

Professional Mil-Spec Motorsport ECU Wiring Harness Construction

Service Loops	RT125 Epoxy	Mil-Spec Wire	Supplies	Connectors	Switches
Crimping Tools	Splices	Shrink Tubing	Concentric Twisting	Literature	Costs

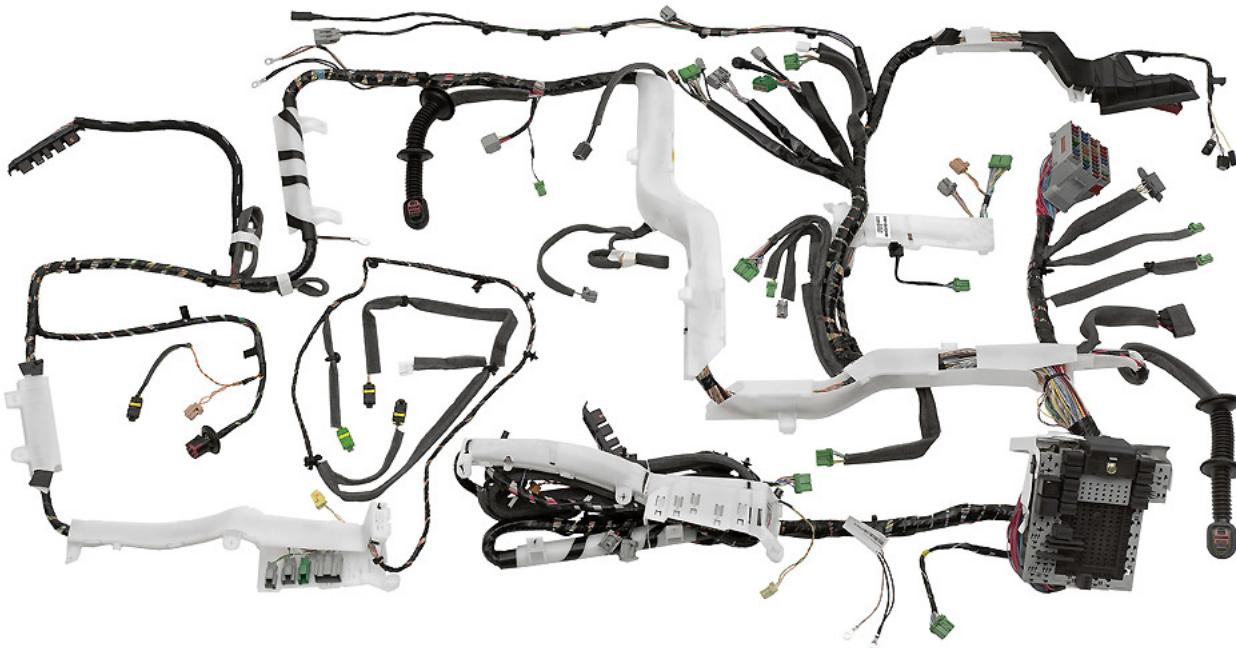
Electrons

Getting electrical signals from point A to point B is pretty standard thing...Put a piece of copper wire between A and B and the job is done. A century of development has left us with increased specialization in wiring, connection devices, and everything in between point A and B. "Mil-Spec" or military specification, has become the buzz-word in motorsport electrical harness construction. Actually motorsport wiring has developed it's own specialized connectors but it's still largely constructed from aerospace components.

Perhaps "Race-Spec" will become the new buzz-word....Probably not with the trillions of dollars spent on drones, F22's, and commercial aircraft.

This is not a definitive guide on building wiring harnesses as this could encompass two wheels, four wheels or no wheels. It does give you a perspective on motorsports ecu wiring and provides access to further literature for you to study and make your own decisions. We build ecu wiring harnesses for our production items and for our own racing activities.

Production OEM Automotive Wiring



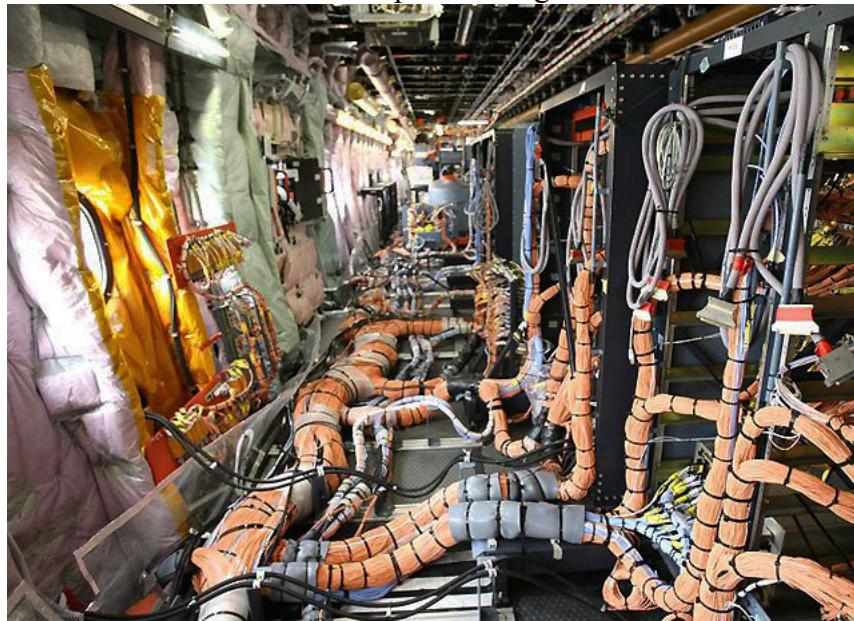
On one end of the scale there is OEM automotive wiring, like on your new passenger vehicle or truck, wherein costs are paramount and warranties are offered, in some cases, bumper to bumper for 100,000 miles. Pictured above is a production passenger car harness in GXL and TXL wires.

These vehicles and their myriad of up to sixty microprocessors, connectors, sensors, relays, and switches are tested for years on end in extremes of temperature, humidity, vibration, and electrical interference. There are no mil-spec metal shell connectors, no airframe tie wrapping or concentric twisting, and no epoxied or glue-shrunk connections...Only plastic connectors and crosslinked polyethylene GXL and TXL multi-strand copper wiring without any silver, tin or nickel plating. Guess what, they work just fine...amid increasing complexity, for years on end. A typical mid-sized car will have about 45-70 lbs of wiring.

One time we scrapped out a 20 year old Honda Civic and were amazed at how all the wiring was still in perfect shape...Connector seals were still sealed and clean inside and all the grime, water and heat had not caused any failures. Wiring was still flexible and not cracked. OEM specifications and engineering are pretty damn good.

In short, automotive grade wiring and connectors have a pretty good track record. Not glamorous, but in business, economics and bean counters seldom are.

Aerospace Wiring



Airbus 380: With 530Km of wires, cables and wiring harnesses weave their way throughout the airframe. With more than 100,000 wires and 40,300 connectors performing 1,150 separate functions, the Airbus A380 has the most complex electrical system Airbus had ever designed. They got to do it twice i.e. rip it all out and do it over due to incompatibility in various software programs spread across a myriad of suppliers. No concentric twisting, no DR-25, no RT-125 epoxy. 20,000 flight hours life. Go figure.

[You Tube Video.](#)

Motorsports Wiring... Race-Spec



This has evolved from aircraft and military specifications wherein light weight and reliability are paramount. As motorsports evolved into an increasingly more sophisticated and expensive professional endeavor, specific motorsport connectors have evolved which are even lighter and smaller than their aerospace counterparts. These products don't have to meet oem production testing requirements...They just have to be reliable in a racing environment which is not the same as freezing in Siberia or bouncing down rural roads in your F150 pickup for decades.

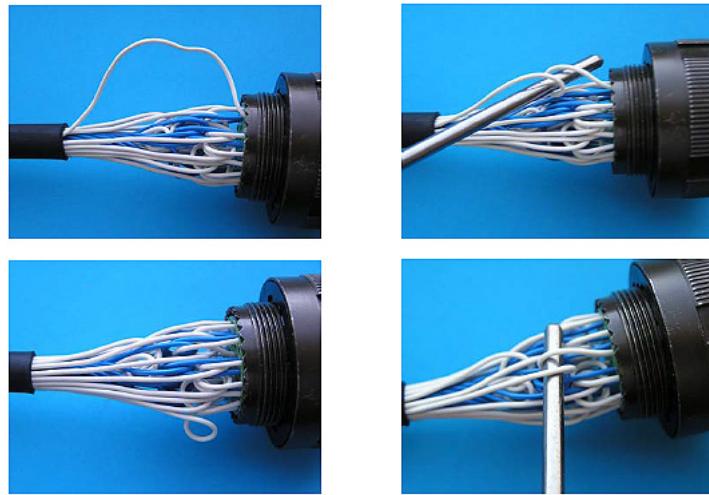
Sort of serious in a Darth Vader, rubber-fetish way. Bondage and latex in the hell of an engine bay. Above are heat shrink boots sealing circular connectors and the DR-25 heat shrink wire protection.

Everything that can slow you down is the enemy....weight of the wires, weight of the connectors and any kind of outright failure, or worse, intermittent failure, which is harder to isolate. This is why F1 might be using tiny 30 gauge wire or why the new McLaren MP4-12C went to extremes in specifying hexagonal aluminum wire to save

both space and weight.

In motorsport electronics Mil-spec circular connectors are the norm, full of all sorts of trickery like strain reducing service loops and concentric twisting for flexibility and more compact wiring harnesses. Reliability at 30,000 feet or going airborne at the Nurburgring...it's all the same thing...well, sort of the same thing. Mil-Spec...Race-Spec...Autosport.

Service loops



"Service Loops" are used on Mil-Spec / Deutsch Autosport circular connectors for wire sizes 16 AWG to 30 AWG. The purpose is to provide strain relief to the wire termination and to provide a surplus length for repair purposes. It is not an aircraft procedure per se and is only used in military and motorsport applications.

Depending on your planning these can go in first or last. The wires have to be loose so doing them as they are installed in the connectors easier with a large number of terminals. In general, it's easier to work from the connector outwards rather than with all the wires bunch up at the connector as shown above...planning all this is a bitch.

In any case extra wire length has to be planned for with concentric twisting, service loops, and bends in the installed wiring harness (longer radius on the outside of the bend). On the average plan for 15% additional length. [PDF on Service Loops](#).

Looping Tool and Procedure



The process is to crimp and insert the wires into the connector either singularly or two at a time. Use an 1/8" or 3 mm round-nosed tool to form a loop in the wires. You can grind down and modify a machinist's scribe or small screw driver to make a looping tool. To hold multiple loops in a line any 1/8" rod will do...We do TIG welding everyday and 1/8" aluminum welding rod works fine. We cut a bunch of 1/8" aluminum welding rods about 4" long to hold the service loops in place as we work.

On circular connectors it is recommended to start at the center and work outwards if the numbering system runs clockwise or counterclockwise. For rectangular or circular connectors identified in rows, it is recommended to work row by row. Loops should face inwards. Loops must be staggered to minimize any increase in the cable diameter. When looping is complete all loops should face inwards to give a neat appearance and to insure that the wires are not trapped or damaged if an adapter or back fitting is present.

If your connector is already terminated and the wires are shrunk with DR-25 it gets a little more difficult as you will have to press back the connector to bow the wires. You may have to cut back on the harness DR-25 to free up the wires.

All of this is a bit stiff to wrestle with so holding the wiring harness, the connector, and the looping tool at the same time is a bit interesting. Think ahead. A specialized connector fixture (best) or a vise with aluminum jaws can be used to hold the connector.



The connector above features concentric (twist) wiring, service (strain relief) loops at the connector, lacing cord and Kynar clear shrink to hold the wires tightly together near the connector. Kapton tape will cover the wires and service loops at the connector to protect them from the specialized boots (shapes) and RT125 harness epoxy.

The DR25 can be terminated with a short length of Raychem SCL adhesive lined heat shrink. With the wires covered by DR-25, the SCL, Kapton tape, and the RT125 sealed boot, the harness will be protected from the environment and from abrasion.

Here flat braided lacing tape is counter-wound to hold the concentric twisted wires in place. Something to think about: Were the service loops put in first or last? Generally first and work outwards. [Guideline for concentric twisting](#).



