMA
Preparer's State: WA
Preparer's Zip Code: 98409-2833
MSDS Serial Number: BZVFY
Hazard Characteristic Code: N1

==========

Ingredients/Identity Information

==========

Proprietary: NO
Ingredient: 1,1-DICHLORO-1-FLUOROETHANE, FREON 141
Ingredient Sequence Number: 01
Percent: 10
NIOSH (RTECS) Number: KI0997000
CAS Number: 1717-00-6
OSHA PEL: 500 PPM

==========

Physical/Chemical Characteristics

==========

Appearance And Odor: BROWN LIQUID W/A SLIGHT AMINE ODOR
Vapor Density (Air=1): >1
Specific Gravity: 1.075
Solubility In Water: COMPLETE

==========

Fire and Explosion Hazard Data

==========

Flash Point: >210F
Extinguishing Media: DRY CHEMICAL, CO2, WATER, FOAM
Special Fire Fighting Proc: DURING A FIRE: IRRITATING &/HIGHLY TOXIC VAPORS MAY BE PRESENT. SCBA & FULL PROTECTIVE GEAR MUST BE USED.
Unusual Fire And Expl Hazrds: NON-COMBUSTIBLE LIQIUD, BUT WILL BURN.

==========

Reactivity Data

==========

Stability: YES
Cond To Avoid (Stability): ROOM TEMP
Materials To Avoid: ISOCYANATES
Hazardous Poly Occur: NO

==========

Health Hazard Data

==========

Route Of Entry - Inhalation: YES
Route Of Entry - Skin: NO
Route Of Entry - Ingestion: YES
Health Haz Acute And Chronic: INGESTION: IRRITATION OF THE MOUTH, PHARYNX, ESOPHAGUS & STOMACH CAN DEVELOP. EYES: WILL CAUSE MODERATE TO SEVERE IRRITATION. SKIN: SLIGHT IRRITATION. INHALATION: OVEREXPOSURE TO 141B VAPOR MAY CAUSE IRRITATION. W/HIGH EXPOSURE LEVELS, EFFECTS CAN INCLUDE CNS DEPRESSION & CARDIAC ARRHYTHMIA.
Carcinogenicity - NTP: NO
Carcinogenicity - IARC: NO
Carcinogenicity - OSHA: NO
Explanation Carcinogenicity: NONE
Signs/Symptoms Of Overexp: IRRITATION, REDNESS, DIZZINESS, LOSS OF CONCENTRATION, INTOXICATION, SUFFOCATION.
Emergency/First Aid Proc: SKIN: REMOVE W/SOAP & WATER. EYES: IMMEDIATELY FLUSH W/PLENTY OF WATER FOR 15 MINS. INGESTION: GIVE 1/2 GLASSES OF WATER TO DRINK. DON'T INDUCE VOMITING. INHALATION: REMOVE TO FRESH AIR. OBTAIN MEDICAL ATTENTION IN ALL CASES.

==========

Precautions for Safe Handling and Use

==========

Figure 13: "Last-A-Foam" FR6700 Part B MSDS page 1.

Steps If Matl Released/Spill: WEAR SKIN, EYE & IF NECESSARY, RESPIRATORY PROTECTION DURING CLEANUP. USE AIR SUPPLIED RESPIRATORY PROTECTION FOR CLEAN UP OF LARGE AREAS IN CONFINED PLACES.
Waste Disposal Method: DISPOSE OF IAW/FEDERAL, STATE & LOCAL REGULATIONS.
Precautions-Handling/Storing: STORE IN TIGHTLY SEALED CONTAINERS AT ROOM TEMP.
Other Precautions: PREVENT SKIN & EYE CONTACT.

Control Measures

Respiratory Protection: USE AIR SUPPLIED RESPIRATOR PROTECTION.
Ventilation: NORMAL FOR STANDARD PROCEDURES IS GENERALLY ADEQUATE. LOCAL EXHAUST USE WHEN LARGE AMOUNTS OF 2 COMPONENTS ARE MIXED.
Protective Gloves: IMPERVIOUS
Eye Protection: SAFETY GLASSES/GOGGLES/FULL FACE SHIELD
Other Protective Equipment: EYEWASH STATION.
Suppl. Safety & Health Data: KEY1:N1.

Transportation Data

Disposal Data

Label Data

Label Required: YES
Label Status: G
Common Name: FRL-6700 LAST-A-FOAM PART B
Special Hazard Precautions: INGESTION: IRRITATION OF THE MOUTH, PHARYNX, ESOPHAGUS & STOMACH CAN DEVELOP. EYES: WILL CAUSE MODERATE TO SEVERE IRRITATION. SKIN: SLIGHT IRRITATION. INHALATION: OVEREXPOSURE TO 141B VAPOR MAY CAUSE IRRITATION. W/HIGH EXPOSURE LEVELS, EFFECTS CAN INCLUDE CNS DEPRESSION & CARDIAC ARRHYTHMIA. IRRITATION, REDNESS, DIZZINESS, LOSS OF CONCENTRATION, INTOXICATION, SUFFOCATION.
Label Name: GENERAL PLASTICS MFG CO
Label Street: 4910 BURLINGTON WAY
Label P.O. Box: 9097
Label City: TACOMA
Label State: WA
Label Zip Code: 98409-2833
Label Country: US
Label Emergency Number: 206-473-5000

Figure 14: “Last-A-Foam” FR6700 Part B MSDS page 2.

6.3 Bicron BC-420 slats

product lines
back

BC-420
Premium Plastic Scintillator

General Description

The premium plastic scintillators described in this data sheet are intended for use in ultra-fast timing and ultra-fast counting applications. BC-418 and BC-422 are recommended for use in small sizes, i.e. when any dimension is less than 4" (100 mm). BC-420 is substantially less expensive than BC-418.

General Technical Data

Base	Polyvinyltoluene
Density	1.032
Refractive Index	1.58
Coefficient of Linear Expansion	7.8 x 10^{-5}, below 67°C
Atomic Ratio, H/C	~1.1
Light Output	At +60°C = 95% of that at +20°C; independent of temperature from -60°C to +20°C
Vapor Pressure	May be used in a vacuum
Solubility	Soluble in aromatic solvents, chlorine, acetone, etc. Insoluble in water, dilute acids, lower alcohols, silicone fluid, grease and alkalis.

Physical Constants

Constant	BC-418	BC-420	BC-422
Light Output, % Anthracene	67	64	55
Rise Time, ns	0.5	0.5	0.35
Decay Time, ns	1.4	1.5	1.6
Pulse Width, FWHM, ns	1.2	1.3	1.3
Light Attenuation Length, cm*	NA**	140	NA**
Wavelength of Max. Emission, nm	391	391	370
No. of H Atoms per cm^3, ($x10^{22}$)	5.21	5.21	5.19
No. of C Atoms per cm^3, ($x10^{22}$)	4.74	4.74	4.71
Ratio H:C Atoms	1.100	1.100	1.102
No. of Electrons per cm^3, ($x10^{23}$)	3.37	3.37	3.34
Principal uses	ultra-fast timimg	ultra-fast timimg	ultra-fast timimg

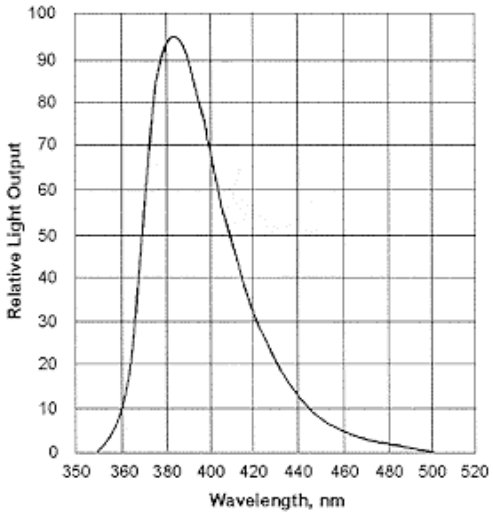
* The typical 1/e attenuation length of a 1 x 20 x 200 cm cast sheet with edges polished as measured with a bialkali photomultiplier tube coupled to one end

** Scintillator recommended for use in small sizes; therefore, the 1/e attenuation length values are not applicable

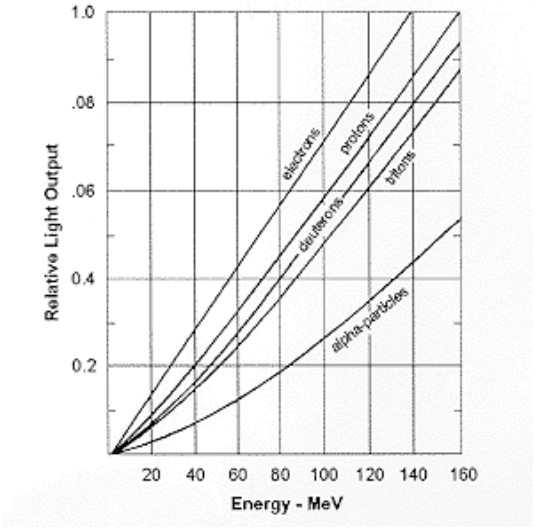
Figure 15: Bicron BC-420 plastic scintillator manufacturer's description page 1.

Emission Spectra

BC-418 & BC-420



Premium Plastic Scintillators
Response to Atomic Particles



Organic Products | Inorganic Scintillation Products | Crystal Products
Bicron RMP | Optics and Oxides | Crismatec | Product Search/Faq
Company Profile | News | Contact Us | NE Technology | Home

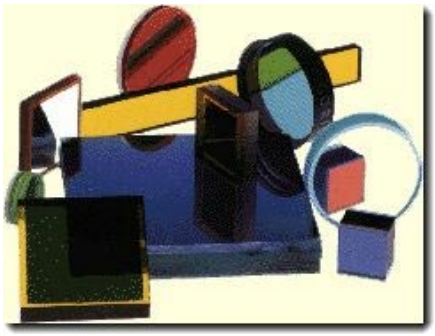
Figure 16: Bicron BC-420 plastic scintillator manufacturer's description page 2.

6.4 Epotek Spectrally Transparent Epoxy

Company
Products
Library RESOURCES
Trade SHOWS
What's NEW
Contact US
Home

Optical

We've got you connected coming and going.



CONNECTING, SPLICING AND BUNDLING are just three of the many jobs that depend on epoxies. The challenge is to choose the ideal epoxy from the many options available. To find the material that will provide optimum connections—for the long haul. And this challenge is shared by the entire range of optical and fiber optic technologies that call for bonding, coating, or encapsulation.

In telecommunication networks, for example, epoxy adhesives must be capable of enduring high temperatures, high humidity, and mechanical tension. The environmental stresses of FTTC and FTTH scenarios and the catastrophic implications of disruptions on fibers carrying traffic at high data rates demand the same assurance of long-term reliability from epoxies as from the fiber itself.

Design Considerations.
The flexibility of epoxy resins allows adhesives, coatings, and encapsulants to be designed with characteristics tailored to the needs of a wide range of uses. For optical and fiber optic applications, key considerations include the spectral transparency and index of refraction of the epoxy, along with its adhesive strength and resistance to heat and moisture. Curing and handling characteristics can also be critical. For example, the consistency of uncured epoxies range from free flowing to nonflowing, so the physical behavior of the material can be matched to the production process. And the emergency of of UV-curing and visible-light-curing fast cure methods without sacrificing the superior strength and durability of epoxies.

Varied Applications.
Optical-grade epoxies provide the adhesion, transparency and refractive indices required for numerous opto-electronic, optical devices and components, including lenses, prisms, beam splitters, filters, encoders, laser windows, LEDs, and photodiodes. For fiber optic telecommunications, data linking, networking and cable TV applications, epoxies are used for fiber-to-connector bonding, fiber-to-fiber splicing, and bonding optical fiber bundles or single fibers into sleeves. Epoxies are also used to reclad PCS fibers to prevent attenuation after stripping for connections, and to bond the core and cladding of plastic fiber optics. In medical fiber optics, the use of epoxies include bundling and terminating light-guide fibers, bonding lenses and other other components to fiber optic terminations as in endoscopes, otoscopes etc.

How to Choose Epoxies.
Extensive information is available on the specifications of EPO-TEK optical-grade adhesives. A detailed explanation of the relevant physical and performance attributes is presented in Technical Paper No. GB-56. See the **Product Selector Guide** and **Products Listing** for additional information.

Applications Listing

Figure 17: Epotek Spectrally Transparent Epoxy manufacturer's description page 1.

	Product															
	301	301-2	302	302-3M	307-1	310	314	320	330	353ND	353ND-T	353ND-4	354	377	390	UVO-114
Application																
Bond 125u glass fiber to fiber optic connector	X	X	X	X	X		X		X	X	X	X	X	X		
Bond 125 or 140u fiber to fiber optic connector		X											X			
Bond fiber optic cable jacket to non-crimp type fiber connect									X	X			X	X		
Glass fiber potting with good visual indication of wicking									X	X			X	X		
Plastic & glass fiber potting or lens & prism bonding		X							X	X			X			X
Coating or potting optically sensitive components								X								
Casting or potting optically clear components & indicators	X	X	X	X			X									
	Product															
	301	301-2	302	302-3M	307-1	310	314	320	330	353ND	353ND-T	353ND-4	354	377	390	UVO-114
Excellent spectral transmission in thin bond lines	X	X	X	X	X		X									
Fast, room temperature curing	X		X		X											
High temperature requirements							X		X	X	X	X	X	X	X	
No electrical resistance change within high humidity environment										X	X			X		
Yag laser (UV transmission)																
Autoclavable										X			X	X		
Medical Device - USP class VI	X	X								X	X			X		
Potting I.R. Detectors		X														
Flexible: Coating or bonding stress sensitive components		X				X										
	Product															
	301	301-2	302	302-3M	307-1	310	314	320	330	353ND	353ND-T	353ND-4	354	377	390	UVO-114
Optical Replication		X														
Fiber Optic bundling in ferrules	X	X		X			X		X	X	X	X	X	X		
Low stress on large core glass fibers in connectors		X											X			

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Product LISTING UV/ VISIBLE

Product Listing | uv/Visible

EPOXY TECHNOLOGY

Figure 18: Epotek Spectrally Transparent Epoxy manufacturer's description page 2.

6.5 Tyvek

TYVEK® – What is TYVEK® ? 12/4/99 2:13 PM

DUPONT Tyvek®

Graphics

T=? What is Tyvek®

Europe, Middle East, and Africa's Region

Home | What is TYVEK® ? | Applications | Working with TYVEK®

- Properties
- Style 10
- Style 14
- Recycling

CASE HISTORIES

TYVEK® is a DuPont registered trademark for a family of tough durable sheet products of high-density polyethylene fibres. The sheet is formed first by spinning continuous strands of very fine interconnected fibres, and then bonding them together with heat and pressure. TYVEK® is white, non-toxic, chemically inert and contains no binders.

The non-woven sheet, after bonding, combines a good printing or coating surface, high opacity and toughness to a degree unique among sheet products of similar weight and price.

TYVEK® is produced in three different types, namely 10, 14 and 16. The fibres in Type 10 Style are bonded to form a tough, dense, opaque sheet. The dense packing of the fine, interconnected fibres produces a smooth surface, high opacity and whiteness. The large number of bonds per unit area results in a stable and abrasion resistant surface with a stiffness similar to paper. Fibre bonding of Types 14 and 16 is restricted to discrete points in the non-woven sheet, producing a high degree of fibre mobility, and giving the non-woven a fabric-like drape.

Other uses for TYVEK®

TYVEK® isn't just used for printing applications. Its unique properties make it the ideal material for :

- Security envelopes
- Protective apparel
- Speciality packaging
- Roofing membranes

Properties - Style 10 - Style 14 - Recycling

Home Graphics - Applications - Working with Tyvek® - Distributors - Case Histories - Enquiry Form

If you have questions or comments, please contact us by e-mail or by phone.

http://www.dupont.com/tyvek/graphics/menu_whatis.htm Page 1 of 1

Figure 19: Tyvek manufacturer's description page 1.

Graphics

Tyvek®

What is TYVEK® ?

Back to What Is TYVEK® Menu

Europe - Middle East & Africa - Asia - U.S.A. Imperial (English) Units

Typical properties of TYVEK® hard structure style 10

Americas - Metric Units

Property	Unit	Style 1025D	Style 1056D	Style 1058D	Style 1070D	Style 1073B	Style 1073D	Style 1079	Style 1085D	Style 7657D	Style 8740D	Test Method
Basis Weight	g/m^2	42.5	55	55	68	75	75	97	108	68	68	ASTM D 3776
Thickness -Range	µm	135 78-197	163 86-239	155 85-209	190 104-272	183 110-260	193 112-274	203 127-279	259 165-353	190 104-272	190 104-272	ASTM D 1777
Tensile MD	N/25.4 mm	90	115	150	165	210	210	295	300	165	165	ASTM D 1682
Tensile CD	N/25.4 mm	105	170	185	180	250	250	310	325	180	180	ASTM D 1682
Elongation at break MD	%	16	14	25	17	30	27	23	22	17	17	ASTM D 1682
Elongation at break CD	%	23	20	29	21	33	31	28	26	21	21	ASTM D 1682
Tear Elmendorf MD	N	8.0	5.8	3.2	4.9	4.5	6.6	3.5	5.4	4.9	4.9	ASMT D 1424
Tear Elmendorf CD	N	7.0	5.4	3.9	4.9	4.5	6.0	3.5	5.8	4.9	4.9	ASTM D 1424
Opacity, Color Quest	%	97.5	97.0	91.0	97.0	93.0	95.5	91.0	97.0	97.0	97.0	
Gurley Porosity	Sec.	28	35	25	28	21	40	87	42	28	28	ASTM D 726-84
Internal Bonding	N/25.4 mm	1.0	1.2	2.2	1.4	2.3	1.7	3.3	2.2	1.4	1.4	ASTM D 2724
Water Resistance Hydrostatic Head	cm	-	-	-	-	170	-	-	-	-	-	AATCC 127
Corona		Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	
Antistat		Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	

Notes:
- All values are Nominals
- MD is Machine Direction
- CD is Cross Direction

Properties - Style 14 - Recycling

Home Graphics - What is TYVEK® - Applications - Working with Tyvek® - Case Histories - Distributors - Enquiry Form

Figure 20: Tyvek manufacturer's description page 2.