Here a Deutsch Autosport connector has its Spec 55 wires wrapped in Kapton tape to prevent the adhesive shrink or harness epoxy from grabbing the wires. The tape allows repairs to be made at a later date. Once the adhesive or epoxy sets it really grabs the connector, the DR-25 wire covering, and anything underneath it. Raychem boots are heat shrunk at about 480F (280C).



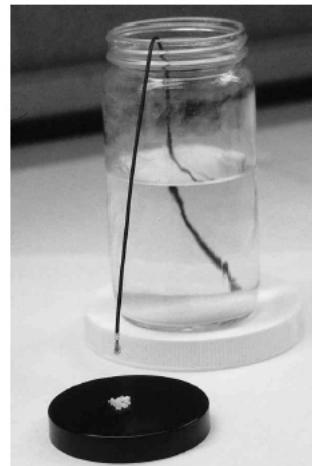
Low Static Kapton adhesive tape is commonly available in 1/4, 3/8" and 1/2" rolls. The silicone adhesive does not leave any residue. It is amber in color.

Motorsports Wiring...Race-Spec



Circular connectors, glue shrunk boots, Raychem DR-25 shrunk over concentric wound silver-plated Raychem Spec 55 XLETFE wiring and, of course, the requisite yellow shrink tube labels covered in Raychem RT-375 clear shrink tubing. [Cosworth Pectel SQ6M ECU](#). Mil-Spec evolved into Race-Spec.

Wicked Wicking



A salt deposit can be seen beneath the end of this 18-AWG, 19-strand wire. The other end of the wire has been immersed in salt water for 24 hours.

In case you doubt the need for epoxy or adhesive-lined terminations, the above picture gives graphic evidence of corrosion traveling down the voids between the strands of copper wires. Since we go to the Bonneville Salt Flats two to three times a year for up to a month, and everything gets bathed in salt, properly sealing the electrical connections is a major concern. Year one OK...year two fix one or two things...year three redo everything. Using adhesive-lined or epoxy-based sealing schemes we can keep corrosion out of our wiring harnesses.

OEM harnesses employ silicone seals on thermoplastic connectors to address these issues. Any gap in the harness can provide a path to internal corrosion.

Sealing With Epoxy



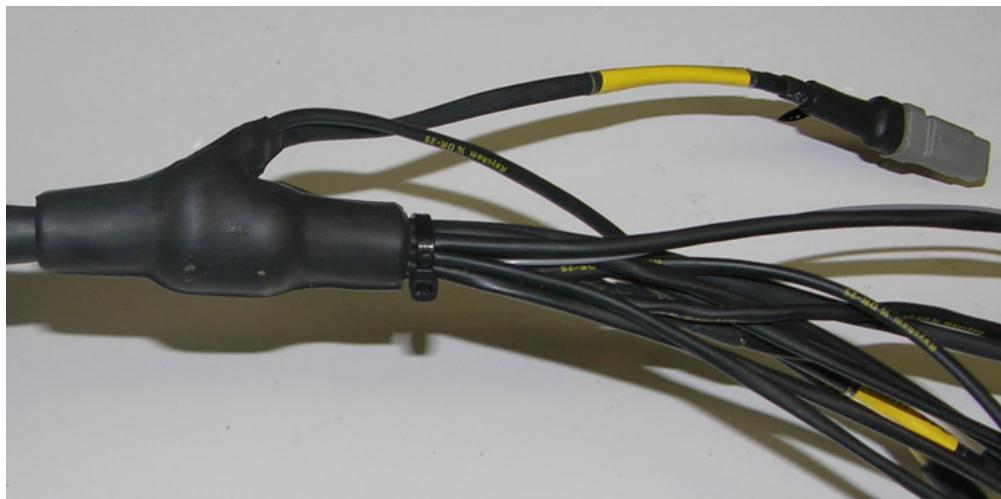
Sealing boots and shapes that do not have adhesive melt can be done with specialized two part epoxies. Abrading the inner surface and applying the epoxy to the connector and cable before the heat shrinking operation. Epoxy is not applied to the inside of the heat shrink. Here the connector is sealed to the cable using V25 Deray thin wall shrink tube (2:1) and sealed with epoxy.

Resintech RT125 Epoxy



The preferred epoxy for sealing wiring harnesses is [Resintech RT125](#). It is a two part semi-flexible epoxy that is mixed 50/50. You can purchase RT125 and a 3M applicator mixing gun from Prowire. These are standard 50ml cartridges. Note they have a shelf life. If you are using this in concert with non-adhesive lined boots do not fill the boot up with epoxy or you will have a real mess. Only seal the ends one at a time. Be prepared to do some clean up wiping with a clean cloth and alcohol as the epoxy hardens much later than the adhesive lined boots.

If the entries and exits of the boot are single round diameters then either adhesive lined or non-adhesive lined boots can be used. If non-adhesive then seal the exits with RT125, one exit at a time, wiping the excess off. Syringes are used for more delicate sealing of smaller parts.



Here we have sealed the multiple branches under the Raychem boot with Resintech RT125 and shrunk the boot over the epoxy. It's a good idea to use an additional tie wrap strain relief at the multiple branch point.

Resintech RT125 3M Mixing Gun



3M EX-PLUS-II-APPLICATOR for the Resintech RT125. This makes the application of the epoxy a lot less messy. [About \\$50.00 from Prowire USA](#)... well spent. You throw away the mixing nozzles after each application as the RT125 starts setting rather quickly. You should let the applied boot and RT125 harden as it can get a bit messy before you go off to the next sealing point. Hanging the harness up so the RT-125 doesn't flow "down" away from the joint is a good idea.



We buy the mixing nozzles in packs of 12 as we use RT125 for other projects in addition to sealing wiring harnesses.

Epoxy Syringes 3cc and Epoxy Needles 15 ga



When working with smaller harness components 3cc Luer Lock style disposable syringes can be used with [15 gauge Luer Lock stainless steel 1.5" needle blunts](#) to dispense harness epoxy. These are inexpensive one time use items...For example, a box of 200 syringes from [Ace Surgical Supply](#) runs about \$17.00.

TE Connectivity S1125



Sold it kits with supporting materials [S1125 adhesive](#) is used to seal DR-25 and Raychem Boots in the same manner as Resintech RT125. [This video](#) shows the proper procedure for sealing and testing the bond on DR-25 and molded boots. S1125 is more expensive than RT125. The procedures are the same for both. Here a non-adhesive lined boot is sealed on both ends.

With Ideal 46-204 Elite Plus Heat Gun use 46-955 Ovelap Adaptor to shrink the boot.

Motorsport Wiring Vises



Inexpensive vises for holding motorsport wiring harnesses and connectors. The SE 8436MVC 3" Universal Table Vise on the left above has slip on soft rubber pleated jaws.

The vacuum base Panavise Model 381 on the right we modified with two 4" x 1" x .25" steel plates replacing the Panavise plastic jaws and added a set of 4" NO-M.A.R [PlastiXrevolution](#) magnetic polymer magnetic jaws. This gives us a 1/2" to 1" diameter grip on wiring harnesses.



Here we are holding an Autosport AS16 26 position connector for socket insertion and service loop forming. Any circular connector clamping diameter beyond 1" and up to 1.250" you will have to fabricate a new lead screw with a 7/16" x 14 x 5" socket head cap screw and drill / insert a 1/4" handle.

Both vises come with soft jaws. Invaluable when holding harnesses for concentric twisting, forming service loops, or pin/ socket insertion. Available from many sources. The SE8436MVC can mount to the table's edge and the Panavise can be moved around and fixed in place if the surface is non-porous.

These are not heavy duty items. Holding wiring harnesses is certainly light duty. We use both. Daniels Mfg has a [\\$750.00 vise](#) for circular connector assembly.

Foam Swabs

**48040**

Chemtronics Coventry [Sealed Foam 48040 Swabs](#) are perfect for dealing with harness epoxy as you don't have to mess with the fuzzies in common cotton swabs. [Available in packs of 500](#) for about \$0.12 each. We use all sorts of potting compounds beyond the harness specific RT125 and have found these to be the best way to clean and manipulate the goo.

Raychem Boots



The comprehensive guide is [Raychem Heat Shrink Products](#). However, it can get a bit confusing and, in general, you will be using System 25 Specifications for your wiring and connector sealing. For example on a Pectel SQ6M with three Autosport connectors we might use a 90 Degree Boot with adhesive. 222K152-25/225-0. The /225 refers to the factory applied adhesive, and the "25" is the boot material used in System 25 applications.

Whether you use adhesive lined boots or seal them on their ends with RT125 Epoxy you use about 480F or 280C with your heat gun with a flat bladed tip.

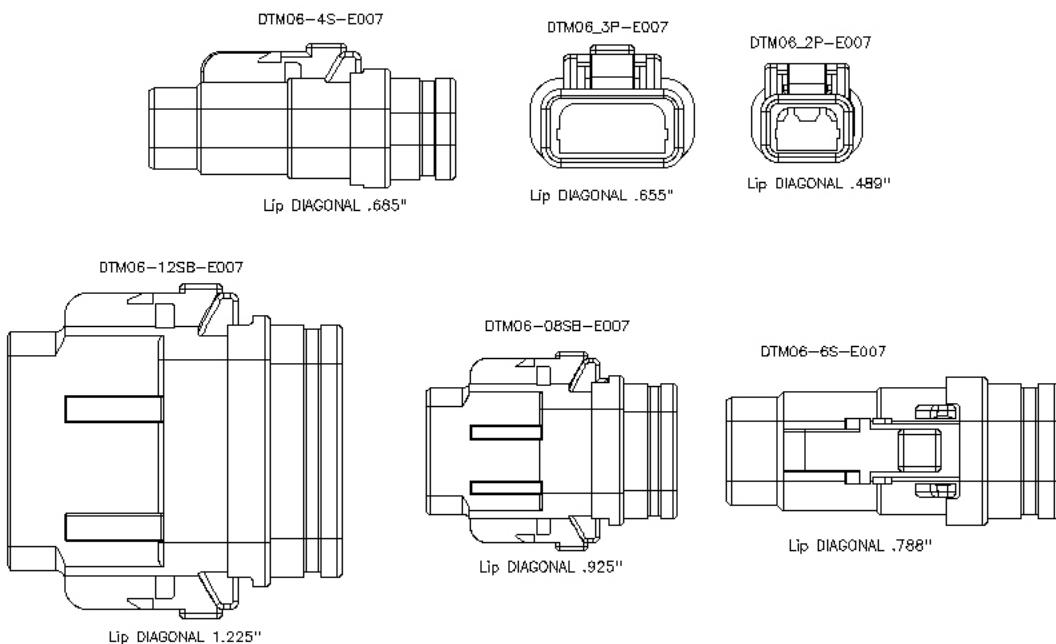
There is a newer "25L" designation for a lighter boot, not listed in the literature.

With Ideal 46-204 Elite Plus Heat Gun use 46-955 Overlap Adaptor to shrink the boots.