DUPONT

Tyvek®

What is TYVEK® ?

Graphics

Properties

Europe, Middle East, and Africa's Region

Home | What is TYVEK® ? | Applications | Working with TYVEK®

- Properties
- Style 10
- Style 14
- Recycling

Colour:
Bright white. Other colours can be obtained by printing, coating or laminating. TYVEK® can be dyed to pastel colours.

Opacity and Hiding Power:
Excellent, wet or dry, even at low weights

Surface:
Smooth and compact suitable for printing, coating or laminating. Excellent surface fibre stability.

Moisture Insensitive:
Physical properties are unaffected when immersed in water.

Rot and Mildew Resistance :
Clean TYVEK® does not promote mildew formation and does not degrade even after extended soil burial.

Chemical Resistance:
Inert to most chemicals including acids, bases and salts.

Solvents, Oils and Greases:
Are readily absorbed, with some swelling and slight loss of physical properties.

Aging:
Accelerated tests indicate good resistance to degradation with age. Physical properties, however, will be reduced with extended direct exposure to ultraviolet rays from sunlight. Ultraviolet resistance can be improved with either heavyweight coating or by adding UV absorbers to the coating.

Temperature range:
Retains toughness and flexibility to -73°C (-100°F). Strength properties decrease at elevated temperatures, and melting occurs at 135°C (275°F).

Porosity:
Moisture vapour transmission of Type 10 products is in the range of coated papers. While MVT of Type 14 products is similar to that of other non-woven and lightly woven fabrics, air porosity is generally low except for Type 16 products.

Linting:
TYVEK® will not generate a significant amount of lint particles under conditions of ordinary use.

Static:
An effective ant-static agent is applied on most styles for printing. Some styles are available without this treatment.

Soiling :
Resistant to water-borne soils, but will readily pick-up oil and grease-borne soil. Garment of Type 14 and 16 can be laundered under proper conditions.

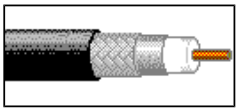
Figure 21: Tyvek manufacturer's description page 3.

6.6 Signal Cable

Belden Detail For: 9310 Amateur Radio and CB Coaxial Cable 12/6/99 11:08 AM

• Contents • Profile • Sales • Trade # • Technical Info • Exit

Amateur Radio and CB Coaxial Cable
RG-58/U Type
20 AWG



1-800-BELDEN-1

Trade Number Industry Stds.	Std. Lgth. (ft.)	Std. Units (lbs.)	AWG (strand) Type (dia.) Nom. D.C.R.	Core O.D. Nom. O.D.	Shields Nom. D.C.R.	Nom. Imp. (ohms)	Vel. of Prop.	Nom. Cap.
9310 UL AWM: 1354 Brilliance	100 U-500 500 U-1000 1000	2.4 10.8 11.5 20.6 21.4	20 (Solid) BC 0.033 in. 10.0 ohms/M'	0.114 in. 0.193 in.	Duobond II 55% TC Braid **Inner** 14.0 ohms/M'	50.0	66.0%	31.0 pF/ft
Metric	(Meters) 30.5 U-152.4 152.4 U-304.9 304.9	(Kg) 1.09 4.9 5.2 9.4 9.7	.838 mm 32.8 ohms/km	2.895 mm 4.902 mm	**Inner** 45.9 ohms/km			101.7 pF/m

Description:		
Insulation:	Polyethylene	Brilliance® 50 Ohm, Transmission and Computer Cable. 20 AWG solid bare copper conductor with polyethylene insulation. Duobond® II plus tinned copper braid, 55% shield coverage. Black PVC jacket. Temperature Rating : 80°C Voltage Rating: 30 Volts (UL) Suggested Operating Temperature Range (Non-UL): -40°C to +80°C. Maximum Operating Voltage (Non-UL): 300 Volts RMS.
Jacket:	PVC	
Plenum Version(s):	n/a	

Attenuation		
Freq MHz	**Nom. Atten. (dB/100ft)**	**Nom. Atten. (dB/100m)**
1.0	0.46	1.51
10.0	1.4	4.59
50.0	2.8	9.18
100.0	3.8	12.5
200.0	5.4	17.7
400.0	7.9	25.9
700.0	11.1	36.4
900.0	12.8	42.0

Attenuation		
Freq MHz	**Nom. Atten. (dB/100ft)**	**Nom. Atten. (dB/100m)**
1000.0	13.9	45.6

▲ Top (Select other related products with BACK or PREVIOUS.)

Disclaimer: Great effort is made to ensure the accuracy of the information presented, but errors or omissions may exist. This listing of information is presented as a courtesy and does not ensure that a product with these specifications is available. Specifications and availablility should be confirmed with a call to our sales representatives or to customer service. Have a question? Call us at 1-800-BELDEN-1 or send us a comment. Page displayed 12/6/99 for category Coaxial Cables.

Figure 22: Coaxial signal cable manufacturer's description.

6.7 HVSys

DISTRIBUTED MULTICHANNEL HIGH VOLTAGE SYSTEM

Contents

MAIN IDEAS

- Make high voltage at place of its comsumption
- Use Cockroft-Walton voltage multiplier
- no high-voltage cables and connectors
- buil-in intellect

Figure 23: HVSys manufacturer's description page 1.

DISTRIBUTED MULTICHANNEL HIGH VOLTAGE SYSTEM

HV Systems are intended for powering of the charged particle detectors in large-scale physical experiments with 10^2 – 10^5 channels

MAIN FEATURES OF THE SYSTEM

- **Cost effective (<100$/channel)**
- **Fully completed functional device**
- **High density, up to 512 individual HV channels per system module**
- **Absence of HV cables and connectors**
- **High stability of output voltages – 0.05%**
- **The own dissipated power less then 0.05 W/channel**
- **The control via serial line: CAN-bus; I2C; RS-232-C**
- **Output voltage and current measurement**
- **Onboard fast output current limitation or tripping**

Figure 24: HVSys manufacturer's description page 2.

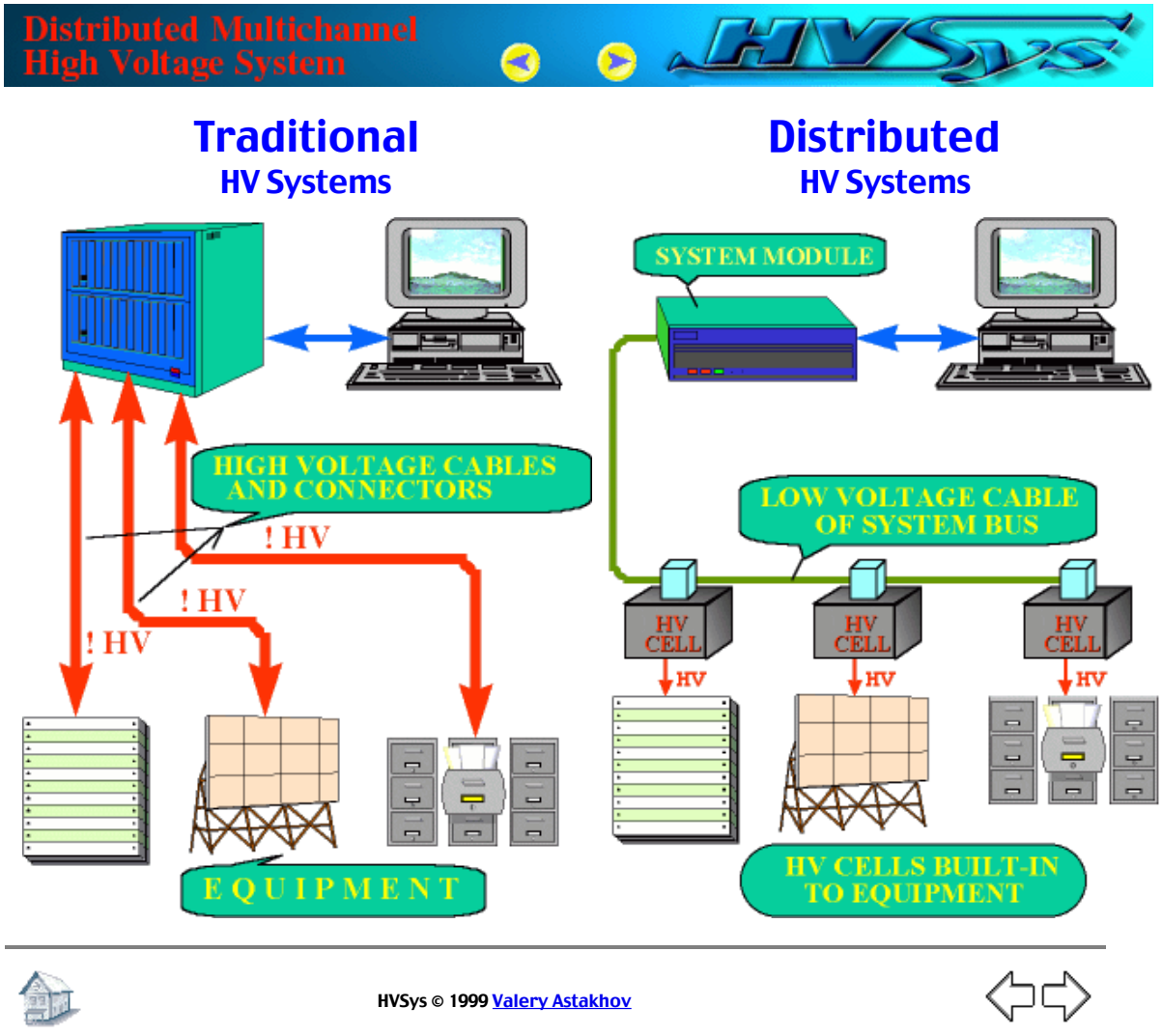


Figure 25: HVSys manufacturer's description page 3.

STRUCTURE OF MULTICHANNEL HIGH VOLTAGE SYSTEM

The High Voltage System (HVS) (Fig. 1) consists of:

- **1. System modules, servicing up to 512 HV cells each. It designed as a module of the EUROMEKHANICS–6 U standard 40 mm wide.**
- **2. System bus, connecting system modules with high–voltage cells. It is made of a 10 lines flat cable.**
- **3. High–voltage cells to provide generation and monitoring of high voltage. They are designed as a small size box.**

Figure 26: HVSys manufacturer's description page 4.

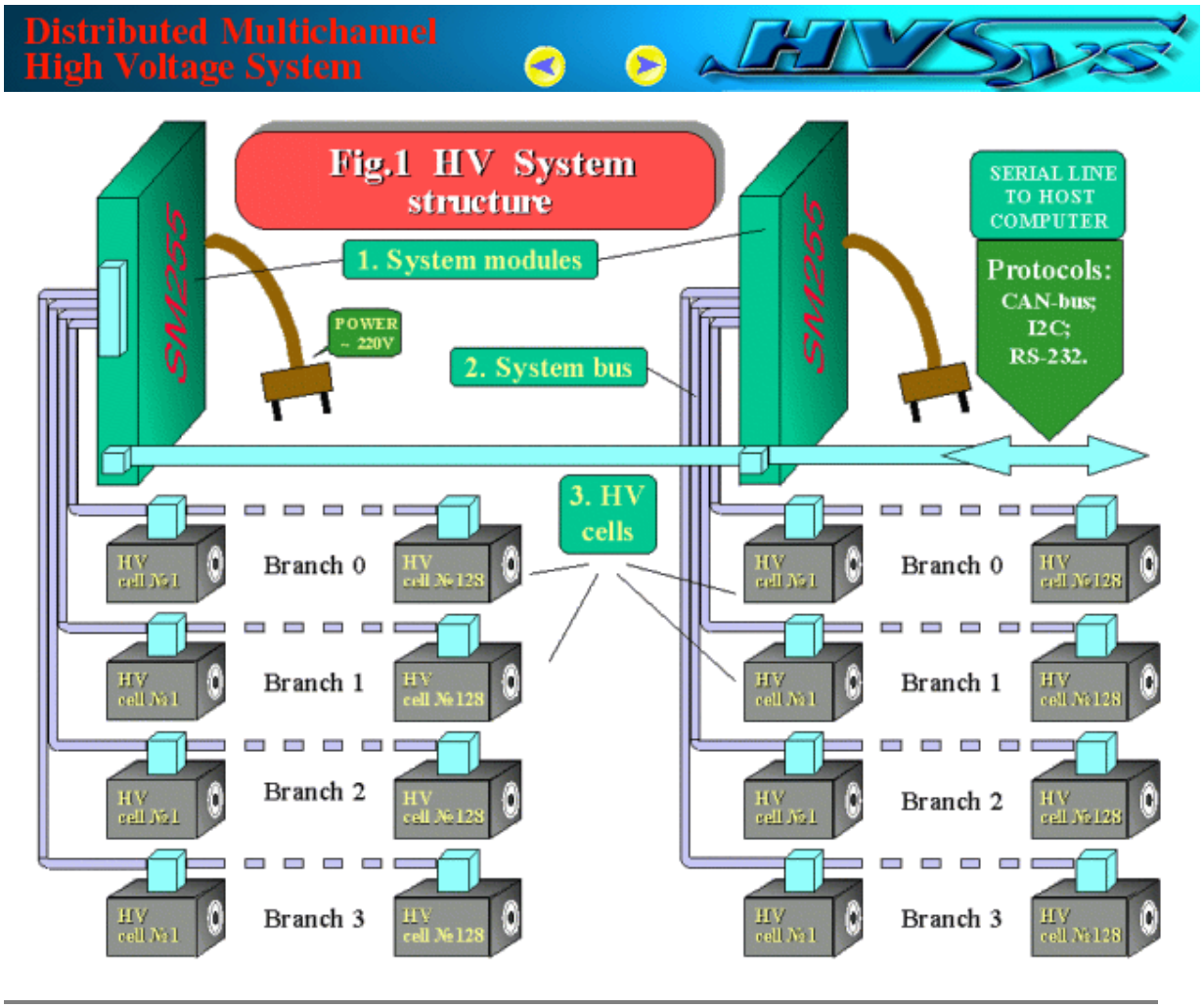


Figure 27: HVSys manufacturer's description page 5.

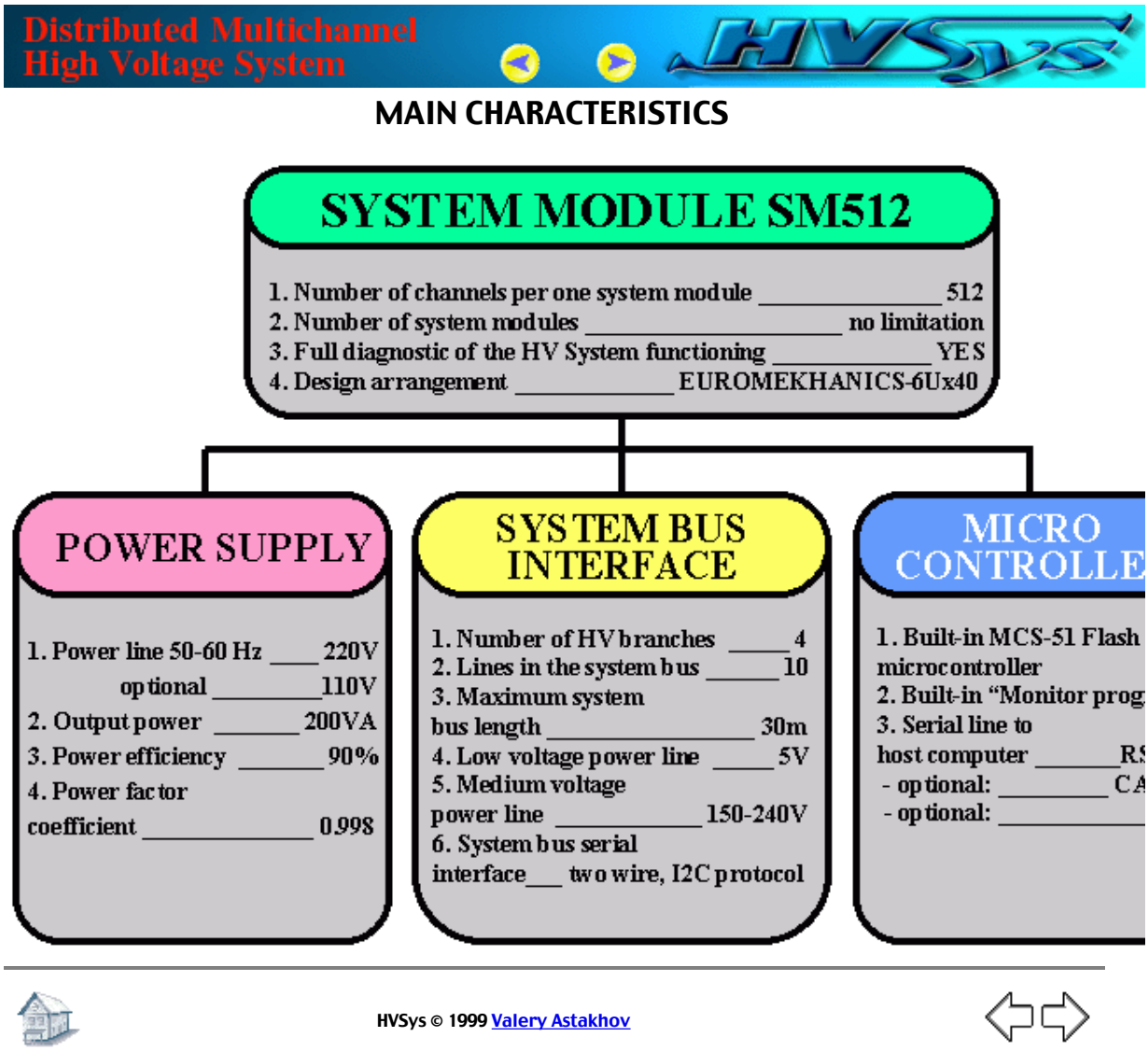


Figure 28: HVSys manufacturer's description page 6.