[Micro Molded Boots](#)

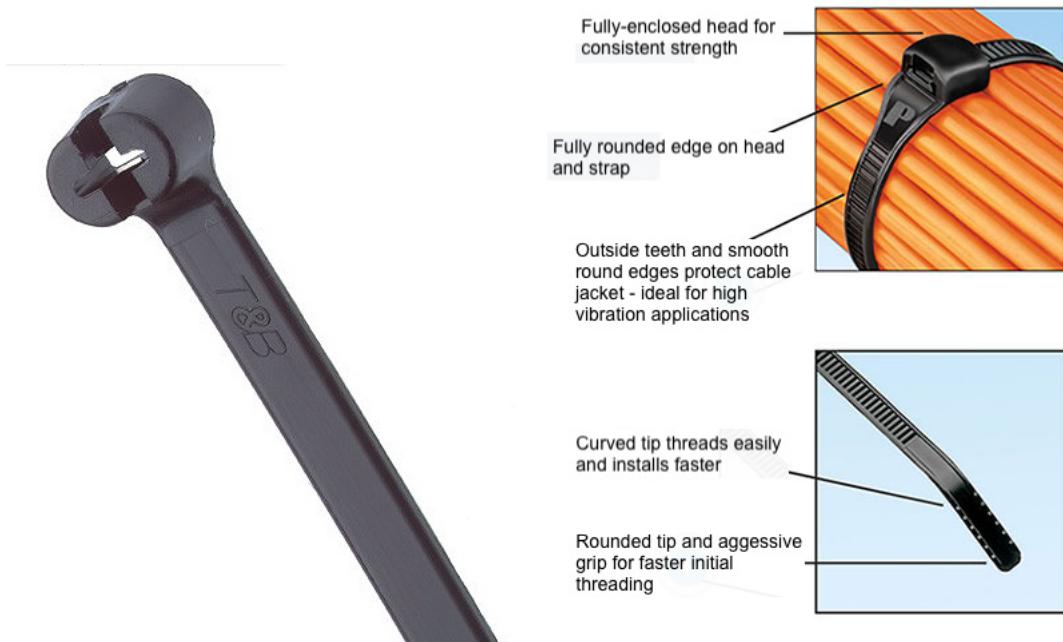
[Instalite Molded Boots](#)

The Raychem boots on Deutsch DTM06_xS_E007 Connectors.



To provide additional sealing and strain relief, either [Raychem molded shapes](#) (boots), or adhesive heat shrink like ATUM (3-1 or 4-1 shrink ratios) can be used on Deutsch DTM Connectors. The lip diagonal dimensions above allow you to decide on the proper sealing boot or shrink tubing.

Cable Ties



We have found the best Cable ties are [Thomas & Betts Ty-Raps](#) with a stainless steel locking mechanism. Metal locking tabs are a NASA requirement (NASA-STD-8739.4 [7.3.4])

An alternative is the Panduit Contour-Ty (right picture). Normally you use Black Nylon cable ties...be sure they are UV Stabilized and only purchase Brand Names like Panduit, Thomas & Betts Ty-Rap, or Hellerman Tyton. Once at Bonneville we bought some cable ties from local auto parts store and they broke when you tightened them

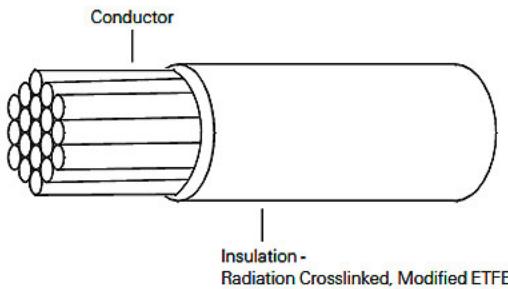
Peek Cable Ties



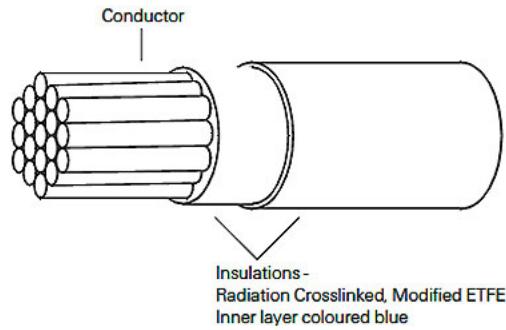
[PEEK Cable ties](#) are rated up to about 500 Deg F... way, way, beyond normal Nylon cable ties (185 Deg F). There are priced in the [\\$1.80 each price range](#) for 100 6" ties. Available from Panduit in 4.0" (PLT1M-C71); 5.9" (PLT1.5M-C71); and 7.4" (PLT2S-C71) lengths.

MIL-W-22759/32-35 and MIL-W-22759/41-46 or Raychem "Spec 55" Primary Wire (Race-Spec)

SPEC 55 insulation system - single wall



SPEC 55 insulation system - dual wall



Raychem Spec 55 wire has become the defacto standard for motorsports wiring. "Spec 55" is a trademark of Tyco Electronics. The actual designation is MIL-W-22759/32-35 and 41-44. MIL-W-22759/44 is the normal wire of choice with silver plated copper stands. Silver plated copper (SPC) strands have a higher temperature rating than does Tinned copper (TC) strands.

Spec 55 Single Wall or "interconnect" wire carries the designation 55A011-xx-xx. Spec 55 Dual Wall or "airframe" wire carries the designation 55A081-xx-xx.

"XLETFE" insulation refers to Cross Linked ETFE Polymer (Tefzel) which provides increases abrasion resistance over Tefzel insulation. Dual wall construction is commonly used in aircraft. ETFE is described as a "modified radiation cross-linked polymer".

Specification	Insulation	Conductor	AWG Range	Temp	Voltage	Wall Type/Thickness	M27500 Symbol
MIL-W-22759/32	XLETFE	TC	30-12	150C	600	Single .006"	SB
MIL-W-22759/33	XLETFE	SPHSCA	30-20	200C	600	Single .006"	SC
MIL-W-22759/34	XLETFE	TC	24-00	150C	600	Double .010"	SD
MIL-W-22759/35	XLETFE	SPHSCA	26-20	200C	600	Double .010"	SE
MIL-W-22759/41	XLETFE	NPC	26-00	200C	600	Double .010"	SM
MIL-W-22759/42	XLETFE	NPHSCA	26-20	200C	600	Double .010"	SN
MIL-W-22759/43	XLETFE	SPC	26-00	200C	600	Double .010"	SP
MIL-W-22759/44	XLETFE	SPC	28-12	200C	600	Single .006"	SR

Dual wall (normal weight) "Spec 55" will have an inner layer of a contrasting color (blue) to indicate when the wire has been nicked, abraded or cut.

TC refers to Tin Plated Copper. SPHSCA refers to Silver Plated High Strength Copper Alloy. NPC refers to Nickel Plated Copper. NPHSCA refers to Nickel Plated High Strength Copper Alloy. Note: 24-30 AWG should use SPHSCA conductor

Nickel has a higher melting point than does silver but this is of little consequence in motorsports ecu wiring.

Alternatives to MIL-W-22759/44 "Spec 55" Race- Spec Primary Wire

A less expensive and more commonly available wiring is the single wall Tin Plated (TC) Copper strand wiring MIL-W-22759/16 or the thinner wall 22759/32. It could be argued that silver has a better conductivity and higher temperature rating than tin plating...but, both offer increased protection against corrosion over bare copper wires.

Specification	Insulation	Conductor	AWG Range	Temp	Voltage	Wall	M27500 Symbol
MIL-W-22759/16	TEFZEL	TC	24-00	150C	600	.011"	TE
MIL-W-22759/32	XLETFE	TC	30-12	150C	600	.006"	SC

The main benefit of Spec 55, MIL-W-22759/44 and MIL-W-22759/32, over the alternative MIL-W-22759/16 is that it is "tougher" i.e. it has better abrasion properties due to its irradiated jacket. This is less of a concern if the harness is sheathed in DR-25 heat shrink, which is a common motorsports practice. In short it is an acceptable alternative to the more expensive 22759/44 silver plated wire.

In 20 AWG it weighs 5.18 lbs/1000 feet as opposed to Spec 55 20 AWG which weighs 4.3 lbs/1000 feet. It is also larger in diameter in 20 AWG .060" versus .050" for the Spec 55 wire.

A thinner and bit tougher insulation alternative to the /44 wire is the MIL-W-22759/32 and saves a few thousandths in diameter and weight...It's the same price as the /16 wire. Both are tin plated copper ("TC"). [Available from ProwireUSA](#). A thinner tougher wire in the 22759/44 and 22759/32 variations.

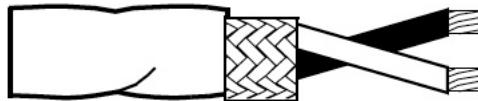
Wire is really the cheapest part of the equation. It's the labor stupid. We use the /32wire for our harnesses.

A word of advice: When you stock up on 22/20/18/16 gauge wires be careful to keep the various gauges physically separated as it's easy to grab, say, some 20ga (22759/32-20-xx) wire when you really are installing 22ga (22759/32-22-xx) wire. This mistake makes it interesting when you go to install the terminals.

Note: Tefzel is Ethylene-Tetrafluoroethylene (ETFE)

Twisted Pairs: Protection From EMI Interference

44A112X (600 V) 2 conductors



How do you strip shielded cable for a solder sleeve?...Well there's always a tool. The [Ideal 45-402 Ringer Cable Stripper](#).

Crankshaft sensors, camshaft sensors, RS 232 and other communications should use twisted pair, shielded, wiring. 20 or 22 AWG is typical for twisted pair sensor and communications. We use 22 gauge [Shielded Tefzel Cable](#) wires for our two wire crank position sensors.

Twisting the wires reduces magnetically induced interference. Forcing the wires together reduces the loop area and therefore the induced voltage. Since the currents are flowing in minimum loop areas, magnetic field generation is reduced. Good idea to avoid signal problems due to noisy ignitions, coils etc.



PRECISION WIRE STRIPPERS

IDEAL Ringer™ Strippers

- Strip most non-round shielded cable and other outer jackets, including extruded Teflon®, Kapton®, PVC and Kynar®.
- Spring-loaded head holds cable, no need for adjustment.
- Fixed blades are sized to insulation, preventing inaccurate cuts.
- Heat-treated stainless-steel blades assure long life.

Part No.	Blade Inc.	Description
45-401 (Or)	K-6492	5 Mil insulation thickness including Kapton®.
45-402 (Ylw)	K-6493	8-10 Mil insulation thickness including Kynar®.
45-400 (Bl)	Sold Separately	Cable diameters up to 0.12 in.
45-403 (Rd)	Sold Separately	Cable diameters from 0.12 in. to 0.22 in.
45-404 (Grn)	Sold Separately	With "deep-V" for larger cable diameters up to 0.20 in.

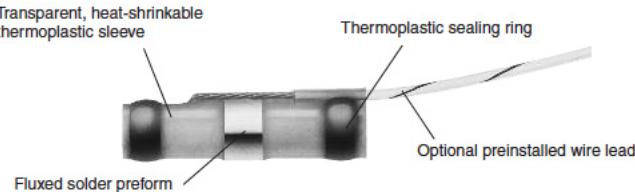
Ringer Blades

Part No.	Cutting Depth	Part No.	Cutting Depth
K-6499	.0120 in	K-6491	.0030 in
K-6500	.0130 in	K-6492	.0044 in
K-6501	.0140 in	K-6493	.0060 in
K-6502	.0160 in	K-6494	.0070 in
K-6503	.0180 in	K-6495	.0080 in
K-6504	.0200 in	K-6496	.0090 in
K-6505	.0220 in	K-6497	.0100 in
		K-6498	.0110 in



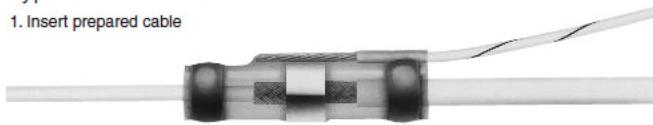
Note that the commonly used model 45-402 comes with a blade and is used on 20-24AWG M27500 SB cable.

Typical SolderSleeve Device (illustration of shield terminator concept)

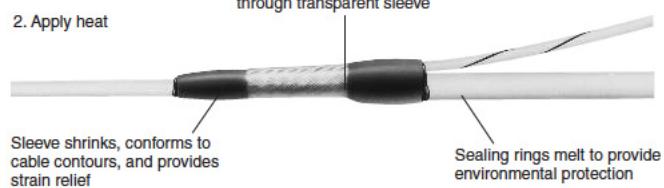


Typical Installation

1. Insert prepared cable



2. Apply heat



Grounding of the shielded cable is accomplished by using dedicated solder splices. Section 8-3 of Tyco Electronics (te.com) main [Wire and Cable 27.9Mb Catalog](#) lists these solder splices. They are available with or without leads. We ground our shielded wire jackets directly at the SQ6M ecu.

Procedures are defined for grounding the of the shielded wires.

Where to Buy Supplies



[Home](#) [Categories](#) [Manufacturers](#) [Customer Service](#)

An excellent source for your wiring supplies for you go it alone types is [ProwireUSA](#) as they stock about everything you need and sell in small quantities. It a good place to pick up your MIL-W-22759/32 and MIL-W-22759/16 wire and supplies. They have 140 Mil-Spec wire color combinations in stock. ProwireUSA has extensive

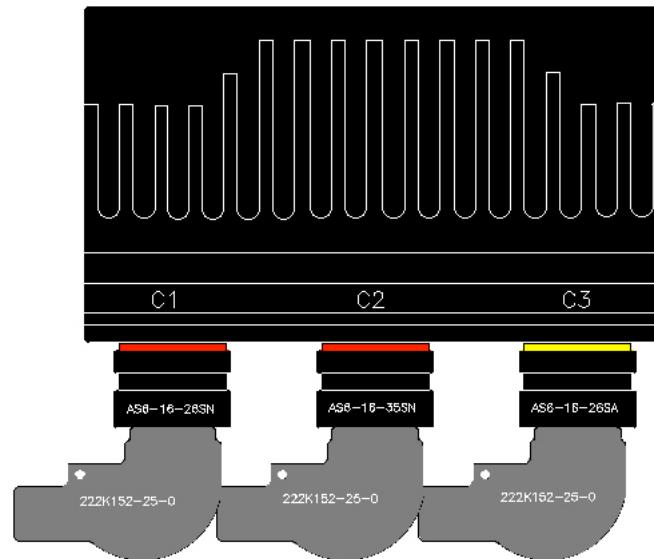
experience building wiring harnesses and only stocks the best and competition proven parts. Quick service and excellent prices.

ProwireUSA
9260 Isaac St Suite B
Santee Ca 92071
Phone 619-440-9473
Fax 866-224-7057
sales@prowireusa.com

Connectors



[Deutsch Autosport](#): Specifically designed for motorsport. Lightweight. Expensive. Requires Mil-Spec crimping and stripping tools. This is [Cosworth Pectel SQ6M](#) that we use on our ORCA motor [turbocharged Harleys](#). The color bands denote the connector shell keyway. The left and right connectors are 26 Pin 20 gauge of different keyway locations so you cannot mix them up. The center connector is a 55 pin 22 gauge connector. Figure on spending about \$400.00 for the associated connectors, sockets, and insertion tools for the SQ6M. 107 pins total.

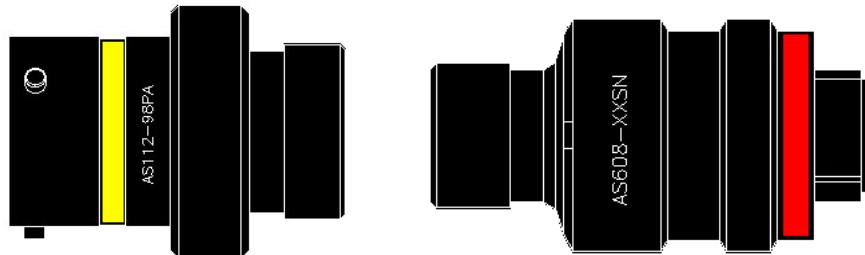


Metal shells don't melt like plastic ones do. Higher end motorsport applications all use Autosport ECU connectors...Pectel, McLaren, Magnetti-Marelli, and Bosch. We model the SQ6M with the Autosport connectors to use in our wiring diagrams.

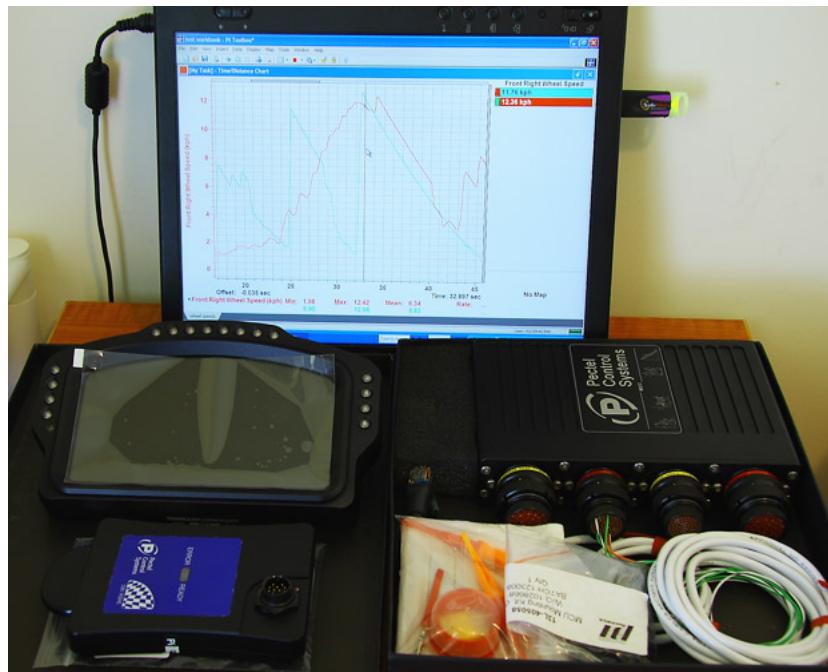


One simple way to do layout planning for wire and heat shrink lengths, where the harness makes some turns, is to use electrical wire that can be bent into shape. Here we are figuring out the lengths where the three SQ6M connectors will exit the three 222K-152-25-0 boots and go to the next boot, a Raychem 202A153-25-0.

8AWG works well. Here we used some 4AWG. It worked out to 16", 19" and 22". From there we subtract the overlap from the boots to get the DR-25 lengths. We fudge wire lengths on either end to allow for concentric twisting.



We model the various Deutsch Autosport connectors that we use in our harnesses. Pricey devils, but they don't melt, and use Raychem lipped boots sealed with Resintech RT125.

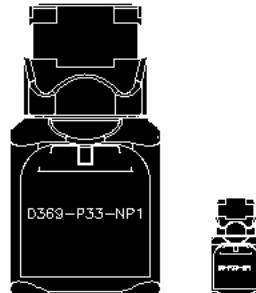


Pectel MQ12 controller. Same as used by Aston Martin, Lotus, Nissan Nismo GTR and in World Superbike. Full Autosport Connectors. In case you are wondering how fast this controller can process things it has a MPC5200 processor that delivers 760 Million MIPS (Instructions per second) to keep track of all your inputs. Four Autosport Connectors.

What's Between Autosport and DTM Connectors?...[Deutsch 369 Series Connectors](#)



[Deutsch 369 Series Connectors](#) come in 3, 6 or 9 pin variations. These are rated at 175 Celsius or about 50 degrees Celsius higher than Deutsch DT or DTM Connectors. They are also IP67 rated. Made of high temperature PEI/PEEK materials with Fluorosilicone seals, they are about 5 times more expensive than DTM connectors. Designed for aerospace they use #22 Contacts 26-22 AWG. Just the ticket for motorsports wiring with its high heat, weight, space, and harsh environment requirements. Less expensive than Deutsch Autosport variations. A video explains the 369 Connector features on [this page](#).



The 369 Series are really small parts. Above left is an oversize model of the Deutsch three pin 369 Receptacle. Above right is an actual size model of the 3 pin Receptacle. The actual part is .389" Width by .752" Length...Smaller than a comparable Autosport Connector. Nice items for motorsports wiring with FBW (6 wire) and other sensors which use 22 Gauge wires where heat, space, and packaging issues are at a premium. We use these in conjunction with Black DTM connectors, with the DTM connectors being used with larger gauge wires.

Where to Buy [Deutsch Connectors](#)



Deutsch DT, DTM and DTP Sealed thermoplastic connectors are the cost effective motorsport standard...A step above the ubiquitous Weatherpack connectors. Used by all motorsport wiring professionals in Mil-Spec and Race-Spec Motorsport wiring.

The best place to buy these is the [Deutsch Connector Store](#). With 100 rated mating cycles and precise pins and sockets these are the next step below the all metal Autosport Connectors which are way, way, more expensive. Its best to buy these from someone who can provide a complete solution in both parts and tooling. Fast shipment and excellent prices.

If you get confused by all the Deutsch Suffixes in the part numbering scheme [check out this page done by LADD](#).

Deutsch DTM

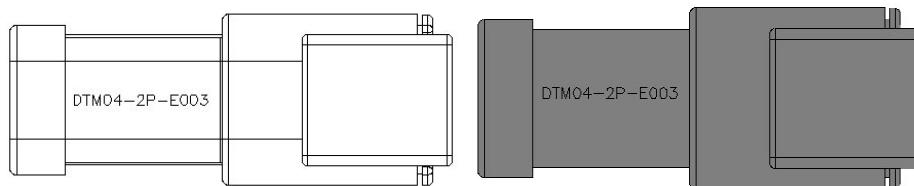


[Deutsch DTM Series](#) : Sealed thermoplastic connectors designed for harsh environments like engine compartments. Reasonably priced. Available from many sources, they offer watertight silicone seals that also act as a strain relief. Available in 2, 3, 4, 6, 8 and 12 pin contacts with size 20 contacts for AWG 16 to 24 gage wire. Either solid pins and sockets or crimped pins and sockets can be used. Solid pins are crimped and are easiest to work with. In no case should the pins and sockets be soldered. Multiple wire size #20 contacts with 7.5A rating.



Pictured above are 2, 3, and 4 pin DTM connectors with the optional shrink boot adapter (Option E007). There are all sorts of suffixes for the DTM connectors and whereas you might spec out a particular option i.e. like the shrink boot...It may not be available in plug and receptacles. We suggest you check out this [interactive product guide](#) first.

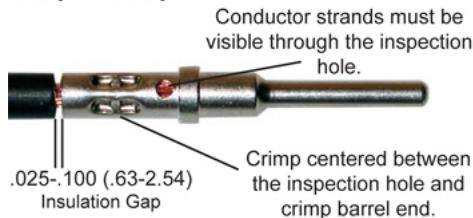
.DXF Files Deutsch DTM Connectors



For our CAD wiring harness drawings we construct .dxf models of these Gray Deutsch DTM Connectors on a 1:1 scale. There are downloadable in Autocad R14 .dxf file formats. In Firefox Browser Choose "File, Save Page As", and open in your CAD program. They can be colored as is the gray two pin DTM above.

Alternatively you can import .dxf files into [Microsoft Visio Professional 2013](#) using [Autodesk TrueView](#).

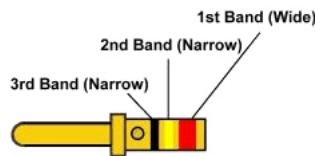
2 pin	DTM04-2P-E003
2 socket	DTM06-2S-E007
3 pin	DTM04-3P-E003
3 socket	DTM06-3S-E007
4 pin	DTM04-4P-E003
4 socket	DTM06-4S-E007
6 pin	DTM04-6P-E003
6 socket	DTM06-6S-E007

Proper Crimp

All of the pins and sockets are made from 98% pure copper and then plated. Standard plating is Nickel. For critical circuits, pins and sockets are plated with Nickel and then Gold. For lighting, power and control circuits choose Nickel. For critical and very low voltage and amperage circuits such as oxygen sensors that operate at 0-1 volt or 0-5V (wideband) and for data transmission circuits that operate at 5 volts, choose Gold. Type K Thermocouple wire should use Chromel or Alumel terminals (see below) in the DTM two or three wire connectors.

Note: rear silicone seal will seal on smooth insulation from .053" to .120" O.D. Of importance is the fact they are rated at 100 cycles of engagement and disengagement. These are your affordable step below the very expensive Deutsch Autosport line. They will melt if they touch something like an exhaust so be careful about securing things before you start an engine.

Deutsch DTM Connectors with Alumel and Chromel Thermocouple Terminals



"MS" Contacts have a BIN (Basic Identification Number) code consisting of three color bands around the crimp barrel. There are 10 colors which designate a number. The BIN codes are read from the wire barrel end of the contact towards the mating end. The first band is wider than the other two to further facilitate identification. Bin-code can also be stamped on the contact. Example: Red/Yellow/Black above would be -240 suffix. Deutsch DTM #20 terminals in Alumel and Chromel are available. The sequence of the color bands defines the terminals material and type.