Distributed Multichannel High Voltage System

HVSys

SYSTEM MODULE SM-255

Module designed as a unit of the EUROMEKHANICS-6 U standard 40mm wide.

SM255 is the previous generation of system modules.

SM512 - Latest generation.

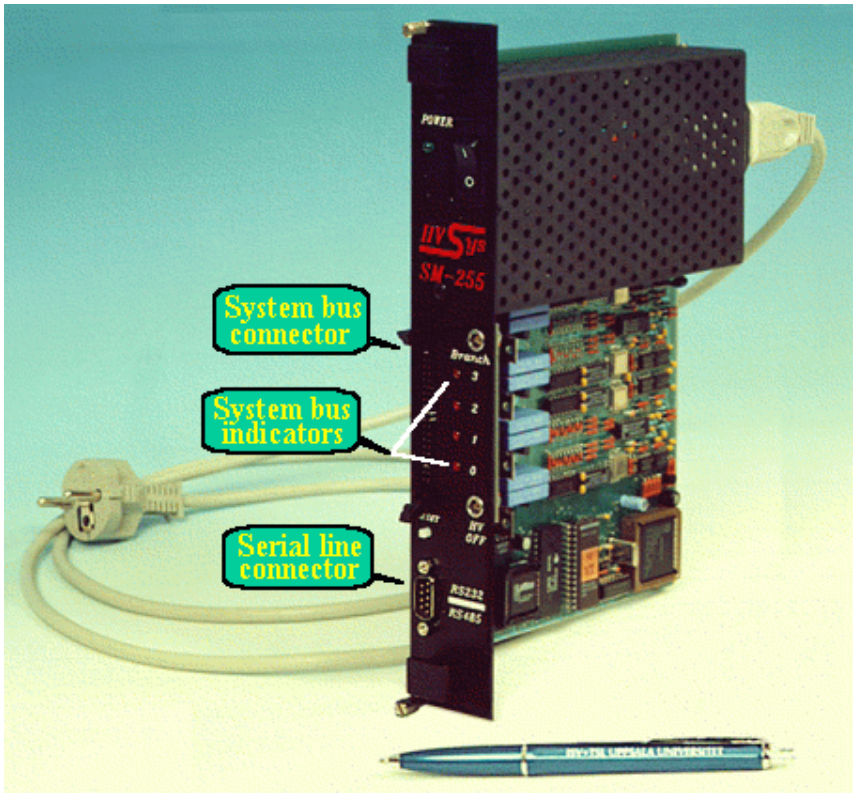


Figure 29: HVSys manufacturer's description page 7.

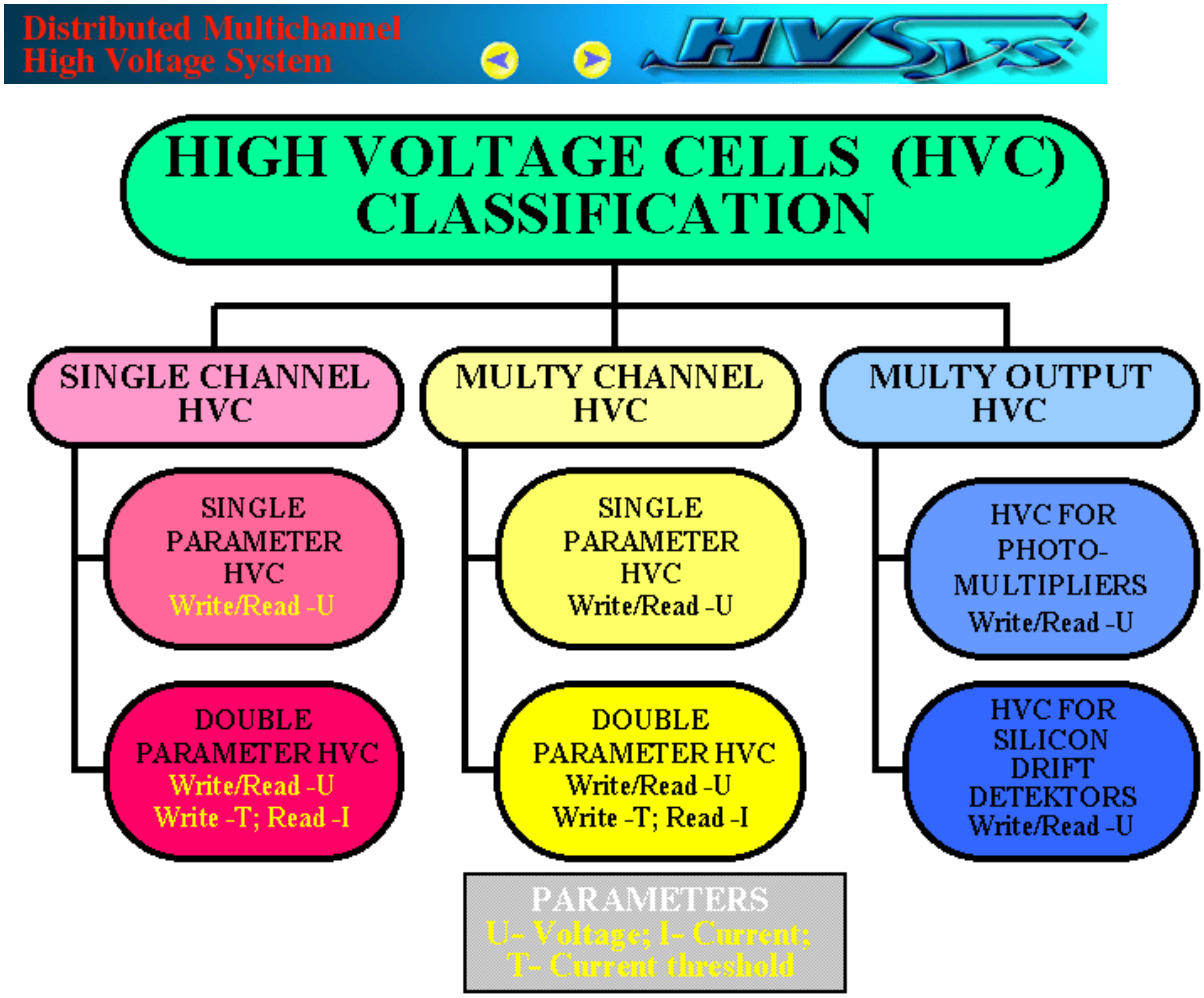


Figure 30: HVSys manufacturer's description page 8.

MAIN CHARACTERISTICS
SINGLE CHANNEL HV CELL

1. Maximum output power	0.5 W
2. Output voltage range	200–10,000 V
3. Output voltage polarity	fixed, pos or neg
4. Output voltage regulation precision	8 or 10 bit
5. Output voltage regulation step	$(U_{max}–U_{min})/256/1024$
6. Output voltage stability	0.05 %
7. Output voltage systematic error	5 %
8. Output voltage temperature factor	200 ppm/K
9. Output voltage ripple	20 mV
10. Current threshold regulation precision	8 or 10 bit
11. Current tripping circuit quick-action	10 ms
12. Voltage and current readout precision	10 bit
13. HV cell power dissipation	0.05 W
14. HV cell dimensions	78x33x12 mm

Figure 31: HVSys manufacturer's description page 9.

Distributed Multichannel High Voltage System

HVSys

MULTICHANNEL MODULE
(example)

Double parameter 8-channel HV module

Design arrangement: EUROMEKHANICS-6Ux20

FUNCTIONS

Write voltage	8 bit
Write current threshold	8 bit
Read voltage	10 bit
Read current threshold	10 bit

Module designed for MDC WASA (Sweden)

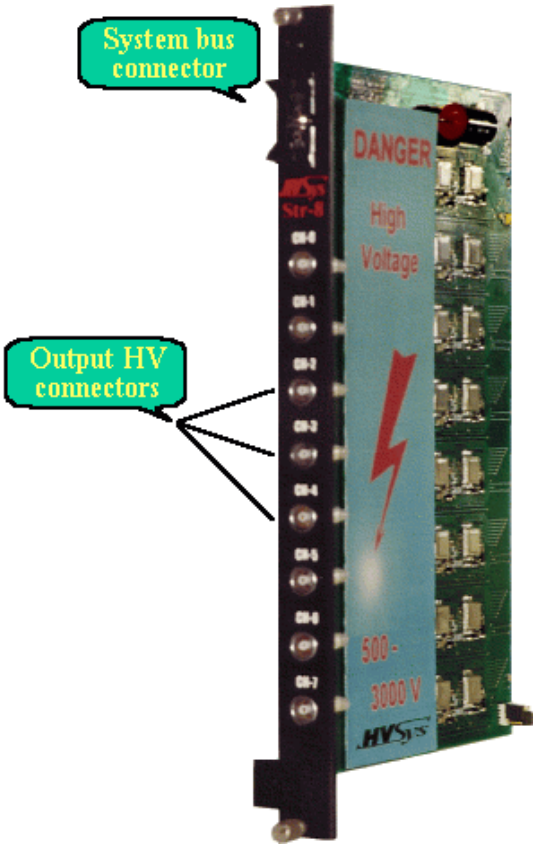


Figure 32: HVSys manufacturer's description page 10.

MAIN CHARACTERISTICS

HV CELL FOR PHOTOMULTIPLIER

1. Output voltage range	200–3000 V
2. Maximum of average output anode current	2 mA
3. Output voltage polarity	fixed, negative
4. Output voltage regulation precision	8 or 10 bit
5. Output voltage regulation step	$(U_{max}-U_{min})/256/1024$
6. Output voltage stability	0.05 %
7. Output voltage systematic error	5 %
8. Output voltage temperature factor	200 ppm/K
9. Crosstalk from the driver to the PMT anode loaded 50 Ohm, scope of voltage, no more	10 uV
10. Voltage readout precision	10 bit
11. Current limitation is fixed	YES
12. HV cell power dissipation	0.05 W
14. HV cell dimensions	see examples

Figure 33: HVSys manufacturer's description page 11.

Distributed Multichannel High Voltage System

CONSTRUCTION OF HV CELL FOR PHOTOMULTIPLIER

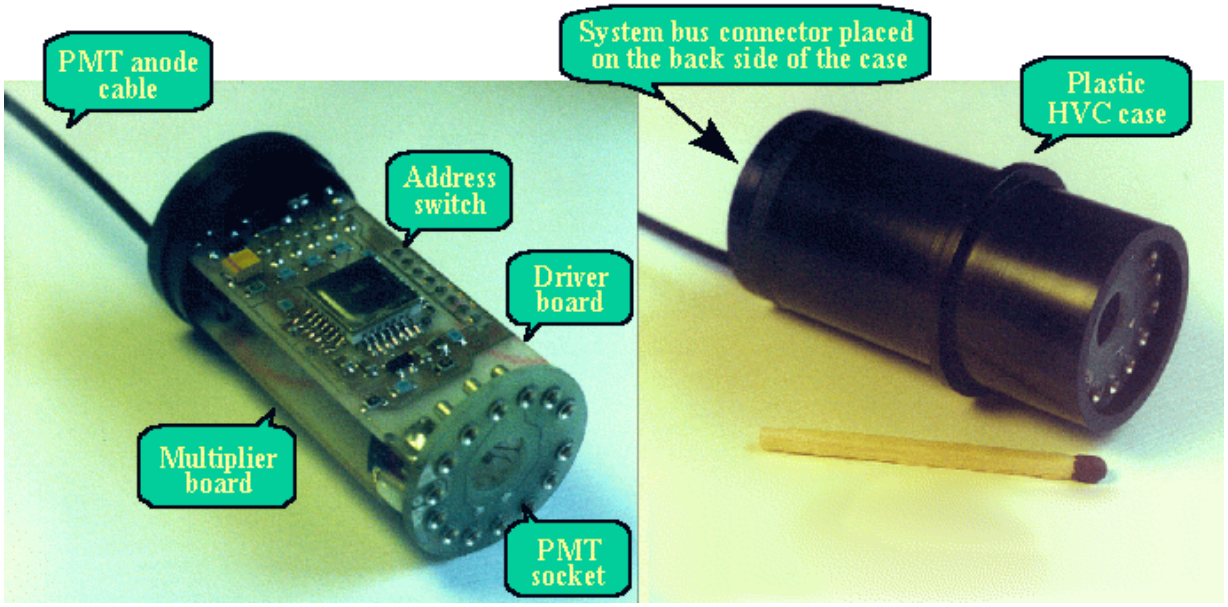


Figure 34: HVSys manufacturer's description page 12.

DEVELOPMENT EXPERIENCE

No	Years	HVC type	Detector	Experiment	Country
1	1993	PMT	Zero Degree Calorimeter	WA98	CERN
2	1995-1997	PMT	CsI Calorimeter	WASA	Sweden
3	1996	PMT	Time-of-Flight	HADES	Germany
4	1996	PMT	Time-of-Flight	STAR	US
5	1998	HVC W-U/T R-U/I	MDC	WASA	Sweden
6	1999	HVC W-U/T R-U/I	PPC	ALICE	CERN

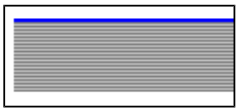
Figure 35: HVSys manufacturer's description page 13.

6.8 HVSys Bus Cable

Belden Detail For: 9L26010 Gray Ribbon Cable 12/7/99 2:33 PM

• Contents • Profile • Sales • Trade # • Technical Info • Exit

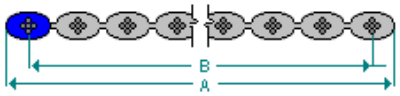
Gray Ribbon Cable
.050" Pitch
26 AWG, 10 Conductors
PVC Available in MIL-C-49055/1



1-800-BELDEN-1

Trade Number	Conductors AWG (Strand) Type	Pitch	Insulation Thickness	Drain Wire AWG Type	Shields	Dielectric Dia. (Type)
9L26010 Mil-C-49055/1(QPL) YP-3305 Mil-C-49055/1Desig. 17	26 (7x34) TC	0.05 ±0.002 in.	0.01 in.			

Description		
Insulation:	Gray PVC	.050" Pitch. 26 AWG, 10 Conductors. PVC. Available in MIL-C-49055/1. Belden's (9L260XX series) .050" pitch extruded gray ribbon cable was designed for general purpose electronic interconnect applications where higher current carrying capabilities are required. The design also conforms to the electrical performance specifications outlined by the SCSI-3 parallel interface document. As with the 9L280XX series, the cable provides reliable mass-termination to standard .100" contact IDC connectors, flexibility, consistent electricals and breakouts can be made easily with the tear feature design. In addition, the overall cable thickness is only .038" ± .002" allowing mateability with all standard IDC connectors. The cable is constructed of stranded 26 AWG (7x34) tinned copper conductors. Insulation material consists of gray PVC, with a blue polarity stripe for proper circuit alignment (black polarity stripe for MIL-C-49055/1). Fifteen various conductor counts are standard, other sizes are available upon request. The cable is UL approved and CSA certified, and passes the VW-1 Vertical Wire Flame Test. Applications: Internal Interconnection or Internal Wiring of Electronic Equipment Packaging: H100, H300, R300 * Test Configuration: G-S-G (ground-signal-ground)
Jacket:		
Substrate:		
Ground Plane:		

Dimensions		
A:	0.5 ± 0.008 in.	
	(Metric) 12.6994 ± .203 mm	
B:	0.45 ± 0.008 in.	
	(Metric) 11.4294 ± .203 mm	
C:		

Approvals			
UL: File # Style	E12683 2651	NEC:	
CSA: File #	LL7874 CSA AWM I A 105°C 300V FT-1	Temperature Rating:	-40°C to +105°C
		Flame Rating: UL CSA	VW-1 FT-1

Electrical			
Voltage Rating:	300.0 V RMS	Impedance (Balanced):	90.0 ohms
Current Rating:	1.5 Amps	Capacitance* @ 1MHz:	18.0 pF/ft (59.1 pF/m)
Conductor Resistance:	43.0 ohms/M'	Impedance* @ 1MHz:	0.15 uH/ft (.49 uH/m)
Insulation Resistance:	>1x10^{10}ohms*10 ft.(3m)	Propagation Delay:	1.48 ns/ft (4.9 ns/m)

▲ Top (Select other related products with BACK or PREVIOUS.)

http://www.belden.com/products/Catalog/allcat2.idc Page 1 of 2

Figure 36: HVSys Bus cable manufacturer's description.

6.9 HVSys Bus Feedthrough Connector

108-5133

Product Specification
AMP-LATCH* Connector
For Flat Cables and Flat Ribbon Cables
(Preliminary)

This specification is subject to change without notice, as a result of product evaluation testing and design changes.

1. Scope:

This specification covers product performance requirements and test methods of AMP-LATCH* Connector for flat cables and flat ribbon cables with round conductors on 1.27mm centers, of the following part numbers.

Part No.	Descriptions
X-172082-X	Receptacle Connector Kit, w/o Strain Relief Clamp
X-172083-X	" " " , w/ Strain Relief Clamp
X-172091-X	Post Header, Vertical Type, w/o Extraction-Lock Lever
X-172092-X	" " " , w/ Extraction-Lock Lever
X-172093-X	Post Header, Horizontal Type, w/o Extraction-Lock Lever
X-172094-X	" , " " , w/Extraction-Lock Lever

2. Material and Finish:
2.1 Receptacle Contact:
2.1.1 Material: Phosphor Bronze
2.1.2 Finish: Selective Gold-Plating, Thk. 0.4μ Min. and 0.8μ Min.
Contact Areas Only
Gold Flash All Over
Over 1.3μ Min. Nickel Underplate

2.2 Contact Post:
2.2.1 Material: Brass
2.2.2 Finish: Gold-Plating, Thk. 0.4μ Min. and 0.8μ Min.
Over 1.3μ Thk. Min. Nickel Underplate

2.3 Housing:
2.3.1 Material: Glass-filled Polybuthylene Terephthalate Resin
2.2.2 Flammability Grade: UL 94V-0

3. Appearance and Color:
3.1 Appearance:

Connector assembly shall be free from defects such as damages, cracks, deformation, blister, dirt and burrs that are detrimental to connector functions and product merchandising value.