- 0 = Black
- 1 = Brown
- 2 = Red
- 3 = Orange
- 4 = Yellow
- 5 = Green
- 6 = Blue
- 7 = Violet
- 8 = Gray
- 9 = White

Thermocouples, either EGT probes or Cylinder head temperature, have to be wired with special thermocouple wire all the way to the ECU input pins. You must use Alumel or Chromel wires and terminals i.e. pins or sockets, or you will have cold-junction errors. The all-metal Deutsch Autosport Connectors have specialized size #22 Alumel and Chromel terminals as well as #23 for the MicroLite Series.

There are also size #20 [Chromel and Alumel Terminals](#) available for the less expensive DTM series of connectors.

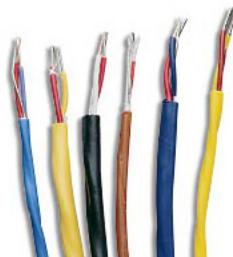
Pectel [SQ6M ECUs](#) have two dedicated EGT Chromel (+) pins: (TC1 POS [YEL Wire], TC2 POS [YEL Wire]); and one common EGT Alumel (-) pin (TC NEG [RED Wire]) in the AS216-35PN connector.

THERMOCOUPLE & COAX CONTACTS – PINS								
SAMPLE CONTACT	CONNECTOR SERIES	CONTACT PART NUMBER	COLOR BANDS			GAUGE MATING WIRE END / BARREL	BIN CODE 0 1 2 3 4 5 6 7 8 9	MATERIAL
			1ST	2ND	3RD			
	MIL-C-26482	MIL-C-39029 / 9	Brown	Orange	Red	20 / 20	132	TC-CU
	SERIES II					20 / 20	133	TC-CO
	MIL-C-81703				Yellow	20 / 20	134	TC-AL
	SERIES III			Orange	Green	20 / 20	135	TC-CH
	MIL-C-83723				Blue	20 / 20	136	TC-FE
	SERIES I & III							
	MIL-C-83733							

Chromel Pins Size #20: MIL-C-39029/9-135; Brown Orange Green
 Alumel Pins Size #20: MIL-C-39029/9-134; Brown Orange Yellow

THERMOCOUPLE & COAX CONTACTS – SOCKETS								
SAMPLE CONTACT	CONNECTOR SERIES	CONTACT PART NUMBER	COLOR BANDS			GAUGE MATING WIRE END / BARREL	BIN CODE 0 1 2 3 4 5 6 7 8 9	MATERIAL
			1ST	2ND	3RD			
	MIL-C-26482	MIL-C-39029 / 10	Brown	Yellow	Grey	20 / 20	138	TC-CU
	SERIES II			Orange		20 / 20	139	TC-CO
	MIL-C-81703			Yellow	Black	20 / 20	140	TC-AL
	SERIES III			Yellow	Brown	20 / 20	141	TC-CH
	MIL-C-83723					20 / 20	142	TC-FE
	SERIES I & III							
	MIL-C-83733							

Chromel Sockets Size #20: MIL-C-39029/10-141; Brown Yellow Brown
 Alumel Sockets Size #20: MIL-C-39029/10-140; Brown Yellow Black



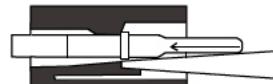
You should always use [twisted thermocouple wire](#) 24ga stranded (7x32), typically shielded, with a integral drain wire. If shielded with a drain wire, use 3 position connector with gold terminals on the drain wire Cover leads with Raychem DR-25 and heat shrink the DTM connectors for strain relief. Typically this is type K Thermocouples.



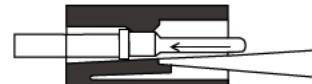
Fast acting (150ms) Thermocouples can be purchased from [HGS Industries](#). For testing and calibration purposes we use a [Thermoworks Microcal 2K](#) that can be set to a particular temperature C/F to .1 degree F and .3 degree C accuracy. A handy C to F and F to C [PDF from Omega](#).

DTM Terminal Removal

Contact Removal Procedure (DTM/DT/DTP)



SCREW DRIVER INSERTED TO UNLOCK CONTACT



CONTACT REMOVED

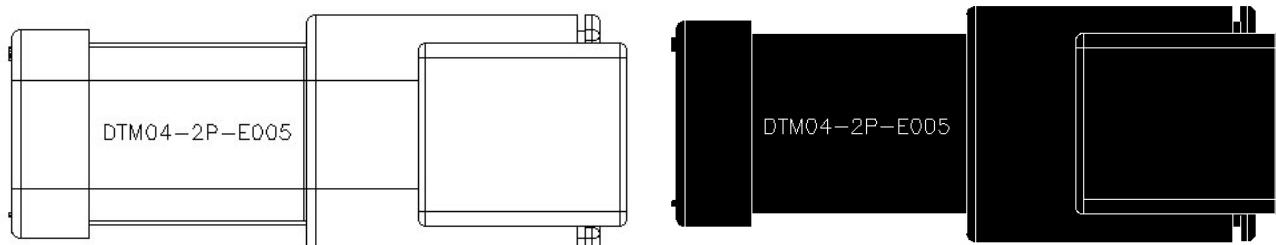
The simplest way to remove DTM Terminals (Pins, Sockets) is to: (1) pull out the plastic terminal lock with a small needle nose plier and then, (2) use a small flat-bladed screwdriver...Typically the one you have that has a magnet on the other end, and release the tab lock by pressing down and pull out the wire. Simple.

Detusch DTM Black



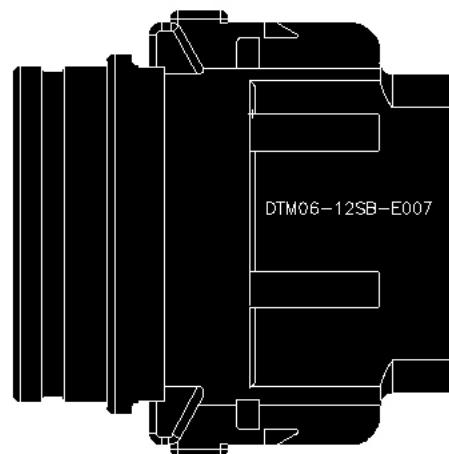
Everyone seems to use only the Gray DTM connectors simply because that's what they see everywhere. The DTM series actually comes in 11 colors. We use the Black DTM connectors on our production street harnesses as they blend in with the DR-25, Raychem Boots, and heat shrink tubing. On motorcycles Black sort of disappears whereas the Gray stands out. We use the E005 End Cap option when it's available...like the "Cat-Spec" DT Series pictured below.

.DXF Files Deutsch DTM Connectors



For our CAD wiring harness drawings we construct .dxf models of these Black Deutsch DTM Connectors on a 1:1 scale. There are downloadable in Autocad R14 .dxf file formats. In Firefox Browser Choose "File, Save Page As", and open in your CAD program. They can be colored as is the black two pin DTM above or the 12 pin DTM

connector below.



Alternatively you can import .dxf files into [Microsoft Visio Professional 2013](#) using [Autodesk TrueView](#).

<u>2 pin</u>	DTM04-2P-E005
<u>2 socket</u>	DTM06-2S-E005
<u>3 pin</u>	DTM04-3P-E005
<u>3 socket</u>	DTM06-3S-E004
<u>4 pin</u>	DTM04-4P-E005
<u>4 socket</u>	DTM06-4S-E004
<u>6 pin</u>	DTM04-6P-E005
<u>6 socket</u>	DTM06-6S-E005
<u>8 pin</u>	DTM04-8PB
<u>8 socket</u>	DTM06-08S-E007
<u>12 pin</u>	DTM04-12PB
<u>12 socket</u>	DTM06-12SB-E007

"Cat-Spec" Detusch DT



Deutsch DT Series have #16 contacts with a 13A rating. Often called "Cat-spec" as they are used by Caterpillar and have improved seal retention on the plug and a cap on the rear of the housing to retain the silicone wire seal.

Controller Area Networks (CAN)



[Specialized DTM Connectors](#) for SAE J1939/15 2-wire CAN systems. DTM04-2P-P007 Receptacle "Y" Connector above left. Right: DTM06-2S-EP10 Plug with molded-in 120 Ohm Resistor. The [Valuecan3](#) is helpful Diagnosing CAN issues.

Sureseal



[Sureseal](#): Interesting rubber push to connect seals. Like any specific connector they require specific and expensive tooling. These connectors are rated at 50 cycles of engagement and disengagement.

Weatherpack



Weatherpack: Ubiquitous automotive silicone sealed thermoplastic connectors designed for harsh automotive environments. These connectors are validated to perform to specification for 10 cycles of engagement and disengagement, but up to 50 cycles probably will not see any signal degradation. In short they are excellent for oem use but a bit wanting in a motorsports environment where >10 engagement/disengagement cycles are normal.

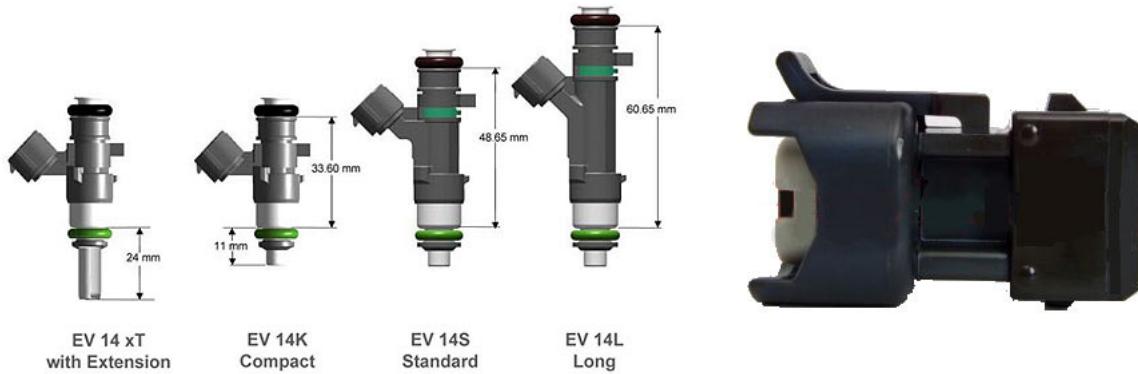


Weatherpack GM MAP Sensors can be further sealed with a [[HellermannTyton](#) (page 63)] [shrink boot](#) available from ProwireUSA. If you use GM 1, 2, or 3 Bar Map Sensors with 22 Gauge 22759/16 or /32 wire use the 15324983 DARK RED Silicone Cavity Seals and Pins 12089307 (22ga). Appropriate pins, sockets and seals for the different wire sizes are available from ProwireUSA.

GM 2 and 3 Bar Connector 12015384 Black; GM 1 Bar Connector 12020403 Green.

Although the Weatherpack connector is "sealed" by the cavity seals it is a good idea to provide additional strain relief. Alternatively seal the ends of the DR-25 with 1.2" of ES2000-1.

Injectors and Connectors



The trend in injectors is to use the [Bosch EV14 injectors](#) which are high impedance, typically 12 Ohms, instead of the older style Low Impedance (2-3 Ohms) as the EV14's are very fast opening and very accurate. To use these you will need to use USCAR EV6 Type B Red style injector connectors (Green Cavity Seal 22ga). The exception to this are the ID2000 Injectors which use a [Sumitomo 6189-039 Injector Connector \(Black Cavity Seal 22ga\)](#).



People tend to yank on the injector wires which are typically 22 ga. Make sure you have the proper crimping tool. Do not solder the wires...ever. We use 22759/32-22 gauge wires for our injectors and we crimp them with our Delphi GT150 Connector crimping tool ([15359996](#)), after we remove spring loaded plastic GT150 terminal stop, using the 22-20 position. If you are using 20 gauge wires you can use the general purpose [Delphi 12014254 Crimping Tool](#).

Bosch Motorsport



These days there is a lot of BS floating around about injector matching etc...Take our advice and use [Injector Dynamics Injectors](#) as they work directly with Bosch Motorsport. Check out the lengths they go to in [this video](#). We use their 750cc, 850cc, 1000cc, 1050cc, 1300cc, 1700cc and 2000cc injectors. Pictured above are the new ID1700X injectors developed in conjunction with Bosch Motorsport. Tony Palo drives a 2400hp GTR so he's crazy like the rest us...only he has more horsepower.