Customer Release
AMP SECURITY CLASSIFICATION
NUMBER 1 5133
PRINT DIST

DR 7-4-77
CHK 7-4-77
APP 7-6-77

AMP
AMP (Japan), Ltd.
TOKYO, JAPAN

LOC J A NO 108-5133 REV O

O Released

SHEET 1 OF 7

NAME Product Specification
AMP-LATCH* Connector for Flat Cables and Flat Ribbon Cables

LTR REVISION RECORD DR CHK DATE

AMP J-522

Figure 37: HVSys Bus Feedthrough Connector manufacturer's description page 1.

108-5133

Customer Release

3.2 Housing Color:

Housing color shall be black.

4. Design Feature, Construction and Dimensions:

Product design feature, construction and dimensions shall be conforming to applicable customer product drawing(s).

(1) Number of Positions:	10, 16, 20, 26, 34, 40 and 50
(2) Center Line Spacing:	2.54mm X 2.54mm, Double Row (Dual)
(3) Type of Post Header:	Vertical and Horizontal
(4) Mounting Method of Post Header:	To Be Soldered after Screwed on PCB
(5) Applicable Wire:	AWG #28 Stranded Wire

5. Performance Requirements:

5.1 Rating:

(1) Current Rating:	1.0A Max. per Contact Position
(2) Voltage Rating:	250V AC
(3) Temperature Rating:	-55°C - +105°C

5.2 Electrical Performance Requirements:

Test Item	Specified Requirements	Test Method
Termination Resistance (Low Level) Para. 5.2.1	15mΩ Max.	Cable-terminated and mated connectors are mounted on PCB test plate as shown in Fig. 1. Measure millivolt drop of the test circuits by applying closed circuit current of 50mA max. at open circuit voltage of 50mV max. Calculate resistance value per contact position.
Insulation Resistance Para. 5.2.2	5,000MΩ Min.	Measure insulation resistance between adjacent contacts of mated connectors by applying test potential of 500V±10% in accordance with Test Condition B, Test Method 302 of MIL-STD-202.
Dielectric Strength Para. 5.2.3	No abnormalities such as short circuit or flashover shall be evident.	Measure dielectric strength by applying test potential of 500V AC (RMS) between adjacent contacts for 1 minute on mated connectors in accordance with Test Method 301 of MIL-STD-202.

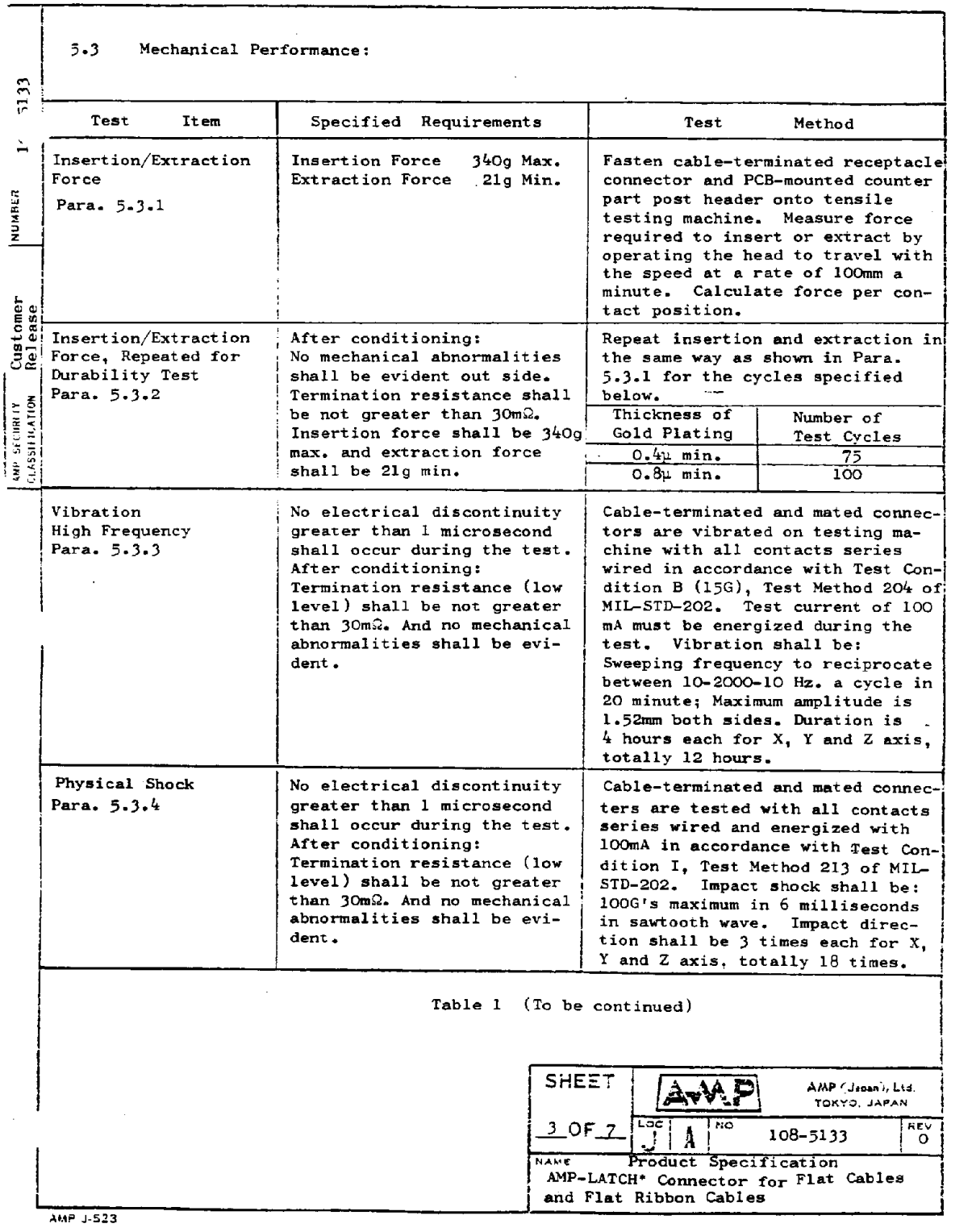
Table 1 (To Be Continued)

SHEET 2 OF 7 | AMP (Japan), Ltd. TOKYO, JAPAN | LOC J A | NO 108-5133 | REV 0

NAME Product Specification
AMP-LATCH* Connector for Flat Cables and Flat Ribbon Cables

AMP J-523

Figure 38: HVSys Bus Feedthrough Connector manufacturer's description page 2.



5133 1 NUMBER
Customer Release
AMP SECURITY CLASSIFICATION

5.3 Mechanical Performance:

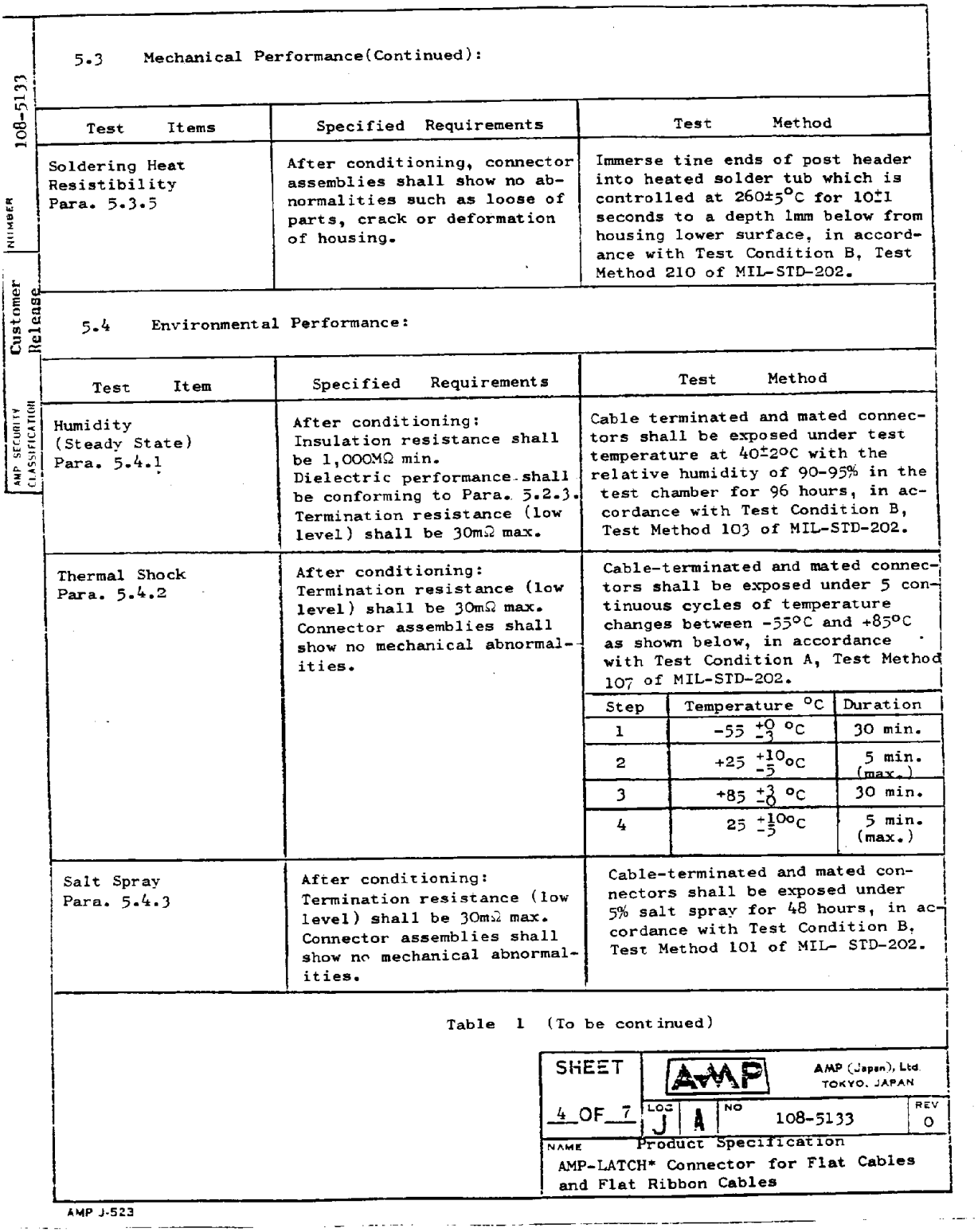
Test Item	Specified Requirements	Test Method
Insertion/Extraction Force Para. 5.3.1	Insertion Force 340g Max. Extraction Force 21g Min.	Fasten cable-terminated receptacle connector and PCB-mounted counter part post header onto tensile testing machine. Measure force required to insert or extract by operating the head to travel with the speed at a rate of 100mm a minute. Calculate force per contact position.
Insertion/Extraction Force, Repeated for Durability Test Para. 5.3.2	After conditioning: No mechanical abnormalities shall be evident out side. Termination resistance shall be not greater than 30mΩ. Insertion force shall be 340g max. and extraction force shall be 21g min.	Repeat insertion and extraction in the same way as shown in Para. 5.3.1 for the cycles specified below. Thickness of Gold Plating / Number of Test Cycles 0.4μ min. / 75 0.8μ min. / 100
Vibration High Frequency Para. 5.3.3	No electrical discontinuity greater than 1 microsecond shall occur during the test. After conditioning: Termination resistance (low level) shall be not greater than 30mΩ. And no mechanical abnormalities shall be evident.	Cable-terminated and mated connectors are vibrated on testing machine with all contacts series wired in accordance with Test Condition B (15G), Test Method 204 of MIL-STD-202. Test current of 100 mA must be energized during the test. Vibration shall be: Sweeping frequency to reciprocate between 10-2000-10 Hz. a cycle in 20 minute; Maximum amplitude is 1.52mm both sides. Duration is 4 hours each for X, Y and Z axis, totally 12 hours.
Physical Shock Para. 5.3.4	No electrical discontinuity greater than 1 microsecond shall occur during the test. After conditioning: Termination resistance (low level) shall be not greater than 30mΩ. And no mechanical abnormalities shall be evident.	Cable-terminated and mated connecters are tested with all contacts series wired and energized with 100mA in accordance with Test Condition I, Test Method 213 of MIL-STD-202. Impact shock shall be: 100G's maximum in 6 milliseconds in sawtooth wave. Impact direction shall be 3 times each for X, Y and Z axis, totally 18 times.

Table 1 (To be continued)

SHEET 3 OF 7 | AMP | AMP (Japan), Ltd. TOKYO, JAPAN
LOC J | A | NO 108-5133 | REV O
NAME Product Specification
AMP-LATCH* Connector for Flat Cables and Flat Ribbon Cables

AMP J-523

Figure 39: HVSys Bus Feedthrough Connector manufacturer's description page 3.



108-5133 NUMBER

Customer Release

AMP SECURITY CLASSIFICATION

5.3 Mechanical Performance(Continued):

Test Items	Specified Requirements	Test Method
Soldering Heat Resistibility Para. 5.3.5	After conditioning, connector assemblies shall show no abnormalities such as loose of parts, crack or deformation of housing.	Immerse tine ends of post header into heated solder tub which is controlled at 260±5°C for 10±1 seconds to a depth 1mm below from housing lower surface, in accordance with Test Condition B, Test Method 210 of MIL-STD-202.

5.4 Environmental Performance:

Test Item	Specified Requirements	Test Method
Humidity (Steady State) Para. 5.4.1	After conditioning: Insulation resistance shall be 1,000MΩ min. Dielectric performance shall be conforming to Para. 5.2.3. Termination resistance (low level) shall be 30mΩ max.	Cable terminated and mated connectors shall be exposed under test temperature at 40±2°C with the relative humidity of 90-95% in the test chamber for 96 hours, in accordance with Test Condition B, Test Method 103 of MIL-STD-202.
Thermal Shock Para. 5.4.2	After conditioning: Termination resistance (low level) shall be 30mΩ max. Connector assemblies shall show no mechanical abnormalities.	Cable-terminated and mated connectors shall be exposed under 5 continuous cycles of temperature changes between -55°C and +85°C as shown below, in accordance with Test Condition A, Test Method 107 of MIL-STD-202.

Step	Temperature °C	Duration
1	$-55\ ^{+0}_{-3}$ °C	30 min.
2	$+25\ ^{+10}_{-5}$ °C	5 min. (max.)
3	$+85\ ^{+3}_{-0}$ °C	30 min.
4	$25\ ^{+10}_{-5}$ °C	5 min. (max.)

Salt Spray Para. 5.4.3	After conditioning: Termination resistance (low level) shall be 30mΩ max. Connector assemblies shall show no mechanical abnormalities.	Cable-terminated and mated connectors shall be exposed under 5% salt spray for 48 hours, in accordance with Test Condition B, Test Method 101 of MIL- STD-202.

Table 1 (To be continued)

SHEET 4 OF 7 | AMP | AMP (Japan), Ltd. TOKYO, JAPAN

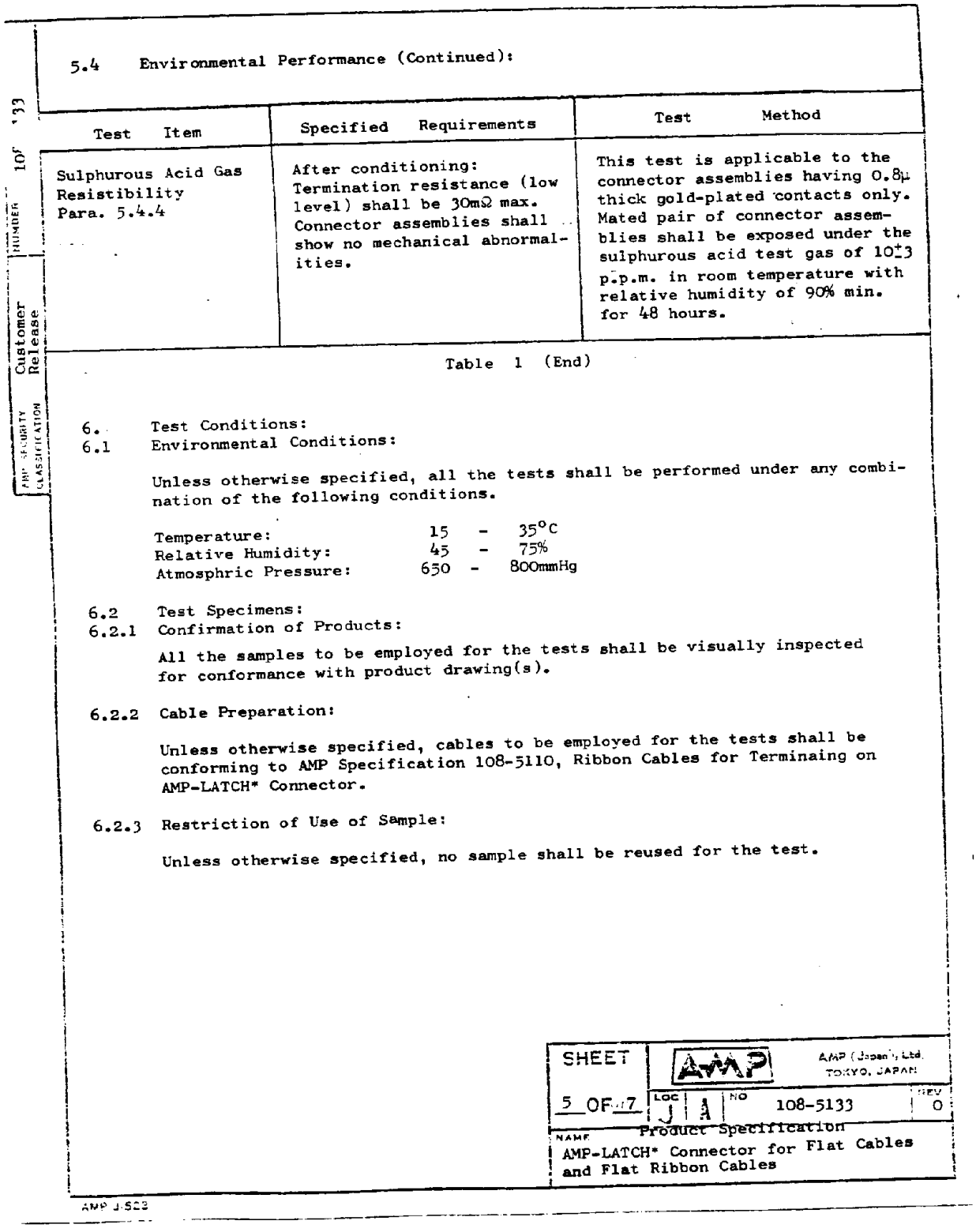
LOC J A | NO 108-5133 | REV 0

NAME Product Specification

AMP-LATCH* Connector for Flat Cables and Flat Ribbon Cables

AMP J-523

Figure 40: HVSys Bus Feedthrough Connector manufacturer's description page 4.



5.4 Environmental Performance (Continued):

Test Item	Specified Requirements	Test Method
Sulphurous Acid Gas Resistibility Para. 5.4.4	After conditioning: Termination resistance (low level) shall be 30mΩ max. Connector assemblies shall show no mechanical abnormalities.	This test is applicable to the connector assemblies having 0.8μ thick gold-plated contacts only. Mated pair of connector assemblies shall be exposed under the sulphurous acid test gas of 10±3 p.p.m. in room temperature with relative humidity of 90% min. for 48 hours.

Table 1 (End)

6. Test Conditions:
6.1 Environmental Conditions:

Unless otherwise specified, all the tests shall be performed under any combination of the following conditions.

Temperature:	15	-	35°C
Relative Humidity:	45	-	75%
Atmosphric Pressure:	630	-	800mmHg

6.2 Test Specimens:
6.2.1 Confirmation of Products:

All the samples to be employed for the tests shall be visually inspected for conformance with product drawing(s).

6.2.2 Cable Preparation:

Unless otherwise specified, cables to be employed for the tests shall be conforming to AMP Specification 108-5110, Ribbon Cables for Terminaing on AMP-LATCH* Connector.

6.2.3 Restriction of Use of Sample:

Unless otherwise specified, no sample shall be reused for the test.

SHEET 5 OF 7 | AMP (Japan), Ltd. TOKYO, JAPAN | LOC J A | NO 108-5133 | REV 0

NAME Product Specification
AMP-LATCH* Connector for Flat Cables and Flat Ribbon Cables

Figure 41: HVSys Bus Feedthrough Connector manufacturer's description page 5.

6.10 Potting Compound

Electronics

Silicone Encapsulants Overview

Product	Description	Features	Potential Uses
Sylgard ® 160 Silicone Elastomer	Low cost; good thermal conductivity	Two part; 1:1 mix, RT/HA cure; minimal shrinkage; no exotherm during cure; UL 94V-0; no solvents or cure byproducts; repairable; good dielectric properties; deep section cure; flexible elastomer	General potting applications: power supplies, connectors, sensors, industrial controls,transformers, amplifiers, high voltage resistor packs, relays
Sylgard ® 165 Silicone Elastomer	Fast cure; low cost; good thermal conductivity	Two part; 1:1 mix, RT/HA cure; minimal shrinkage; no exotherm during cure; UL 94V-0; no solvents or cure byproducts; repairable; good dielectric properties; deep section cure; flexible elastomer	
Sylgard ® 170 Silicone Elastomer	Low viscosity; Mil Spec	Two part; 1:1 mix, RT/HA cure; minimal shrinkage; no exotherm during cure; UL 94V-0; no solvents or cure byproducts; repairable; good dielectric properties; deep section cure; flexible elastomer	
Sylgard ® 170 Fast Cure Silicone Elastomer	Fast cure; low viscosity	Two part; 1:1 mix, RT/HA cure; minimal shrinkage; no exotherm during cure; UL 94V-0; no solvents or cure byproducts; repairable; good dielectric properties; deep section cure; flexible elastomer	
Dow Corning ® 96-082 A & B Encapsulant	Very low viscosity; flame retardant; nonemelting; self-extinguishing; extremely long pot life; wide temperature range		Applications requiring the thorough impregnation possible only with a very low viscosity resin
Sylgard ® 182 Silicone Elastomer	Transparent; long pot life; heat cure; Mil Spec	Two-part; 10:1 mix; minimal shrinkage; no exotherm during cure; no solvents or cure by-products; deep section cure; repairable; good dielectric properties; flexible elastomer	General potting applications: power supplies, connectors, sensors, industrial controls, transformers, amplifiers, high voltage resistor packs, relays; adhesive/ encapsulant for solar cells; adhesive handling beam lead integrated circuits during processing
Sylgard ® 184 Silicone Elastomer	Transparent; RT/HA cure; Mil Spec		
Sylgard ® 186 Silicone Elastomer	Clear; RT/HA cure; high tear strength		
Dow Corning ® 3-6121 Encapsulating Elastomer	Low temperature performance below -40°C (-40°F); clear; high tear and tensile strength; RT/HA cure; high refractive index		Low-temperature encapsulating applications; optical applications requiring high refractive index

Primerless Silicone Encapsulants			
Product	**Description**	**Features**	**Potential Uses**
Dow Corning ® 3-6642 Thermally Conductive Adhesive	Excellent themal conductivity; self-priming; low viscosity liquid; elastomeric	Two-part; 1:1 mix; heat cure; minimal shrinkage; no exotherm during cure; no solvents or cure by-products; deep section cure; repairable; good dielectric properties	Encapsulating applications requiring high thermal conductivity and/or good primerless adhesion
Dow Corning ® 3-8264 Primerless Silicone Adhesive	Excellent unprimed adhesion; heat cure; elastomeric		Encapsulating applications requiring good primerless adhesion and lower heat cure temperatures
Dow Corning ® 567	Mil Spec; heat cure; unprimed		Low cost primerless adhesion

Figure 42: Sylgard 182 manufacturer's description page 1.

Primerless Silicone Encapsulant	adhesion; elastomeric		encapsulation applications

[1] These data were collected on 50-100 gram samples of a lot believed to be typical and should be used as initial estimates of cure times. Times will vary slightly from batch to batch and can be longer or shorter due to thermal mass of your parts and your heating ramp rate. Pretesting is recommended to confirm adequate cure for your application.

[2] For primerless adhesion products, cure time is based on time to reach durometer. Full adhesion may take more time at the cure temperature.

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Technical Data Tutorial

Dow Corning Home. Electronics. Products. Silicone Encapsulants. Silicone Encapsulants Overview

Figure 43: Sylgard 182 manufacturer's description page 2.

Electronics

Silicone Encapsulants -- Technical Data

TYPICAL PROPERTIES **These values are not intended for use in preparing specifications.**									
Dow Corning **® Brand Product**	***Sylgard*** **® 160 Silicone Elastomer**	***Sylgard*** **® 165 Silicone Elastomer**	***Sylgard*** **® 170 Silicone Elastomer**	***Sylgard*** **® 170 Fast Cure Silicone Elastomer**	***Dow Corning*** **® 96-082 A & B Encapsulant**	***Sylgard*** **® 182 Silicone Elastomer**	***Sylgard*** **® 184 Silicone Elastomer**	***Sylgard*** **® 186 Silicone Elastomer**	***Sylgard*** **® 3-6121 Encapsulating Elastomer**
Mix Ratio	1:1	1:1	1:1	1:1	1:1	10:1	10:1	10:1	10:1
Color	Gray	Gray	Dark gray to balck	Dark gray to balck	Black	Clear	Clear	Translucent	Translucent
Viscosity, centipoise	6500	9100	2900	2850	1100	3900	3900	65,000	25,000
Durometer, Shore A	60	52	40	42	31	50	50	24	30
Specific Gravity	1.57	1.57	1.37	1.37	1.21	1.03	1.03	1.12	1.13
Working Time at RT	30 min	<2 min	15 min	<5 min	14 days	>8 hours	>2 hours	2 hours	2 hours
Unprimed Adhesion, Lap Shear, psi	NA	NA	NA	NA	NA	NA	NA	NA	NA
Thermal Conductivity, Watt-meter- °K	0.58	0.58	0.40	0.40	0.30	0.15 - 0.2	0.15 - 0.2	0.2	0.15 - 0.2
Coefficient of Thermal Expansion, um/m - °C	240	230	270	–	285	310	310	330	290
Shelf Life from Date of Manufacture at Room Temp, months	18	18	24	18	12	24	24	12	18
UL Listing:									
Flammability Classification	94 V-0	94 V-0	94 V-0	94 V-0	94 V-0	94 V-1	94 V-1	94 HB	NA
UL Temperature Index, Electrical/Mechanical, °C	105/105	105/105	170/170	170/170	170/170	130/130	130/130	140/140	NA
Mil Spec:									
Specification	NA	NA	MIL-PRF-23586F (grade B2)	NA	NA	MIL-I-81550C	MIL-I-81550C	NA	NA
Type, Class, Group	Type I, Class H, QPL	NA	Type I, Class H, QPL	NA	NA	Type II, QPL	Type II, QPL	NA	NA
Dielectric Strength, volts/mil	530	530	480	530	500	540	540	450	415
Dielectric Constant, at 100Hz	3.30	3.30	3.17	2.97	3.14	2.65	2.65	2.93	2.92
Dielectric Constant, at 100 kHz	3.20	3.20	3.16	2.90	3.12	2.65	2.65	2.87	2.92
Volume Resistivity, ohm-cm	1.0×10^{15}	1.0×10^{15}	3.1×10^{15}	1.4×10^{15}	9.5×10^{14}	1.2×10^{14}	1.2×10^{14}	1.1×10^{14}	1.4×10^{14}
Dissipation Factor at	0.01	0.01	0.003	0.005	0.0055	0.0005	0.0005	0.0012	0.1

Figure 44: Sylgard 182 manufacturer's description page 3.

100 Hz									
Dissipation Factor at 100 kHz	0.002	0.002	0.0008	<0.002	0.0002	0.0005	0.0005	<0.0002	<0.0008

Primerless Silicone Encapsulants

TYPICAL PROPERTIES
These values are not intended for use in preparing specifications.

Dow Corning **® Brand Product**	***Dow Corning*** **®3-6642 Thermally Conductive Adhesive**	***Dow Corning*** **® 3-8264 Primerless Silicone Adhesive**	***Dow Corning*** **® 3-8264 Primerless Silicone Adhesive**
Mix Ratio	1:1	1:1	1:1
Color	Gray	Black	Black
Viscosity, centipoise	5100	2900	1500
Durometer, Shore A	82	45	45
Specific Gravity	2.21	1.32	1.24
Working Time at RT	0.5 hour	5 hours	>3 days
Unprimed Adhesion, Lap Shear, psi	470	385	140
Thermal Conductivity, Watt-meter- °K	1.00	0.35	0.30
Coefficient of Thermal Expansion, um/m - °C	180	290	300
Shelf Life from Date of Manufacture at Room Temp, months	8 @ <5 °C (41 °F)	9	24
UL Listing:			
Flammability Classification	NA	NA	NA
UL Temperature Index, Electrical/Mechanical, °C	NA	NA	NA
Mil Spec:			
Specification	NA	NA	MIL-PRF-23586 (Grade B2)
Type, Class, Group	NA	NA	Type I, Class IV, QPL
Dielectric Strength, volts/mil	440	545	520
Dielectric Constant, at 100Hz	–	3.11	2.85
Dielectric Constant, at 100 kHz	4.20	3.05	2.79
Volume Resistivity, ohm-cm	1.1×10^{13}	3.5×10^{14}	1.0×10^{14}
Dissipation Factor at 100 Hz	–	0.007	0.008
Dissipation Factor at 100 kHz	0.0013	<0.001	0.002

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Overview Tutorial

Dow Corning Home. Electronics. Products. Silicone Encapsulants. Technical Data

Figure 45: Sylgard 182 manufacturer's description page 4.

DOW CORNING -- SYLGARD 182 SILICONE ELASTOMER CURING AGENT - INSULATING COMPOUND KIT, ELECTRICAL
MATERIAL SAFETY DATA SHEET
NSN: 5970007717670
Manufacturer's CAGE: 71984
Part No. Indicator: C
Part Number/Trade Name: SYLGARD 182 SILICONE ELASTOMER CURING AGENT

General Information

Item Name: INSULATING COMPOUND KIT, ELECTRICAL
Company's Name: DOW CORNING CORP
Company's Street: 3901 SOUTH SAGINAW ROAD
Company's P. O. Box: 997
Company's City: MIDLAND
Company's State: MI
Company's Country: US
Company's Zip Code: 48640
Company's Emerg Ph #: 517-496-5900
Company's Info Ph #: 517-496-6000
Record No. For Safety Entry: 003
Tot Safety Entries This Stk#: 004
Status: FE
Date MSDS Prepared: 18JUN92
Safety Data Review Date: 21OCT94
Supply Item Manager: CX
MSDS Serial Number: BVHDZ
Specification Number: MIL-I-81550
Spec Type, Grade, Class: TYPE II
Hazard Characteristic Code: N1
Unit Of Issue: KT
Unit Of Issue Container Qty: CAN
Type Of Container: CAN

Ingredients/Identity Information

Proprietary: NO
Ingredient: DIMETHYLVINYLATED AND TRIMETHYLATED SILICA
Ingredient Sequence Number: 01
Percent: 12 %
NIOSH (RTECS) Number: 10081847T
CAS Number: 68988-89-6
OSHA PEL: NOT ESTABLISHED
ACGIH TLV: NOT ESTABLISHED
Other Recommended Limit: NONE RECOMMENDED

Proprietary: NO
Ingredient: DIMETHYL,METHYL HYDROGEN SILOXE COPOLYMER
Ingredient Sequence Number: 02
Percent: 60 %
NIOSH (RTECS) Number: 1009440DM
CAS Number: 68037-59-2
OSHA PEL: NOT ESTABLISHED
ACGIH TLV: NOT ESTABLISHED
Other Recommended Limit: NONE RECOMMENDED

Proprietary: NO
Ingredient: NON-HAZARDOUS INGREDIENTS
Ingredient Sequence Number: 03
Percent: BALANCE
NIOSH (RTECS) Number: 1000314NH
OSHA PEL: NOT ESTABLISHED
ACGIH TLV: NOT ESTABLISHED
Other Recommended Limit: NONE RECOMMENDED

Physical/Chemical Characteristics

Appearance And Odor: WATER WHITE TO LIGHT STRAW COLORED LIQUID, VERY LITTLE ODOR
Boiling Point: NOT GIVEN
Melting Point: NOT GIVEN

Figure 46: Sylgard 182 MSDS page 1.

Vapor Pressure (MM Hg/70 F): < 5
Vapor Density (Air=1): NOT GIVEN
Specific Gravity: 1.03
Decomposition Temperature: UNKNOWN
Evaporation Rate And Ref: NOT GIVEN
Solubility In Water: NEGLIGIBLE
Percent Volatiles By Volume: < 5%
Corrosion Rate (IPY): UNKNOWN

Fire and Explosion Hazard Data

Flash Point: >212F,>100C
Flash Point Method: CC
Lower Explosive Limit: NOT GIVEN
Upper Explosive Limit: NOT GIVEN
Extinguishing Media: WATER FOG, DRY CHEMICAL, CARBON DIOXIDE, FOAM
Special Fire Fighting Proc: FIRE FIGHTERS SHOULD USE NIOSH APPROVED SCBA & FULL PROTECTIVE EQUIPMENT WHEN FIGHTING CHEMICAL FIRE.
Unusual Fire And Expl Hazrds: NONE SPECIFIED BY MANUFACTURER.

Reactivity Data

Stability: YES
Cond To Avoid (Stability): WATER, ALCOHOLS, ACIDIC OR BASIC MATERIAL AND MANY METALS OR METALLIC COMPOUNDS
Materials To Avoid: STRONG OXIDIZING AGENTS
Hazardous Decomp Products: SILICON DIOXIDE, CARBON DIOXIDE AND TRACES OF INCOMPLETELY BURNED CARBON PRODUCTS
Hazardous Poly Occur: NO
Conditions To Avoid (Poly): NONE. WILL NOT OCCUR.

Health Hazard Data

LD50-LC50 Mixture: NOT GIVEN FOR PRODUCT AS A WHOLE
Route Of Entry - Inhalation: NO
Route Of Entry - Skin: YES
Route Of Entry - Ingestion: NO
Health Haz Acute And Chronic: DIRECT EYE CONTACT MAY CAUSE TEMPORARY DISCOMFORT WITH MILD REDNESS AND DRYNESS SIMILAR TO WINDBURN. A SINGLE SKIN PROLONGED EXPOSURE (24-48 HRS) CAUSES NO KNOWN ADVERSE EFFECTS. NO INJURY IS LIKELY FROM INHALATION. SWALLOWING LARGE AMOUNTS MAY CAUSE DIGESTIVE DISCOMFORT.
Carcinogenicity - NTP: NO
Carcinogenicity - IARC: NO
Carcinogenicity - OSHA: NO
Explanation Carcinogenicity: THIS COMPOUND CONTAINS NO INGREDIENTS AT CONCENTRATIONS OF 0.1% OR GREATER THAT ARE CARCINOGENS OR SUSPECT CARCINOGENS.
Signs/Symptoms Of Overexp: EYE IRRITATION, NAUSEA, VOMITING, DIARRHEA.
Med Cond Aggravated By Exp: NONE SPECIFIED BY MANUFACTURER.
Emergency/First Aid Proc: EYES: FLUSH WITH WATER FOR 15 MINUTES WHILE HOLDING EYELIDS OPEN. GET MEDICAL ATTENTION. SKIN: REMOVE CONTAMINATED CLOTHING. WASH WITH SOAP AND WATER. IF IRRITATION PERSISTS, GET MEDICAL ATTENTION. INHALATION: NO FIRST AID SHOULD BE NEEDED. INGESTION: NO FIRST AID SHOULD BE NEEDED.