Circuit Breakers not Fuses



Passenger cars use fuses everywhere whereas, in motorsports, re-settable aviation-style circuit breakers are preferred. Circuit breakers have the advantage of being re-settable which allows you to perhaps just "push it in" and get going until you diagnose the problem. You also don't need to replace a fuse. Harley uses truck style thermal breakers...your bike would sign off due to some short and a few minutes later it would run again...but you didn't melt your wires.



Tyco W23, ETA 483, and Klixon 2TC14 series push to set circuit breakers are a standard aviation item and are available in many amperages. They "pop up" when they

trip and you push them down to reset them. If you are using the popular sealed WeatherPack silicone sealed fuse holders you can use Bussmann 227 series circuit breakers that are a drop in replacement, albeit pricey, for the cheaper one time fuses.

[Klixon 2TC14-X](#) (green breaker) are available from ProwireUSA in varying amperages from 1A to 25A for about \$20.00. Higher end ETA 483 series are about four times more expensive.

Breakers like the Tyco W23 are usually installed in panels that a race car driver can reach and reset. "Reach and reset" doesn't work on motorcycles. Space is also a premium on motorcycles and there is the issue of being exposed to the elements like pressure washers. If you go to the Bonneville Salt Flats like we do then corrosion is a major issue.



[Cooper Bussman 227](#) Low Profile ATC Blade Type Manual Reset Circuit Breakers pictured above. There are normally installed in a fuse box in place of the standard ATC fuses. These are too tall to fit in Delphi Metri-Pack Sealed Fuse Holders (12033731 Cap Cover and 12033769 Female Connector).

We normally just use fuses as they fit into the Metri-Pack Sealed Fuse Holders. Waterproof and no screw terminals or panel nuts to get loose.

Waterproof Fuse/Circuit Breaker and Micro Relay Enclosures



[Sealed Busmann Enclosures](#) can house a various combination of fuses, resetable ATC circuit breakers (227), and [ISO 280 Micro Relays](#). These use Delphi Metri-Pack 280 Series (sealed-tangless) connections on the back side. There are a variety of these bussed and non-bussed, so be careful when you order them. IP 66 weather tight sealed. Cheap and compact...or use \$2000.00 and up programmable PDMs.

Metri-Pack 280 silicone cable seals 15324982 (green 18-16ga GPT; 20-18 SXL); 15324980 (gray 14ga GPT; 16ga SXL); Cavity Seal Green 12010300; Terminals: 12110847 (18-16ga); 12129409 (16-14ga).

Panel Mount Circuit Breakers



High Amp Series 17 Waterproof Panel Manual Reset Circuit Breakers from Mechanical Products are available from [Waytek Inc.](#)

Amperage Ratings from 25 to 300 Amps

Trip-free operation

Industry standard terminations available in panel and surface mount

New "Easy Access" Panel Mount and "Side by Side" Surface Mount configurations available

Surface Mount available with 1/4" and New 3/8" stainless steel terminal studs and sems nuts

Panel Mount available with 1/4" brass, nickel plated terminal studs and stainless steel sems nuts

Auto, manual, or manual push-to-trip options

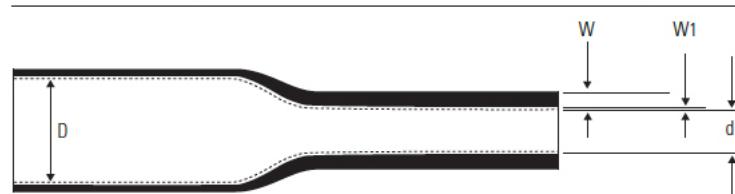
Dustproof and waterproof

Visible trip indication

Ignition Protected

Sealing Backs of Circuit Breakers

Semi-rigid selectively crosslinked heat-shrinkable encapsulation tubing



Raychem SCL heat shrink can be used to seal circuit breakers and other types of switches from the environment. Much niftier than trying to heat shrink a couple of screw terminals. It is a dual-wall adhesive lined shrink tube with a 2.5:1 shrink ratio.

A greater shrink ratio (4:1) can be accomplished by using [Raychem ES2000](#), or DSG-Canusa CDR adhesive-lined semi-rigid shrink tubing. Raychem ES2000 is available in small quantities (4' sticks) from various electronic suppliers like Mouser.

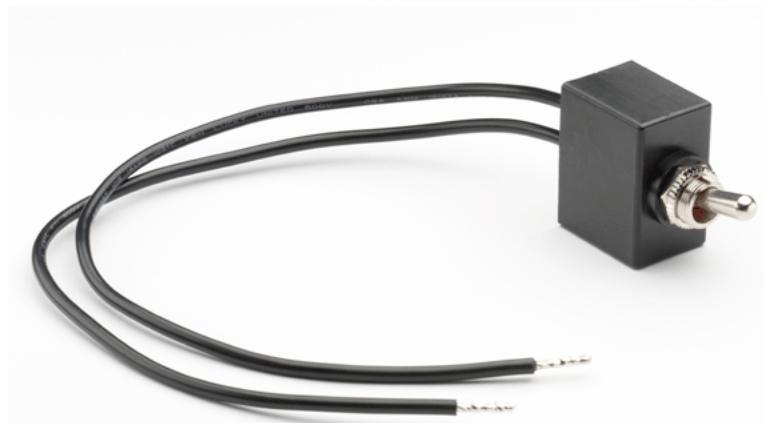
Sealed K4 Toggle Switches





K4 Triple Sealed Switches are used in off road racing and other motorsports where moisture and dust are your enemy. [Complete K4 Catalog](#). Available from [ProwireUSA](#).

Sealed Toggle Switches with Leads



Instead of having to deal with exposed blade contacts or tiny brass screws with eyelets, get a sealed toggle switch with lead wires and install a Deutsch DTM Connector. [Grote 82-2111 SPST Toggle](#) pictured above left. Similar switches, above right, are also available from [Littelfuse](#).



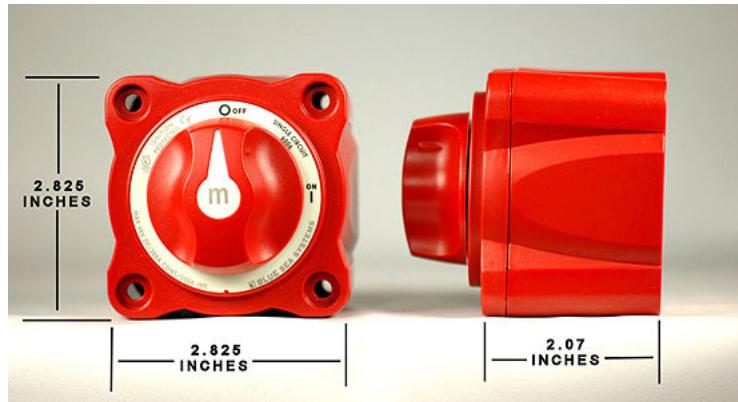
Several less things to worry about...no loosening of screws or issues of sealing blade contacts from corrosion. Here with a DTM connector, Raychem DR-25, RT125 sealing and ATM 16/4. Alternatively you can hardwire the switch with two step-down butt connectors (offset them) and seal the connections with 1.2" ES2000-1 and cover with 1/4" DR-25 sealing both ends of the DR-25.

Pushbuttons..Momentary or Latched



Sealed Mil-Spec OTTO pushbutton switches are available from [ProwireUSA](#). They come in different color buttons but you really need to label them where they are installed.

K4 Battery Disconnect Switch



K4 Battery Disconnect Switch. If you run expensive Lithium Racing batteries you need to remove any parasitic draw to prevent the battery voltage from dropping when the vehicle sits for awhile. If the voltage drops too low due to long term milliamp draws it will permanently kill the battery. The switch also serves as a safety kill switch where regulations require and manual disconnect.

Rotary Map Selection Switches



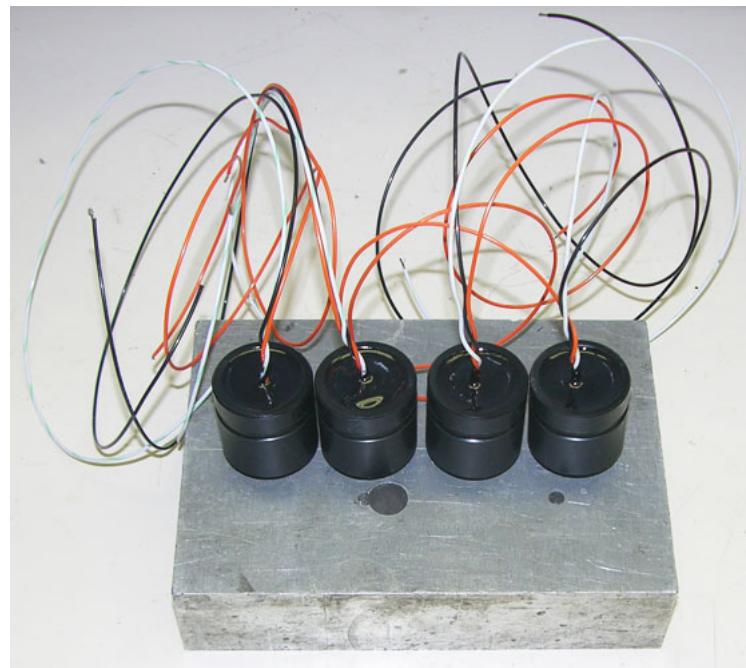
Rotary position switches are a fact of life in Formula 1...Fuel, suspension, traction control, braking bias and whatever the rules allow these days with the spec ecus from McLaren Electronics are all switchable on the carbon fiber steering wheel.



We make up our own Rotary Map Switches that have to survive on a Harley-Davidson. We set these up for four map positions. Traction control maps, fuel and spark maps...all changeable on the fly. Four position switch pictured uses three resistors to set voltages from 5 VDC to 0 VDC in equal steps.



Here is the final assembled switch with the laser cut stainless steel mounting bracket and faceplate. Laser cut slots allow the faceplate and the mounting bracket to index to each other. We stamp the switch positions into the faceplate. The entire assembly is sealed for reliability. We label the color of the signal wire so it can marry up with the appropriate DTM connector on the wiring harness.



We machine the switch enclosure from Delrin plastic and encapsulate the rotary switch in epoxy to waterproof it and use DR-25 heat shrink and formed boots to protect the wiring and install a three position Deutsch DTM connector. 5 VDC, Analog Ground and Signal wires (color coded). We pot the Delrin enclosure / switch with Resintech RT125 on both ends. It takes a few days to cure.



Eight Position Traction Control Rotary Switch. Seven resistors set voltages from 0 VDC to 5 VDC in equal steps. Pectel SQ6M controllers have 7 traction control settings. Position #1 will be traction control "Off".

Stripping & Crimping



Ideal Ergo Elite, pictured on the left, is an excellent wire stripper...Be sure you order the model 55-1987 for MIL-W-22759 wire plus the LB-1904 Clear Plastic Wire Stop. About \$250.00. The clear plastic Wire stop cuts accurately but can trap the insulation between the stop and the blades. Often we leave the stop off.

The Ideal 45-177 Stripmaster Lite (16-26 AWG, Type E Teflon), on the right, is also an excellent choice. Keep the screws in the jaw tightened as they tend to loosen with use. You should also order the L5720 Wire Stop Assembly. About \$150.00

We suggest you get the Ideal Ergo Elite for the most precise work.

Wire Stripping Thermal



The claim is that thermal wire strippers do not nick or cut or scrape the wiring. There are several manufacturers like Teledyne and Hakko. The Teledyne Strippal® Plus pictured to the left above is a self-contained hand-held stripper that either comes with a fixed or variable temperature control. The insulation melts and is stripped cleanly and quickly, readying the wire for crimping or soldering. To the right is the Hakko FT-801 thermal wire stripper.

We don't like getting burned by hot objects. We tried but it was back to mechanical and automatic blade strippers.

Ideal 950 Stripmaster



This is the pricey pneumatic stripper we use at RB Racing. It simplifies doing production work and the stripped insulation collects in the tray. Of course we still use hand strippers because the 950 is a stationary unit, not suited for lugging around the shop doing prototypes in place. Bench item.

Schleuniger UniStrip 2300



If you are doing production work and don't want to spend the day squeezing manual crimpers then you need spend about 25 times more money for an electric stripper like this one. [Video of it in action](#).