Precautions for Safe Handling and Use

Steps If Matl Released/Spill: EVACUATE AREA. WEAR PROPER PERSONAL PROTECTIVE EQUIPMENT. CONTAIN SPILL. STOP LEAK IF CAN DO SO WITHOUT RISK. ABSORB LIQUID WITH SUITABLE ABSORBENT MATERIAL. COLLECT FOR DISPOSAL.
Neutralizing Agent: NONE SPECIFIED BY MANUFACTURER.
Waste Disposal Method: PREVENT WASTE FROM CONTAMINATING SURROUNDING ENVIRONMENT. DISCARD ANY PRODUCT, RESIDUE, DISPOSAL CONTAINER OR LINER IN ACCORDANCE WITH ALL FEDERAL, STATE AND LOCAL REGULATIONS.
Precautions-Handling/Storing: STORE IN A COOL, DRY PLACE WITH ADEQUATE VENTILATION. KEEP AWAY FROM OPEN FLAMES AND HIGH TEMPERATURES.
Other Precautions: AVOID SKIN CONTACT. LAUNDER CONTAMINATED CLOTHING BEFORE REUSE.

Figure 47: Sylgard 182 MSDS page 2.

Control Measures

Respiratory Protection: NOT NORMALLY REQUIRED.
Ventilation: LOCAL EXHAUST AND MECHANICAL (GENERAL) VENTILATION TO MAINTAIN EXPOSURE LEVELS.
Protective Gloves: IMPERVIOUS
Eye Protection: SAFETY GLASSES OR GOGGLES
Other Protective Equipment: PROTECTIVE CLOTHING AS REQUIRED TO AVOID SKIN CONTACT. AN EMERGENCY EYE WASH STATION AND SHOWER SHOULD BE AVAILABLE.
Work Hygienic Practices: WASH WITH SOAP AND WATER AFTER HANDLING PRODUCT AND BEFORE EATING DRINKING OR SMOKING.
Suppl. Safety & Health Data: XYLENE IS EPA REPORTABLE ONLY; DOT EXEMPT BECAUSE CONCENTRATION <2%.

Transportation Data

Trans Data Review Date: 94294
DOT PSN Code: ZZZ
DOT Proper Shipping Name: NOT REGULATED BY THIS MODE OF TRANSPORTATION
IMO PSN Code: ZZZ
IMO Proper Shipping Name: NOT REGULATED FOR THIS MODE OF TRANSPORTATION
IATA PSN Code: ZZZ
IATA Proper Shipping Name: NOT REGULATED BY THIS MODE OF TRANSPORTATION
AFI PSN Code: ZZZ
AFI Prop. Shipping Name: NOT REGULATED BY THIS MODE OF TRANSPORTATION
Additional Trans Data: FILM OR SHEEN UPON THE WATER SURFACE OF DISCOLORATION OF THE WATER OR ADJOINING SHORELINE DUE TO SPILLAGE OF THIS PRODUCT IS REPORTABLE TO THE NATIONAL RESPONSE CENTER AT 1-800-424-8802.

Disposal Data

Label Data

Label Required: YES
Technical Review Date: 21OCT94
MFR Label Number: NONE
Label Status: G
Common Name: SYLGARD 182 SILICONE ELASTOMER CURING AGENT
Chronic Hazard: NO
Signal Word: CAUTION!
Acute Health Hazard-Slight: X
Contact Hazard-Slight: X
Fire Hazard-Slight: X
Reactivity Hazard-Slight: X
Special Hazard Precautions: STORE IN A COOL, DRY PLACE WITH ADEQUATE EYES: FLUSH WITH WATER FOR 15 MINUTES WHILE HOLDING EYELIDS OPEN. GET MEDICAL ATTENTION. SKIN: REMOVE CONTAMINATED CLOTHING. WASH WITH SOAP AND WATER. IF IRRITATION PERSISTS, GET MEDICAL ATTENTION. INHALATION: NO FIRST AID SHOULD BE NEEDED. INGESTION: NO FIRST AID SHOULD BE NEEDED.
Protect Eye: Y
Protect Skin: Y
Label Name: DOW CORNING CORP
Label Street: 3901 SOUTH SAGINAW ROAD
Label P.O. Box: 997
Label City: MIDLAND
Label State: MI
Label Zip Code: 48640
Label Country: US
Label Emergency Number: 517-496-5900

Figure 48: Sylgard 182 MSDS page 3.

6.11 FEE

Lead Edge Discriminator

The purpose of the device is to detect the moment when a pulse amplitude passes a set threshold. Due to the characteristics of pulses (fast rise edges and small pulse width), the circuitry has to be designed with some constraints. Length of traces on the printed circuit board (pcb) has to be minimized, the traces has to be designed as transmission lines with a standard characteristic impedance Z_0. Ground planes has to be properly chosen, so to cover a maximum surface of a pcb layer, but to avoid unwanted feedback capacitances for the amplifying elements.
The LED has as components:

-**Matching input resistor** (network). It is necessary in order to terminate properly the coax cable carrying signals from the photomultiplier tube (PMT). The cables that we have used have Z_0 = 93 Ω.

-**Comparator.** It is used one of the fastest integrated circuit comparators: AD96687 (it contains two identical devices). This device will compare the amplitude of the incoming pulse to a dc negative voltage (threshold). When the pulse is larger (absolute value) than the threshold, the outputs of the comparator flip the state. The output is ECL compatible (signal low = -1.6V, signal high= -0.9V).

-**Differential amplifier**. It is the load of the comparator and makes the level translation ECL-NIM. Besides, this stage improves the rise and fall edges of the output signal. A 16 mA pulse will have a rise edge of 600ps, as compared with the 2ns rise edge from the comparator.

-**Pulse width circuitry.** The output pulse width can be adjusted in the range 15ns to 100ns. During the output pulse, the circuit also inhibits the input of the LED to detecting any other incoming pulses.

-Differentiator. This circuit will sense only the change in state of the output pulse, generating a very narrow positive pulse for the rising edge and a very narrow negative pulse for the falling edge.
-Comparator. Noninverting input is driven by the positive pulse from the differentiator. The inverting input is driven by the ramp generated by the ramp generator. The steady state of this circuit is "low". A positive spike from the differentiator will toggle the circuit in a "high" state. That makes the ramp generator to charge the timing capacitor on the inverting input. When the voltage on this capacitor exceeds the voltage on Noninverting input, the comparator changes state back to "low". That will stop the ramp generator to charge the capacitor. The output pulse duration is adjusted with a potentiometer.
-Ramp generator. This circuit will charge the timing capacitor with a constant current. It is started or stopped by the comparator.

-**PMT signal buffer**. This is a gain=1 noninverting amplifier. The output has a 50 Ω circuit trace on the pcb, to avoid reflections. A Lemo connector and a coax cable with a Z_0 = 50 Ω takes the signal to the TDC.

-**Voltage reference**. A LM385-2.5 at 1mA current, followed by a constant load presented by an inverting amplifier. In this configuration, the reference voltage will vary in value with only the magnitude of the wideband noise of the assembly LM385 AD8056, which is bellow 150 μV. The threshold is adjustable with a potentiometer placed as a load to AD8056.

-**Power supply.** The proper functioning requires a +5.0V , -2.0V, and a –5.2V supply

Components used:

AD96687	Dual ultra fast comparator
AD8056	Dual fast operational amplifier
AT-41411	HF transistors

603 surface mount resistors and capacitors
50 Ω pcb embedded transmission lines
Lemo connectors

Nick Adams
10-01-1999

Figure 49: Rice FEE Version IV manufacturer's description.

Lead Edge Discriminator –V6

Problems noticed with V4:

-Need for four layer board for a better positioning of components and a better routing of traces. Also, the 50Ω trace can be done with a "decent" 20 mil copper line.

-There has been observed a cross talk between channels.

-Necessary a better circuit for determining the pulse width.

The new design, V5 is a four layer board.

-It has been provided a voltage regulator for the –2.0V line. That will prevent cross talk between channels.

-It has been added a buffering stage in order to have a "smooth" pulse width adjustment (the problem had to be solved even if we wanted a fixed pulse width)

At tests, V5 proven to be **worse** than V4. The cause is loading the output with the "pulse width" function.

The version V6 has the features:

-The detection circuit (comparison of the incoming pulse with a fixed threshold) is the same as in the previous versions.

-It has been added a current generator and bypass circuitry to avoid saturation of the transistors in the differential amplifier following the comparator. This will improve the rise (fall) time of the output pulse. Currently, for a 16 mA output pulse (800mV on a 50 Ω load) the rise time is 500 psecond.

-The output duration can be adjusted between 20 ns and 100 ns.

-The dead time (the time in which the discriminator is not responding to any incoming pulse) starts three nanosecond after an incoming pulse is passing the threshold and can be trimmed between 40 ns and 1 μsecond.

-The voltage regulator will provide the –2.0V line for the ECL output of the comparator. It is a voltage regulator provided for each LED (that is there are five voltage regulators LM 337 on each board). The heat generated by each LM 337 is small in comparison with what would be for a single LM 337 on a board. The price is no problem ($0.47 each) it comes cheaper than using a heat sink.

-It has been provided a 1.2 gain for the buffer on each LED. This is to compensate for losses that are seen in the system. The buffer drives a 50 Ω load and has an output compliance of $-4.0V_{peak}$ (larger pulses are clipped to this value). The gain can be put back to 1.0 or to any necessary value by soldering another resistor.

-The threshold voltage is routed to all LED's in the tray. In order to avoid loading of the threshold generator, each LED has a buffer with the gain of 1.00. Due to a strong filtering of the threshold voltage, the LED is responding to 6mV difference between threshold and pulse, at the rise time of the incoming pulse of 100mV/ns.

-The power on board is brought on two lines: +5.0V and –5.2V. The necessary –2.0V is derived from the –5.2V. The current on –5.2V is about 850 mA. The 3A fuse will prevent overloading of the power supply. For a current of about 250 mA on the +5.0V line, there is a 1.5A fuse.

Components used in version V6:

AD96687	5	Dual fast comparator	Analog Devices
AD96685	5	Single fast comparator	Analog Devices
AD8056	5	Dual fast opamp	Analog Devices
Transistors AT-41411	45	High frequency npn	Hewlett-Packard
Transistors MRF597	5	High frequency pnp	Hewlett-Packard
Diodes HBAT-5400	15	Schottky	Hewlett-Packard
Voltage regulator LM337	5	Adjustable negative voltage	National Semiconductors
Resistors and capacitors	695	0603 surface mount	
Lemo connectors	15		
Picofuse UL-248-14	2	Fuses 3A and 1A	Wickmann
LM 3.50/135/2bk	4	Terminal block – power	Weidmuller

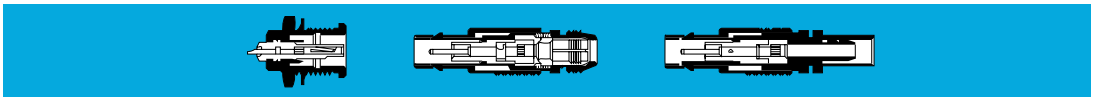
Nick Adams
12-14-1999

Figure 50: Rice FEE Version VI manufacturer's description.

6.12 Lemo Connectors

LEMO

General Characteristics



Outer Shell

Brass
LEMO series 00 connectors have a brass outer shell as standard, and this is suitable for most general purpose applications, including civilian and military.
The brass outer shells have a nickel-plated surface which ensures very good protection against most atmospheres. Alternative protective coatings are available:
– Nickel-chrome offering higher protection against salt air and most corrosive agents
– Nickel-gold
– Nickel-black chrome. After the black chrome treatment, the part is coated with a protective film.

Aluminium Alloy
Aluminium alloy outer shells find numerous applications where light weight is a predominant factor; such as in the aeronautics and space industries, and for portable and mobile equipment.
These materials have high mechanical strength and excellent resistance to corrosion.
The shell surface is protected by anodizing which is available in six colours: blue, yellow, black, red, green, and natural.

Plastic Materials
A PEEK beige coloured outer shell is available which offers excellent insulating properties and is mostly used in the medical industry. This material is suitable for gas or vapour sterilization.

Other Metallic Components
In general, other components are manufactured from brass. However, bronze is used where good elasticity is required (for example: earthing crown).
These parts are nickel or nickel-gold plated depending on the utilization.

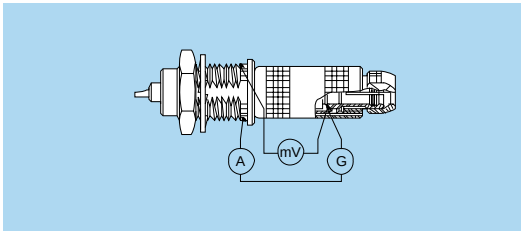
Materials and Treatment

Component	Material (Standard)	Surface Treatment (µm)										
		Nickel		Chrome			Gold			Black Chrome		
		Cu	Ni	Cu	Ni	Cr	Cu	Ni	Au	Cu	Ni	Cr
Outer shell, collet nut, conical nut	Brass (UNS C 38500)	0.5	3	0.5	3	0.3	0.5	3	0.5	–	1	2
	Alu. alloy (AA 6012)	anodized										
	PEEK (MIL-P-46183)	beige coloured										
Earthing crown	Cu-Be (UNS C 17300)	0.5	3	–	–	–	0.5	3	1.5	–	–	–
Latch sleeve	Special Brass	0.5	3	–	–	–	0.5	3	1.5	–	–	–
Crimp ferrule	Copper (UNS C 18700)	0.5	3	–	–	–	0.5	3	1.5	–	–	–
Locking washer	Bronze (UNS C 52100)	0.5	3	–	–	–	0.5	3	0.5	–	–	–
Hexagonal nut	Brass (UNS C 38500)	0.5	3	–	–	–	0.5	3	0.5	–	–	–
	Alu. alloy (AA 6012) [1]	anodized										
Other metallic components	Brass (UNS C 38500)	0.5	3	–	–	–	0.5	3	0.5	–	–	–
Sealing glands	Silicone or FPM	without treatment										

Notes: the surface treatment standards are as follows:
– nickel QQ-N-290A, or MIL-C-26074C
– chrome QQ-N-320B
– gold MIL-G-45204C type I, class 1 (1.5 µm) class 00 (0.5 µm)
– black chrome MIL-C-14538C
[1] supplied only with aluminium alloy free or fixed sockets.

Electrical Characteristics

Screen continuity: according to test MIL-STD-1344A, method 3007.

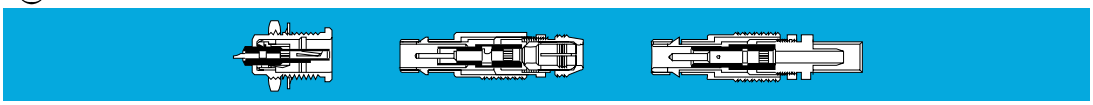


R_1 Values with earthing crown and latch sleeve or inner-sleeve nickel plated.
R_2 Values with gold-plated earthing crown and nickel plated latch sleeve or inner-sleeve.
R_3 Values with earthing crown and gold-plated latch sleeve or inner-sleeve.

R_1 (mΩ)	R_2 (mΩ)	R_3 (mΩ)
3.5	2.8	2.0

Testing current: 1A
A = Ammeter
mV = Millivoltmeter
G = Generator

Figure 51: Lemo connectors manufacturer's description page 1.



Insulator

Technical Description

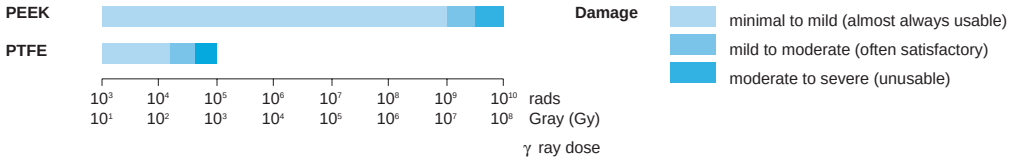
LEMO uses virgin quality PTFE for the insulator material of coaxial connectors, which guarantees excellent insulating properties.
LEMO also proposes PEEK (Polyether Etherketone). Its higher mechanical strength and excellent radiation resistance make it ideal for most applications.

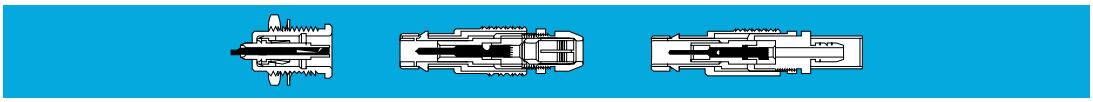
Technical Characteristics

Property	Test method	Unit	PEEK	PTFE
Dielectric strength	ASTM D 149	kV/mm	19 - 25	17.2 - 24
Volume resistivity at 50% HR and 23°C	ASTM D 257	Ω • cm	10^{16}	10^{18}
Surface resistivity	ASTM D 257	Ω	10^{15}	10^{17}
Thermal conductivity	ASTM C 177	W/K • m	0.25	0.23
Comparative tracking index	IEC 112	V	CTI 150	CTI 500
Dielectric constant (10^6 Hz)	ASTM D 150	–	3.2 - 3.5	2 - 2.1
Dissipation factor (10^6 Hz)	ASTM D 150	–	< 0.005	< 0.0003
Continuous service temperature	–	°C	250	260
Water absorption in 24h at 23°C	ASTM D 570	%	< 0.3	< 0.01
Radiation resistance	–	Gy	10^7	$2 \cdot 10^2$
Flammability rating	UL 94	–	V 0	V 0

Note: the technical data contained in this chapter gives a general information about plastic materials used by LEMO as electrical insulator materials. LEMO reserves the right to propose new material which would have higher technical characteristics and to withdraw any material contained in this publication or others from LEMO and its subsidiary companies. LEMO only uses granulated, powdered plastic materials or bars from specialized suppliers. LEMO is not responsible, in any case, for these materials.

Radiation resistance

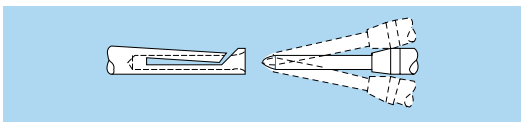




Electrical Contact

Technical Description

The secure, reliable electromechanical connection achieved with LEMO female contacts is mainly due to two important design features:
1. **Prod proof entry** which ensures perfect concentric mating even with well used and/or carelessly handled connectors.
2. **The pressure spring** that maintains a constant, even force on the male contact when mated. The leading edge of the spring is chamfered to slide smoothly on the male contact, preserving the gold-plated surface treatment and preventing undue wear.



Contact Material

LEMO female electrical contacts are made from bronze (UNS C 54400). Bronze is chosen because of its high modulus of elasticity, its excellent electrical conductivity and a high mechanical strength.
LEMO male solder and print contacts are made from brass (UNS C 38500). Male crimp contacts are made from brass (UNS C 34500) which is ideal for crimping onto the electrical conductor.

Conductor retention method

Both male and female contacts are available in crimp, solder or print versions.

Figure 52: Lemo connectors manufacturer's description page 2.

Technical Characteristics

Mechanical and climatical

Characteristics	Value	Standard	Method
Contact retention force	> 18 N	MIL-STD-1344A	2007.1
Cable pull off force	> 100 N	MIL-STD-1344A	2009.1
Connector pull off force	> 90 N		
Endurance	> 1000 cycles	MIL-STD-1344A	2016
Operating temperature [1]	- 55°C + 260°C		

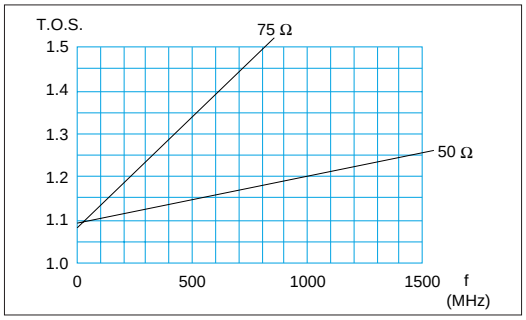
Note: 1) to seal both the watertight and vacuumtight models, LEMO uses and epoxy resin. The operating temperature is limited between -20°C and +80°C.

Electrical

Characteristics		Value	Standard	Method
Impedance		50 Ω		
Operating voltage (50 Hz)		0.7 kV rms	IEC 130-1 1ère ed.	§ 14.5
Test voltage (50 Hz)		2.1 kV rms	MIL-STD-1344A	3001.1
Rated current		4 A	IEC 512-3	
Contact resistance		< 6 mΩ	MIL-STD-202 F	307
Screen resistance		< 3.5 mΩ	MIL-STD-1344A	3007
Insulating resistance		> 10^{12} Ω	MIL-STD-1344A	3003.1
VSWR (f. in GHz)	50 Ω	1.09+0.11f	IEC 169-1-1	
	75 Ω	1.08+0.51f	IEC 169-1-1	

Voltage Standing Wave Ratio

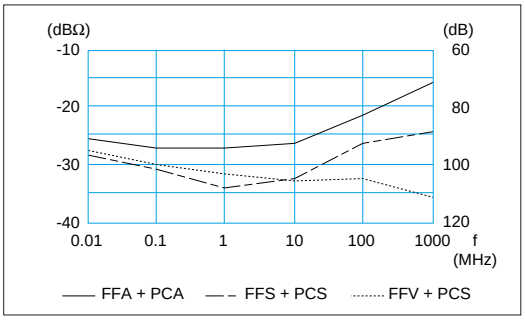
The VSWR (Voltage Standing Wave Ratio) is the value representing the power reflected in a connection. In most cases, the working frequency range is where VSWR ≤ 1.25



Note: value for FFS plug and PCS socket mated (with PTFE insulator). Impedance measured under 50 Ω with a RG-174 A/U cable or under 75 Ω with a RG-179 B/U cable.

Screening efficiency (EMC properties) in dB (transfer impedance in dBohm)

The screening efficiency is the ratio between the electromagnetic field inside the connector and a power source at the outside of the connector (or vice versa).



Note: measured according to IEC-169-1-3 standard.

Recommended cables

Cable group	Standard MIL-C-17	Standard IEC 96-2	Standard CCTU 10-01A	Other cable	Imp. (Ω)
6	RG.58 C/U	50.3.1	KX 15	Belden 8262	50 ± 2 Ω
7	RG.142 B/U				50 ± 2 Ω
3	RG.174 A/U	50.2.1	KX 3A	Belden 8216	50 ± 2 Ω
				Lemo CCH.99.281.505	50 ± 2 Ω
1	RG.178 B/U	50.1.1	KX 21A	Belden 83265	50 ± 2 Ω
2	RG.179 B/U	75.2.1			75 ± 3 Ω
5	RG.180 B/U				95 ± 5 Ω
2	RG.187 A/U	75.2.2			75 ± 3 Ω
4	RG.188 A/U	50.2.3		Belden 83269	50 ± 2 Ω
1	RG.196 A/U	50.1.2			50 ± 2 Ω
4	RG.316 /U	50.2.2	KX 22A	Belden 83284	50 ± 2 Ω
3				Dätwyler HF-2114	50 ± 2 Ω
8				Storm 421 099	50 ± 2 Ω
8				H+S G02232D-60	50 ± 2 Ω

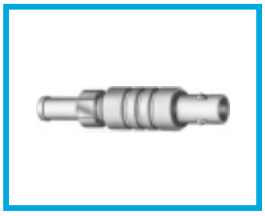
Colour of connectors in anodized aluminium alloy

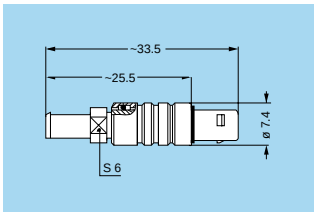
When ordering a connector with an aluminium alloy, the outer shell colour must be chosen from the table variant listed below and included in the position of the part number.

Reference	Colour
A	blue
J	yellow
N	black
R	red
T	natural
V	green

Figure 53: Lemo connectors manufacturer's description page 3.

LEMO



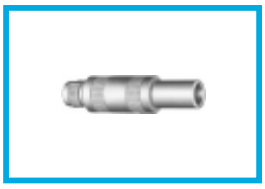


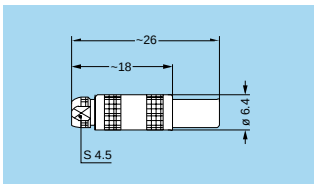
FFE Straight plug with front sealing ring, cable collet and nut for fitting a strain relief

Part number	Cable group	Note
FFE.00.250.NTAC22Z	1	○
FFE.00.250.NTAC29Z	2-3-4	○
FFE.00.250.NTAC31Z	8	○

Note: the strain relief must be ordered separately (see page 29).

M1 Cable assembly

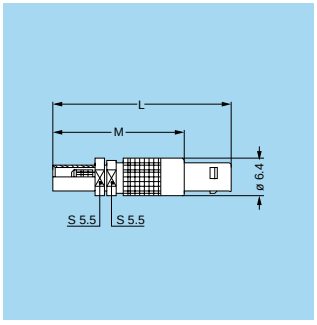




FFF Straight plug, non-latching, with cable collet

Part number	Cable group	Note
FFF.00.250.NTAC22	1	●
FFF.00.250.NTAC29	2-3-4	●
FFF.00.250.NTAC31	8	●

M1 Cable assembly



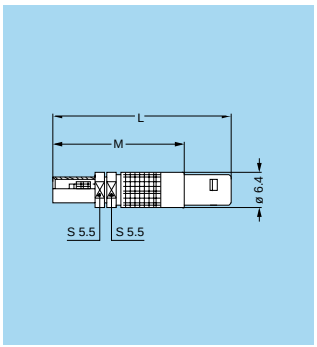
FFS Straight plug with cable crimping

Part number	Cable group	Dim. L	Dim. M	Note
FFS.00.250.NTCE24	1	31	23	●
FFS.00.250.NTCE30	2	31	23	●
FFS.00.250.NTCE31	3-4	31	23	●
FFS.00.250.NTCE35	8	31	23	○
FFS.00.250.NTCE44	5	31	23	●
FFS.00.250.NTCE52	6	34	26	●
FFS.00.250.NTCE56	7	31	23	○

Note: the strain relief must be ordered separately (see page 29).

M4 Cable assembly, crimp contact

M5 Cable assembly, solder contact (on request)



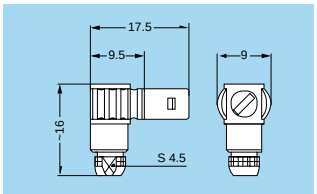
FFV Straight plug for cable crimping with improved screen efficiency

Part number	Cable group	Dim. L	Dim. M	Note
FFV.00.250.NTCE24	1	31	23	○
FFV.00.250.NTCE30	2	31	23	○
FFV.00.250.NTCE31	3-4	31	23	○
FFV.00.250.NTCE35	8	31	23	●
FFV.00.250.NTCE44	5	31	23	○
FFV.00.250.NTCE52	6	34	26	○
FFV.00.250.NTCE56	7	31	23	●

Note: the strain relief must be ordered separately (see page 29).

M4 Cable assembly, crimp contact

M5 Cable assembly, solder contact (on request)



FLA Elbow plug (90°) with cable collet

Part number	Cable group	Note
FLA.00.250.NTAC22	1	●
FLA.00.250.NTAC27	2-4	●
FLA.00.250.NTAC31	3-8	●

M6 Cable assembly

● Available ○ On request

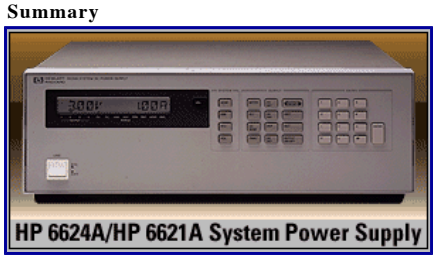
Figure 54: Lemo connectors manufacturer's description page 4.

6.13 FEE Low Voltage Power Supply

Product Information

HP 6621A System Power Supply, 80 W

Summary



The HP 6621A is a dual-output, GPIB system power supply. It has linear low noise power supply outputs combined with a built in GPIB interface. Simple programming commands ease access to all features and capabilities. Dual ranging outputs provide greater flexibility in available voltage and current.

Features

- GPIB programming of volage and current
- Measured voltage and current readback over the GPIB
- Two outputs can be connected in parallel or in series
- Automatic selection of operating voltage and current range
- Programmable overvoltage and overcurrent protection
- Self-test occurs at power-on from an GPIB command
- Electronic calibration via GPIB
- 10 store-recall states
- SCPI (Standard Comments for Programming Instruments)
- HP VXI *plug&play* drivers

Product Details

Key Specifications

Additional Information

Check here for related product, application, and support information for this product.

HP 6621A Products & Applications

HP 6621A Technical Support

How To Buy

Price and ordering information

Find your local contact to purchase this product.

Country Name

Go

Products Available for On-line Ordering

Notify Me

You can change your profile to denote your interest in this product and ensure you receive news of future products enhancements or promotions.

Notify Me.

Figure 55: Low Voltage Power Supply manufacturer's description page 1.

Agilent Test & Measurement

6621A Specifications	
Output Power (0 - 55 deg C)	80-watt output Low-range: 0 to 7 V, 0 to 10 A High-range: 0 to 20 V, 0 to 4 A
Number of Outputs	2
Programming accuracy (at 25 deg C +/- 5 deg C)	Voltage: 0.06% + 19 mV Current: 0.16% + 100 mA
Ripple and noise (p-p: 20 Hz to 20 MHz) (rms: 20 Hz to 10 MHz)	Constant Voltage (rms): 500 uV Constant Voltage (p-p): 3 mV Constant Current (rms): 1 mA
Load regulation	Voltage: 2 mV Current: 2 mA
Load cross regulation	Voltage: 1 mV Current: 2 mA
Line regulation	Voltage: 0.01% + 1 mV Current: 0.06% + 1 mA
Transient response time	Less than 75 us for the output to recover to within 75 mV of nominal value following a load change within specifications.
Supplemental Characteristics	
Average programming resolution	Voltage: 6 mV (3.2 mV high) Current: 50 mA (131 uA high) OVP: 100 mV
Output programming response time	2 ms
Physical Specifications	
Dimensions	425.5 mm W x 132.6 mm H x 497.8 mm D (16.75 in x 5.22 in x 19.6 in)
Net Weight	17.4 kg. (38 lbs)
Shipping Weight	22.7 kg. (50 lbs)

Close

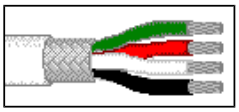
Figure 56: Low Voltage Power Supply manufacturer's description page 2.

6.14 Low Voltage Bus cable

Belden Detail For: 9954 Control, Instrumentation and Computer Cable 12/10/99 10:52 AM

• Contents • Profile • Sales • Trade # • Technical Info • Exit

Control, Instrumentation and Computer Cable
Braid Shield
16 AWG, 4 Conductors
MIl-W-16878 (Type B)



1-800-BELDEN-1

Trade Number Industry Stds.	Std. Lgth. (ft.)	Std. Units (lbs.)	AWG (strand) Type (Nom. D.C.R.)		Insul Thick (Jkt Thick)	Nom. O.D.	Nom. Imp. (ohms)	Vel. of Prop.	Nom. Cap.
			Conductors	Shields					
9954	100 500 1000	7.1 33.4 71.0	16 (19x29) TC	90% TC Braid	0.012 in. x 0.004 in. 0.027 in.	0.291 in.			49.0 pF/ft* 94.0 pF/ft**
Metric	(Meters) 30.5 152.4 304.9	(Kg) 3.23 15.2 32.3			.305 mm x .102 mm .686 mm	7.391 mm			160.7 pF/m* 308.3 pF/m**

Description:		
Insulation:	PVC/Nylon	Communication and Instrumentation Cable. 16 AWG stranded, tinned copper conductors. Color coded PVC/Nylon insulation with a clear Nylon jacket 0.004 inches thick. Tinned copper braided shield, 90% coverage. White PVC jacket. Temperature Rating: 105°C. Suggested Working Voltage: 600 Volts. Passes VW-1 Vertical Wire flame Test. Color Code: White, Green, Red and Black.
Jacket:	PVC	
Plenum Version(s):	n/a	

▲ Top (Select other related products with BACK or PREVIOUS.)

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Figure 57: Low Voltage bus cable manufacturer's description.

6.15 Low Voltage Feedthrough Connectors

Industrial Power Connectors online catalog Amphenol

HOME

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Part Information | Specifications | Line Drawings | Panel Cutout

Part Information:

Part Number: C016 20C005 100 2

Description: Male receptacle, flange mounting with mounted gasket, 5+PE screw termination

Family: C16-3

Click below to add part to your request list.
When you have finished browsing, click
"Process Info Request" button.

Add to Information Request

Specifications

Shell Size 2				
Number of contacts	5+PE	12+PE	14+PE	19+PE
Termination	screw	crimp	crimp	crimp
Wire gauge	4 mm^2	0.14 - 2.5 mm^2	0.14 - 2.5 mm^2	0.14 - 1.0 mm^2
Rated Insulation Voltage	400V	3 x 500V 9 x 300V	400V	250V
Current carrying capacity	21 A	3 x 21 A 9 x 11 A	4 x 11 A 11 x 12 A	7 A
Pollution degree	3	3	3	3
Installation category	III	III	III	III
Protection class	IP 65	IP 65	IP 65	IP 65

General	Standard	Characteristics			
Number of contacts		5+PE	12+PE	14+PE	19+PE
Electrical					
Rated insulation voltage	IEC 60664-1	400 V	3 x 500 V 9 x 300 V	400 V	250 V
Rated impulse withstand voltage	IEC 60664-1	6000 V	3 x 6000V 9 x 4000V	3110 V	4000 V
Pollution degree	IEC 60664-1	3	3	3	3
Installation (overvoltage)	IEC 60664-1	III	III	III	III

Figure 58: Low Voltage feedthrough connector manufacturer's description page 1.

category					
Material group	IEC 60664-1	II	II	II	II
Test voltage	IEC 60664-1	2900 V	3 x 2900 V 9 x 1960 V	3110 V	1960 V
Current carrying capacity	IEC 60512-3	21 A	3 x 21 A 9 x 11 A	4 x 11 A 11 x 12 A	7 A
Insulation resistance	IEC 60512-2	>10 ^{8}W			
Contact resistance	IEC 60512-2	≤5 m W			
Climatical					
Climatic category	IEC 60068-1	40 / 100 / 56	40 / 125 / 56		
Temperature range		-40°C ... +125°C (5+PE: + 100°C)			
Mechanical					
IP-degree	IEC 60529	IP 65			
Insertion and withdrawal forces	IEC 60512-7	≤ 15 N	≤ 25 N	≤ 30 N	≤ 25 N
Mechanical operation	IEC 60512-5	≥ 500 mating cycles			
Materials					
Housing		Polyamid 6.6			
Dielectric		Polyamid 6.6			
Gasket		Neoprene			
Contact plating		Silver			
Other Characteristics					
Termination technique		screw	crimp		
Wire gauge		4 mm^2	0.14 - 2.5mm^2	0.14 - 2.5mm^2	0.14 - 1.0mm^2
Flammability		UL 94 VO			
Locking system		bayonet			

TOP **Line Drawings**

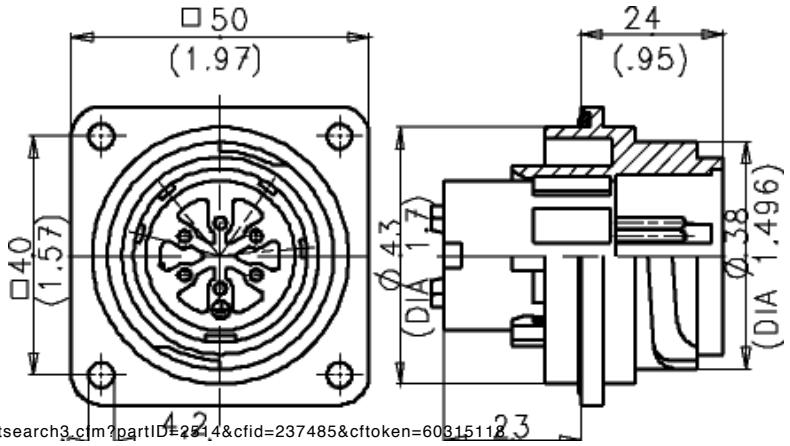

Figure 59: Low Voltage feedthrough connector manufacturer's description page 2.