Crimping Tools



Daniels crimping tools are the defacto standard for motorsports connector pins and sockets. We also use specialized tools to crimp Weatherpack connectors and Deutsch

connectors.

Daniels AFM8 Turrets



M22520/2-07 Autosport 22 gauge sockets

M22520/2-09 Autosport 22 gauge pins

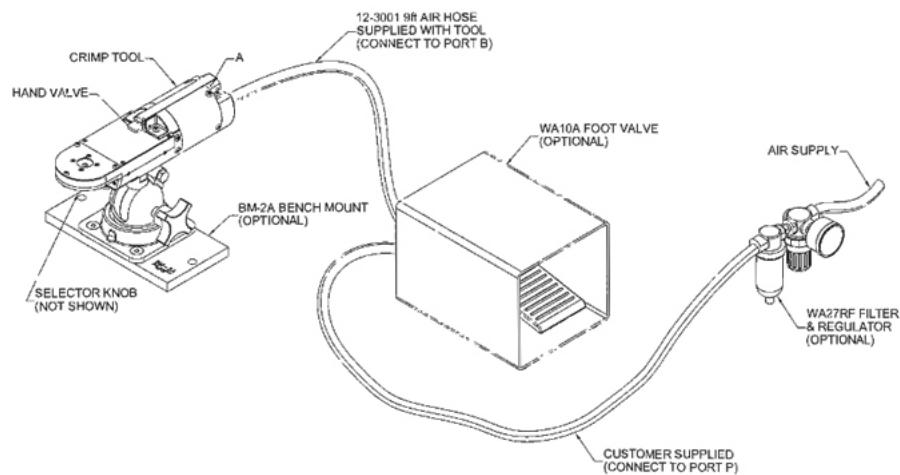
M22520/2-10 Autosport 20 gauge sockets

M225034 Autosport micro sockets

M225035 Autosport micro pins

M22520/2-02 Turret for DTM and Mil Spec

Pneumatic Daniels WA22 Crimper



In addition to hand crimpers we use a Daniels WA22 pneumatic crimper for consistency and to save time. Mounted on a BM-2A Bench Mount and controlled by a WA10A foot pedal. Makes a nice whooshing sound.



This is a selection of the crimping tools that we use to make our motorcycle harnesses. Daniels, Delphi, AMP, Rennsteig, and Deutsch crimpers. We don't do custom wiring harnesses except for our own products and racing.

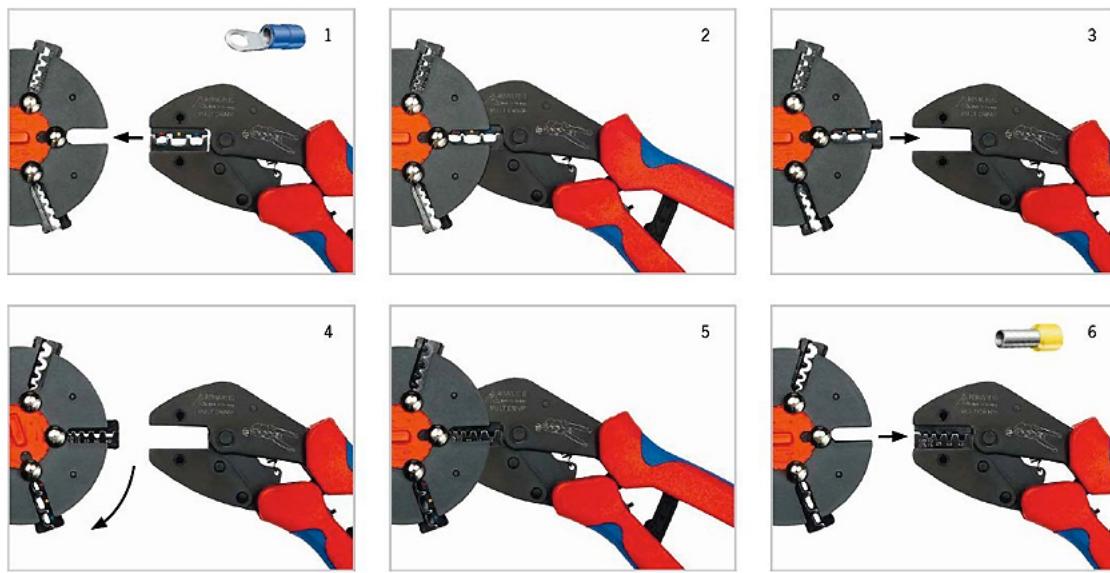
Ratcheting Crimper Rennsteig PEW-9



There are different types of crimps used for different purposes i.e. insulated or non-insulated connectors. The [Rennsteig PEW-9](#) shown here with a hexagonal crimp die for non-insulated splice connectors. These are moderately expensive, around \$120.00. No interchangeable dies as it is calibrated at the factory. The hexagonal crimp is a superior crimping method for splice connectors. For single splices 18/16/14 ga and for multiple of smaller wires.

Rennsteig MultiCrimp Ratcheting Crimper

Motorsports ECU Wiring Harness Construction



Rennsteig also has a MultiCrimp tool with interchangeable dies. About \$250.00. Fives dies are available. It normally ships with:

- 1x (P/N 629 050 3 0 1) Die Set for Non-Insulated Plug Connectors (0.5 - 6.0 mm² | 20 - 10 AWG)
- 1x (P/N 629 060 3 0 1) Die Set for Insulated Terminals (0.5 - 6.0 mm² | 20 - 10 AWG)
- 1x (P/N 629 090 3 0 1) Die Set for End-Sleeves/Ferrules with and without Collar (0.25 - 6.0 | 24 - 10 AWG)
- 1x Tool magazine for up to 5 Die Sets

Less expensive ratcheting crimpers are available from Del City. Some aerospace items can be up in the thousands of dollars.

A good guide to crimping is in the [Molex Industrial Crimp Handbook](#). Page 18 of the Molex PDF describes the types of crimp dies.

ProwireUSA Motorsport Battery Cables



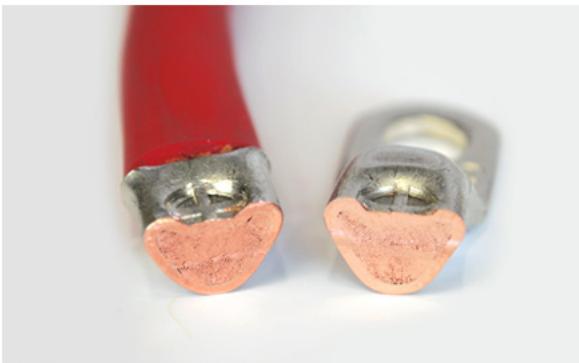
These are the best battery cables for your racing application. Don't go looking for welding cables, get the correct motorsport ones. ProwireUSA also has the correct lugs. In order to crimp the lugs you can spend anywhere from \$35.00 to \$3,000.00 for specialized hexagonal crimp tools.



If you are only going to do this occasionally a cheap Hydraulic Crimper (read China) with insertable hex dies can be had for under \$40.00. Pictured is an 8 ton crimper with 4, 6, 10, 16, 25, 35, 50, and 70mm die sets. Definitely not Aircraft Milspec but cheap.

Metric to AWG Conversions: 10mm (6AWG); 16mm (4AWG); 25mm (3AWG); 35mm (2AWG); 50mm (0AWG); 70mm (2/0AWG).

Crimp Guides from [TEMco](#)



Indent crimp made with a hammer crimper.



Hexagonal compression crimp made with a hydraulic crimper.

Wire Size & Crimp Quality

The thicker the wire (e.g. 1/0, 2/0, etc.), the more power you will need to get a proper crimp. At a certain point, manually powered crimpers will take too much effort or cannot provide enough pressure to crimp thicker wire gauges.

How can you tell if you've made a high quality crimp with a hexagonal compression type hydraulic crimper? See the quick reference guide below.



Best
Corners should be as crisp and sharp as possible.

Acceptable
Corner radius should be shorter than the length of the flat sides.

Too Loose
Die size is too large. Select a smaller die.

Over-Crimped
Die size is too small. Select a larger die.

Battery and Starter Lugs and Boots



[A.C. Terminals](#) makes a wide selection of heavy duty copper terminals. [Their catalog](#) lists a wide range of top quality products. A wide selection of battery and alternator boots are available from [Waytek Inc.](#)

Wire to Wire Splices



Planning for splices in your wiring harness represents the most complex and critical part of the design process. Careful planning can reduce complexity and increase reliability. You need to plan all your splices first as the ecu pin direct to input circuits are easily defined. We typically have about ten or more defined splices for the various circuits. We construct these first with splice points typically within the Raychem boots where wires branch out.

Stub (Parallel) Splices can be grouped in your ecu connector boots so individual runs can be run for circuits like 5V sensors. Step Down butt connectors can also be used

ECU's like the Pectel SQ6M have two separate 5V and two separate 12V programmable output channels. These, in turn, can be grouped into parallel stub splices within a harness boots and the individual 5V and 12V outputs can be sent downstream. Splice planning is something that must be done at the start of the design process.



Wire to wire splices can be accomplished with Tyco Raychem D-406, or Sumitube W79 adhesive lined shrink tube. Do not solder the wires together. Proper crimping is the preferred method .Raychem part # D-406-0001, Red in color, marked "Duraseal 18-22" pictured. We tend to use the un-insulated butt, step-down and parallel splices (below) and seal them with the Raychem SCL.

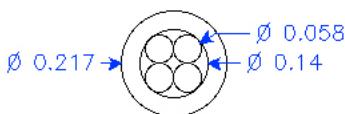


Alternatively, un-insulated step down butt connectors (left and center above) can be used and sealed with adhesive-lined Raychem ES2000 heat shrink. Often wires will branch i.e. 1-2, 1-3, 1-6 etc. and splices are necessary. To the right above is a Stub (Parallel) Splice...these have an overall shorter length and can be sealed with SCL or ES2000-1 heat shrink.

Below are the diameters and number of wires that can be placed in these connectors for your planning purposes. We use hexagonal crimping tools for the most secure crimp.

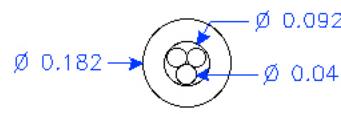
Number of Wires in a Butt or Parallel Splice

Yellow Band 12-10 Butt Connector



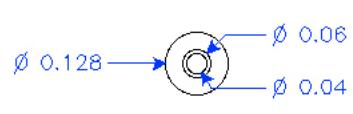
- (4) 16 AWG 22759/32 (shown above)
- (5) 18 AWG 22759/32
- (8) 20 AWG 22759/32
- (10) 22 AWG 22759/32

Blue Band 16-14 Butt Connector



- (2) 16 AWG 22759/32
- (3) 18 AWG 22759/32 (tight)
- (3) 20 AWG 22759/32 (shown above)
- (5) 22 AWG 22759/32 (tight)

Red Band 22-18 Butt Connector



- (1) 16 AWG 22759/32
- (1) 18 AWG 22759/32
- (1) 20 AWG 22759/32 (shown above)
- (2) 22 AWG 22759/32 (tight)

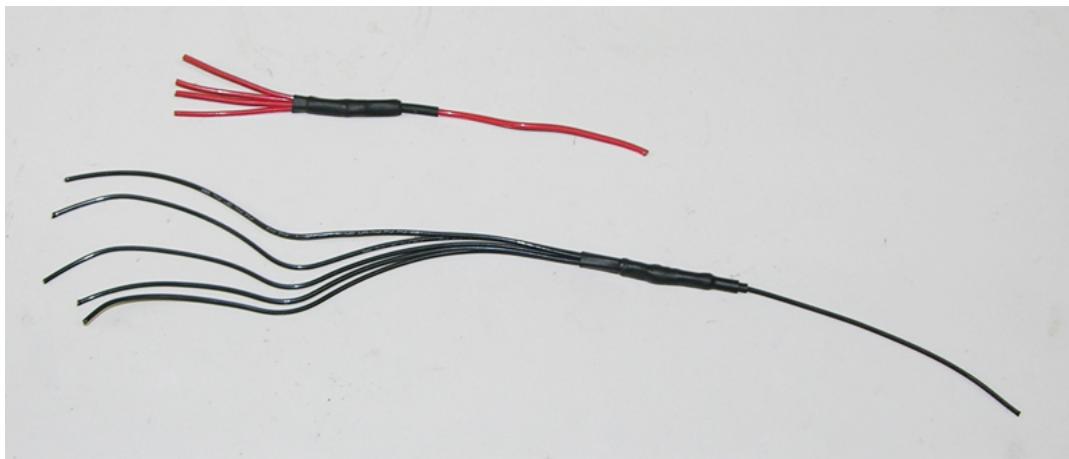
For planning purposes when grouping and crimping multiple wires in Step-down butt connectors: Picture above shows the number of wires that fit in a Parallel or Butt Splice.