6.16 Threshold Bus Cable

Belden Detail For: 9747 Instrumentation and Control Cable 12/8/99 2:30 PM

• Contents • Profile • Sales • Trade # • Technical Info • Exit

Instrumentation and Control Cable
Unshielded
22 AWG, 12 Pairs

1-800-BELDEN-1

Trade Number Industry Stds.	Std. Lgth. (ft.)	Std. Units (lbs.)	AWG (strand) Type (Nom. D.C.R.)		Insul Thick (Jkt Thick)	Nom. O.D.	Nom. Imp. (ohms)	Vel. of Prop.	Nom. Cap.
			Conductors	Shields					
9747 UL AWM: 2576 NEC: CMG CEC: CMG	100 500 1000	11.5 55.7 108.1	22 (7x30) TC		0.01 in. 0.04 in.	0.425 in.			
Metric	(Meters) 30.5 152.4 304.9	(Kg) 5.23 25.3 49.1			.254 mm 1.016 mm	10.794 mm			

Description:		
Insulation:	PVC	Tinned Copper, PVC insulated, twisted pairs. Chrome PVC jacket. Rating: 150V 80°C
Jacket:	PVC	
Plenum Version(s):	n/a	

Color Codes	
#	Color
1	Black & Red
2	Black & White
3	Black & Green
4	Black & Blue
5	Black & Yellow
6	Black & Brown
7	Black & Orange
8	Red & White
9	Red & Green
10	Red & Blue
11	Red & Yellow
12	Red & Brown
13	Green & White

Color Codes	
#	Color
14	Green & Blue
15	Green & Yellow
16	Green & Brown
17	Green & Orange
18	White & Blue
19	White & Yellow
20	White & Brown
21	White & Orange
22	Blue & Yellow
23	Blue & Brown
24	Blue & Orange
25	Brown & Yellow

Color Codes	
#	Color
26	Red & Orange
27	Brown & Orange
28	Orange & Yellow
29	Purple & Orange
30	Purple & Red
31	Purple & White
32	Purple & Dark Green
33	Purple & Light Blue
34	Purple & Yellow
35	Purple & Brown
36	Purple & Black
37	Gray & White

▲ Top (Select other related products with BACK or PREVIOUS.)

Figure 60: Threshold bus cable manufacturer's description.

6.17 Threshhold Bus Feedthrough Connector

Part Details for P/N: 737097-1 12/9/99 3:12 PM

Products

- Part Number Search
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- Competitor Cross Reference
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CPC (Circular Plastic) & Metal-Shell CPC Connectors
CPC Connectors

737097-1 *-- 1 of 2 products* Active

Y2K - OK

NEXT | ASSEMBLY SUBCONTRACTORS | STEP SEARCH | DRAWINGS SPECIFICATIONS | SALES INFO | GENERAL INFO

Please use the customer drawing for all design activity.

- **Customer Drawing: 737097**, Rev. E
  Document Title: KIT CONECTOR CPC TAMANO 23-24 VIAS.

175937.pdf (37K)

Searchable Features:	
Product Type:	Receptacle Kit
No. of Positions:	24
Sex:	Receptacle
Preloaded:	No
Pin/Socket:	Socket
Terminate To:	Wire
Shell Size:	23
Shell Type:	All Plastic
Shell Thread Size:	5/8 - 24 UNEF-2A
Numbering:	Standard
Panel Attachment:	Yes
Panel Hole Type:	Mounting Holes
Sealed:	No
VDE Tested:	No
Contact Mating Area Plating:	Tin
Sealing Type:	None
Contact Termination End Plating:	Tin
Standard or Reverse Sex:	Reverse

Other Properties:	
Panel Attachment Method:	Square Flange
Housing Material:	Thermoplastic
Housing Material Flammability Rating:	UL 94V-0
Housing Color:	Black
Contact Material:	Copper Alloy

http://connect.amp.com/AMP/bin/AMP.Connect?C=10574&P=25479,2343&M=PROP&N=1&LG=1&I=13&G=G Page 1 of 2

Figure 61: Threshold Bus Feedthrough Connector manufacturer's description.

6.18 Low Voltage & Threshold Lead Wire

Belden Detail For: 83030 TFE Teflon 12/08/99 11:40 AM

• Contents • Profile • Sales • Trade # • Technical Info • Exit

1-800-BELDEN-1

TFE Teflon
UL: 300V, 200°C
(Type EE) MIL-W-16878/5 Teflon, 1000V, 200°C

Trade Number Industry Std.	Std. Lgth. (ft.)	Std. Units (lbs.)	AWG (strand) Type (dia.) Nom. D.C.R.	Sq. mm Strand in mm	Insul Thick	Jacket Thick.	Nom. O.D.	Breakdown Voltage
83030 UL 1180	100 500 1000	1.2 6.0 11.8	16 (19x29) SCC		0.015 in.		0.088 in.	
Metric	(Meters) 30.5 152.4 304.9	(Kg) .5 2.7 5.4			.381 mm		2.235 mm	

Description:

Stranded silver-coated copper conductor insulated with extruded TFE Teflon®. Passes VW-1 Vertical Wire Flame Test. Complies with MIL-W-16878 except stranding. Spools may contain more than one piece. Length may vary ±10% from length shown. Teflon is a fluorinated thermoplastic with outstanding thermal, physical, and electrical properties. Teflon is generally restricted to applications requiring its special characteristics because its basic resin and processing costs are relatively high. Belden® Teflon wire products are highly recommended for miniature cable applications because of their superior thermal and electrical properties. Teflon is especially suitable for internal wiring-soldering applications where insulation melt back is a specific problem. Belden wiring products insulated with Teflon are outstanding in their resistance to oil, oxidation, heat, sunlight, and flame; and also in their ability to remain flexible at low temperatures. They have excellent resistance to ozone, water, alcohol, gasoline, acids, alkalis, aromatic hydrocarbons, and solvents.

Color Codes	
Color No.	Color Combination
1	Brown
2	Red
3	Orange
4	Yellow
5	Green
6	Light Blue
7	Violet
8	Gray
9	White
10	Black
11	Tan
12	Pink
13	Dark Blue
14	Whilr/Black
15	White/Red
16	White/Green
17	White/Yellow
18	White/Blue

Color Codes	
Color No.	Color Combination
19	White/Brown
20	White/Orange
21	White/Gray
22	White/Violet
23	White/Black/Red
24	White/BlackGreen
25	White/BlackYellow
26	White/BlackBlue
27	White/BlackBrown
28	White/BlackOrange
29	White/BlackGray
30	White/BlackViolet
125	White/Red Tracer
132	White/Black Tracer
189	Green/Yellow
620	Green/Min.30%Yellow
876	Nickel Gray
B02	Purple

Put Up	Color Code
100	1-10
500	1-10
1000	1-10

Top

(Select other related products with BACK or PREVIOUS.)

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Figure 62: Low Voltage and threshold lead wire description.

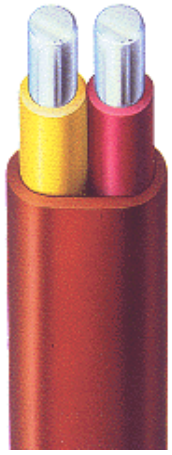
6.19 Thermocouple wire

PMC CORPORATION
OnLine Catalog

Home Corporate Catalog Reference Contact

FEP Insulated Thermocouple and Extension Wire

Product Code: TE/TE



- Calibrated conductors for high system accuracy
- 400°F (204°C) FEP insulation for improved electrical properties and high temperature applications, FEP jacket for chemical inertness to solvents, acids and oils

The thermocouple grade products shown are used to form temperature sensors and the extension grade products become the interconnecting link in the temperature system. Suggested operating temperature is -90°F to 400°F (-67°C to 204°C). The insulation on the individual conductors and the jacketing are both color coded to ANSI standards for quick identification of conductors and calibration.

Part Numbers

Grade of Wire	AWG (Wire Type)	Part Numbers					
		Type J	Type K	Type T	Type E	Type N	Type R/S
Thermocouple	20 (Solid)	J-TE/TE-20	K-TE/TE-20	T-TE/TE-20	E-TE/TE-20	N-TE/TE-20	-
Thermocouple	20 (7/28)	J-TE/TE-20F	K-TE/TE-20F	T-TE/TE-20F	E-TE/TE-20F	N-TE/TE-20F	-
Thermocouple	24 (Solid)	J-TE/TE-24	K-TE/TE-24	T-TE/TE-24	E-TE/TE-24	N-TE/TE-24	-
Thermocouple	24 (7/32)	J-TE/TE-24F	K-TE/TE-24F	T-TE/TE-24F	E-TE/TE-24F	N-TE/TE-24F	-
Thermocouple	30 (Solid)	J-TE/TE-30	K-TE/TE-30	T-TE/TE-30	E-TE/TE-30	N-TE/TE-30	-
Extension	16 (Solid)	JX-TE/TE-16	KX-TE/TE-16	TX-TE/TE-16	EX-TE/TE-16	NX-TE/TE-16	RSX-TE/TE-16
Extension	20 (Solid)	JX-TE/TE-20	KX-TE/TE-20	TX-TE/TE-20	EX-TE/TE-20	NX-TE/TE-20	RSX-TE/TE-20
Extension	20 (7/28)	JX-TE/TE-20F	KX-TE/TE-20F	TX-TE/TE-20F	EX-TE/TE-20F	NX-TE/TE-20F	RSX-TE/TE-20F
Extension	24 (Solid)	JX-TE/TE-24	KX-TE/TE-24	TX-TE/TE-24	EX-TE/TE-24	NX-TE/TE-24	RSX-TE/TE-24
Extension	24 (7/32)	JX-TE/TE-24F	KX-TE/TE-24F	TX-TE/TE-24F	EX-TE/TE-24F	NX-TE/TE-24F	RSX-TE/TE-24F

Figure 63: Type-T Thermocouple wire manufacturer's description page 1.

PMC CORPORATION
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Properties of Thermoelement Material

Properties of Thermoelement Material										
Property	**JP**	**JN, EN, TN**	**TP**	**KP, EP**	**KN**	**RP**	**SP**	**RN, SN**	**BP**	**BN**
Melting point (solids temperatures)										
ºC	1,490	1,220	1,083	1,427	1,399	1,860	1,860	1,769	1,927	1,826
ºF	2,715	2,228	1,981	2,600	2,550	3,380	3,362	3,216	3,501	3,319
Resistivity:										
Ω-cm:										
at 0ºC	8.57	48.9	1.56	70	28.1	19.0	18.4	9.83	--	--
at 20ºC	9.67	48.9	1.724	70.6	29.4	19.6	18.9	10.4	19.0	17.5
Ω cmil/ft:										
at 0ºC	51.5	294.2	9.38	421	169	114.3	110.7	59.1	--	--
at 20ºC	58.2	294	10.37	425	177	117.7	114.0	62.4	114.5	106
Temperature coefficient of resistance, Ω/Ω ºC (0 to 100ºC)	65 x 10^{-4}	-0.7 x 10^{-4}	43 x 10^{-4}	4.1 x 10^{-4}	23.9 x 10^{-4}	15.6 x 10^{-4}	16.6 x 10^{-4}	39.2 x 10^{-4}	13.3 x 10^{-4}	20.0 x 10^{-4}
Coefficient of thermal expansion, in./in. ºC (20 to 100ºC)	11.7 x 10^{-6}	14.9 x 10^{-6}	16.6 x 10^{-6}	13.1 x 10^{-6}	12.0 x 10^{-6}	9.0 x 10^{-6}	9.0 x 10^{-6}	9.0 x 10^{-6}	--	--
Thermal conductivity at 100ºC:										
Cal. cm/s										
cm2 . ºC	0.162	0.0506	0.901	0.046	0.071	0.088	0.090	0.171	-	-
Btu . ft/h										
ft2 . ºF	39.2	12.2	218	11.1	17.2	21.3	21.8	41.4	-	-
Specific heat at 20ºC cal/g ºC	0.107	0.094	0.092	0.107	0.125	-	-	0.032	-	-
Density:										
g/cm3	7.86	8.92	8.92	8.73	8.60	19.61	19.97	21.45	17.60	20.55
lb/in3	0.284	0.322	0.322	0.315	0.311	0.708	0.721	0.775	0.626	0.743
Tensile strength (annealed):										
kgf/cm2	3,500	5,600	2,500	6,700	6,000	3,200	3,200	1,400	4,900	2,800
psi	50,000	80,000	35,000	95,000	85,000	46,000	45,000	20,000	70,000	40,000
Magnetic attraction	strong	none	none	none	moderate	none	none	none	none	none

Figure 64: Type-T Thermocouple wire manufacturer's description page 2.

PMC CORPORATION
OnLine Catalog

Accuracy of PMC Thermocouple Wire

PMC insulated and bare thermocouple wire is matched to meet standard or special limits or error for temperatures above 32ºF (0ºC), as given in ANSI MC 96.1 and shown below.

Initial Calibration Tolerances for Thermocouple Wire							
Thermocouple Type Wire Alloys		**ANSI Symbol**	**Temperature Range**	**Standard Limits**	**Order Code**	**Special Limits**	**Order Code**
****Iron (+) vs. Constantan(TM) (-)**	ºF	J	+32º to +545º +545º to +1400º	±4º ±.75%	J	±2º ±.4%	JJ
	ºC		0º to +285º +285º to +750º	±2.2º ±.75%		±1.1º ±.4%	
CHROMEL®* (+) vs **ALUMEL®* (-)	ºF	K	-330º to -165º -165º to +32º +32º to +545º +545º to +2300º	±2% ±4º ±4º ±.75%	K	±2º ±.4%	KK
	ºC		-200º to -110º -110º to 0º 0º to +285º +285º to +1250º	±2% ±2.2º ±2.2º ±.75%		±1.1º ±.4%	
Copper (+) vs. Constantan(TM) (-)	ºF	T	-330º to -85º -85º to +270º +270º to +660º	±1.5% ±1.8º ±.75%	T	±.8% ±.9º ±.4%	TT
	ºC		-200º to -65º -65º to +130º +130º to +350º	±1.5% ±1º ±.75%		±.8% ±.5º ±.4%	
CHROMEL®* (+) vs. Constantan(TM) (-)	ºF	E	-330º to -270º -270º to +480º +480º to +640º +640º to +1600º	±1% ±3º ±3º ±.5%	E	±1.8º ±1.8º ±.4% ±.4%	EE
	ºC		-200º to -170º -170º to +250º +250º to +340º +340º to +900º	±1% ±1.7º ±1.7º ±.5%		±1º ±1º ±.4% ±.4%	
Nicrosil(TM) (+) vs. Nisil(TM) (-)	ºF	N	+32º to +545º +545º to +2300º	±4º ±.75%	N	±2º ±.4%	NN
	ºC		0º to +285º +285º to +1250º	±2.2º ±.75%		±1.1º ±.4%	

NOTE: Percent limits apply directly to temperature in °C units, but for °F equivalents are applied to the numbers of °F above or below the ice point (+32°F).
(i.e. Limit (°F) = (Temp. °F-32°F) x Percentage)

Thermocouple wire cannot be expected to meet the limits of error at temperatures below the ice point unless specified at time of purchase.

** Magnetic

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Manchester, NH 03103

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Fax: (603) 622-7023
Fax: (800) 639-5701 US only

Figure 65: Type-T Thermocouple wire manufacturer's description page 3.

PMC CORPORATION
OnLine Catalog

Thermocouple Wire Insulations

Insulation Singles [Saturant]	Jacket [Saturant]	Service Temp. Limits Continuous [Single]	ANSI Color Coded	Abrasion Resistance	Moisture Resistance
PC/PC+ - Polyvinyl Chloride					
PVC (.014" - .015") [--]	PVC (.015" - .020") [--]	-15 to 221 ºF -26 to 105 ºC [--] [--]	Yes	Good	Excellent
NY/NY+					
Nylon (.005" - .006") [--]	Nylon .006" - .008" [--]	248 ºF 120 ºC [--] [--]	Yes	Excellent	Fair
TZ/TZ+					
Tefzel® (.008") [--]	Tefzel® .010" [--]	302 ºF 150 ºC [392 ºF] [200 ºC]	Yes	Excellent	Excellent
TE/TE+					
Teflon® FEP (.008") [--]	Teflon® FEP (.010") [--]	400 ºF 240 ºC [482 ºF] [250 ºC]	Yes	Very Good	Excellent
TA/TA+					
Teflon® PFA (.008"0 [--]	Teflon® PFA (.010") [--]	500 ºF 260 ºC [550 ºF] [288 ºC]	Yes	Very Good	Excellent
TF/TF+ - Taped and Fused					
Teflon® TFE (.006") [--]	Teflon® TFE (.008") [--]	500 ºF 260 ºC [550 ºF] [288 ºC]	Yes	Good	Excellent
CK/NK+ - FEP Binder melts at 500 ºF (260 ºC)					
Kapton® Tape (.006" color coded) [--]	Kapton® Tape (.004") [--]	500 ºF 260 ºC [800 ºF] [427 ºC]	No	Excellent	Excellent
NK/NK - Non Color Coded; FEP Binder melts at 500 ºF (260 ºC)					
Kapton® (.004") [--]	Kapton® Tape (.004") [--]	500 ºF 260 ºC [800 ºF] [427 ºC]	No	Excellent	Excellent
FB/FB+ - Saturant good to 400 ºF (204 ºC)					
Fiberglass Braid (.006") [Modified Silicone]	Fiberglass Braid (.006") [Modified Silicone]	900 ºF 482 ºC [1000 ºF] [537 ºC]	Yes	Good	Good
FB2/FB - Saturant good to 400 ºF (204 ºC)					

http://www.pmcwire.com/ThermocoupleInsulations.htm

Figure 66: Type-T Thermocouple wire manufacturer's description page 4.