22-18 hole size 1.7mm (.060") RED
16-14 hole size 2.3mm (.092") BLUE
12-10 hole size 3.5mm (.140") YELLOW
8 hole size 4.6mm (.180")
6 hole size 5.9mm (.230")

22759/32 wire diameter 19 strand insulation stripped. Use drawings above to plan splices.

22ga .033"
20ga .040"
18ga .050"
16ga .058"
14ga .075"

Splice Testing



Here we have two multi-wire splices via step-down un-insulated butt connectors: (below) five 22 gauge 22759/16 black wires going into one black 22 gauge wire; and (above) four 18 gauge 22759/16 red wires going into one 16 gauge 22759/16 wire. The connections are glue shrunk. In the case of multi-wire butt splice connections we use 1/8" adhesive lined shrink tube on the single wire and a larger size (3/16" or 1/4") over the entire splice.



We make sample splices, in this case stripping the wires and crimping them in the butt or parallel splice connectors. Do not twist or solder the multiple wires together. All connections must be adhesive sealed, typically with 3/16" or 1/4" Raychem SCL (1" on Parallel Splices and 1.5" on Butt Splices). Make notes as to the crimp position and connector to use to avoid assembly errors.



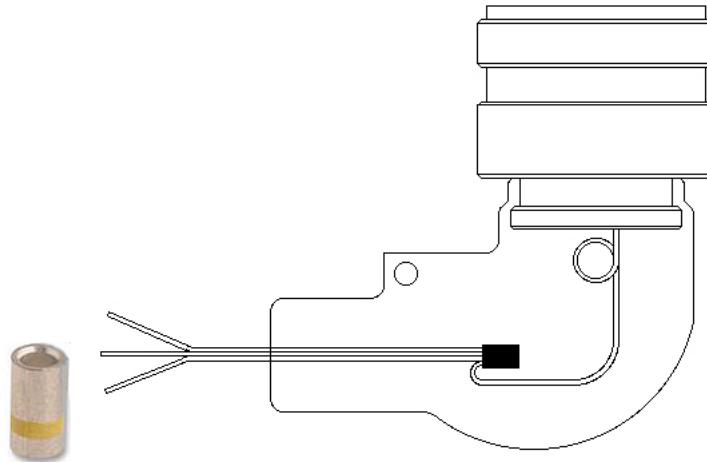
For a comprehensive guide to Un-Insulated butt connectors see the TE Connectivity/AMP [Solistrand Un-Insulated Terminals and Splices PDF](#). These go down to

26AWG-20AWG (#321198) pictured above. Uses AMP Crimper Crimp Tool 69363 26-24 22-20.

We don't have pull testing equipment so we simply take the test pieces and yank on the wires as hard as we can. Be careful to insure all wires are fully seated into the butt connector. Refine your crimper choice and crimp techniques until you can be assured your splices will not come apart. Not sophisticated but it works.

FYI: NASA-STD 8739.4: Minimum Tensile Strengths: 22ga 13 lb; 20ga 21 lb; 18 ga 32 lb; 16 ga 41 lb.
 SAE AS7928: Minimum Tensile Strengths: 22ga 15 lb; 20 ga 19 lb; 18 ga 38 lb; 16ga 50 lb.

Raychem Stub (Parallel) Splices



When you are terminating multiple wires in a splice in your harness, and not a wire-to-wire butt splice, Raychem Stub (Parallel) Splices (above left) are called for. Use [MiniSeal Stub Splices](#) and crimp with a Rennsteig Hexagonal crimp tool or a DMC GMT232 Crimping Tool and then seal the stub splice with a Raychem ES Cap.

In the above illustration we show a Raychem Stub (Parallel) Splice application... Here we have a 5V 50mA output from the #2 Autosport Connector on a Pectel SQ6M sending out 5V sensor power to three destinations. AS6-16-35SN connector with a Raychem 222K152-25-0 boot. The SQ6M has four programmable sensor supply outputs: Two @ 5V 50mA and two @ 12V 1A. Using parallel stub splices simplifies having many butt connector splices downstream.

Lots of planning is required for concentric twisting of your harness. Placing the parallel stub splice in the connector boot cleans up things.

[PDF of Dimensions](#)

Stub (Parallel Splice) Red Tin Plated; Raychem D-609-03
 Stub (Parallel Splice) Blue Tin Plated; Raychem D-609-04
 Stub (Parallel Splice) Yellow Tin Plated; Raychem D-609-05

Raychem ES Caps for Parallel Stub Splicing



Use [Raychem ES Caps](#) to seal Parallel Stub Splices. They are designed to seal the wires and the MiniSeal Splice that you crimp. [Three sizes ES-1, ES-2 and ES-3](#).

Part Number	Inside Diameter (Including Core)			Recovered Wall Thickness**		
	Standard Length* as Supplied (Millimetres)	Minimum Expanded as supplied	Maximum Recovered After Heating	Minimum Total Wall After Heating	Minimum Jacket Wall After Heating	Minimum Adhesive Wall After Heating
ES Cap-No.1	30, 35	5.72 [0.225]	1.27 [0.050]	1.20 [0.047]	0.64 [0.025]	0.56 [0.022]
ES Cap-No.2	30, 35	7.44 [0.293]	1.65 [0.065]	1.52 [0.060]	0.76 [0.030]	0.76 [0.030]
ES Cap-No.3	40, 50	10.85 [0.427]	2.41 [0.095]	1.91 [0.075]	0.89 [0.035]	1.02 [0.040]

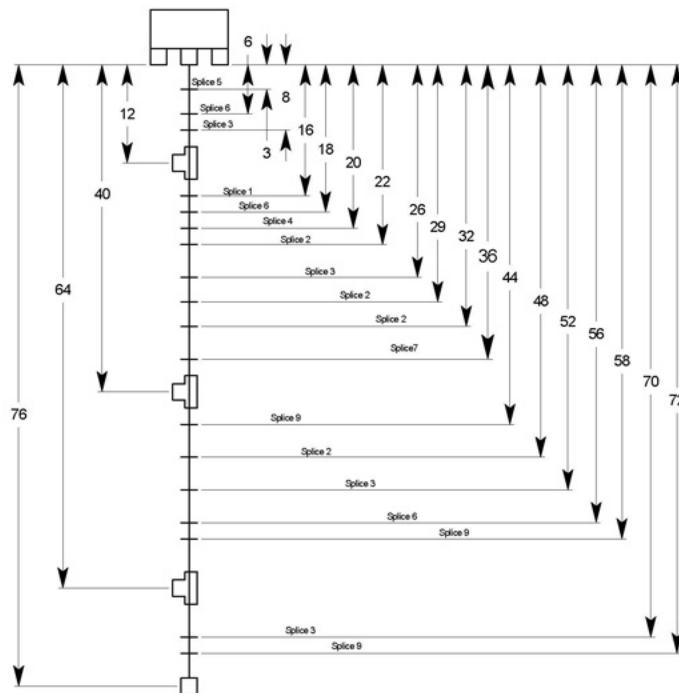
Alternatively you can use 1.2" of Raychem SCL Encapsulating Tubing, typically [SCL-3/16-0 or SCL-1/4-0](#).

Wire to Wire Solder Splices



Joining wires without crimping in a sealed manner requires the use of specialized solder sleeves that both solder the wires together and adhesive seal them at the same time. Pricey devils. Figure upwards of \$3.00+ each. Pictured is Raychem / Tyco [D-1744 Series SolderSleeve Wire Splice](#). Designed to provide an environment resistant inline splice in wires having tin (22759/16 or 22759/32) or silver-plated conductors (22759/44) and insulation rated for at least 125C. Example pricing via DigiKey.

Staggered Splices



We stagger our splices in each harness. Here we have staggered the splice joints for a Pectel SQ6M ECU. This avoids overlapping the splice points, which are sealed in adhesive shrink tubing.

Pin and Socket Retention Testing



Daniels makes a [relatively inexpensive tool](#) to test retention of pins and sockets...Simply push until flush and the socket/pin is tested to about 30% of its yield i.e. if it is actually seated.

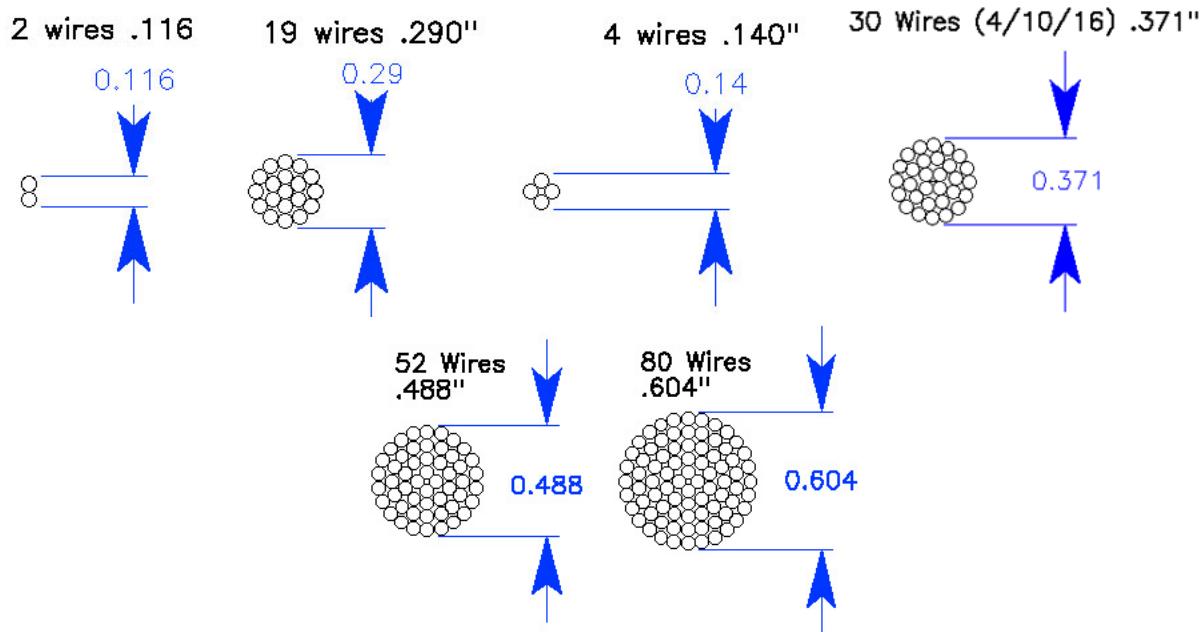
If you are a big buck operation and you need to test your crimp connection strengths you buy one of these from Alphatron

DR-25 Heat Shrink and Molded Parts



DR-25 heat shrink and transitions are joined with Raychem or Hellerman molded parts. To seal the ends of the transitions or boots there are two options: Use adhesive lined boots (expensive) or use syringe-applied Resintech RT125 black epoxy on the connector or the DR-25 wire cover. The shrink ratio is 2-1. This environmentally seals the wires and connectors and provides a protective layer against abrasion.

Raychem DR25 is simply the best wire covering. The suffix determines the color of the printing on the tubing DR-25-1/8-0 is Yellow; while DR-25-1/8-UK is White lettering. Color of the lettering is simply customer preference as the DR25 is exactly the same. We use DR-25 in the standard thickness with the yellow print as it seems a bit sexier and is visually different than other suppliers being instantly recognizable as genuine Raychem. The special lightweight motorsport version with white lettering DR-25-TW saves weight.



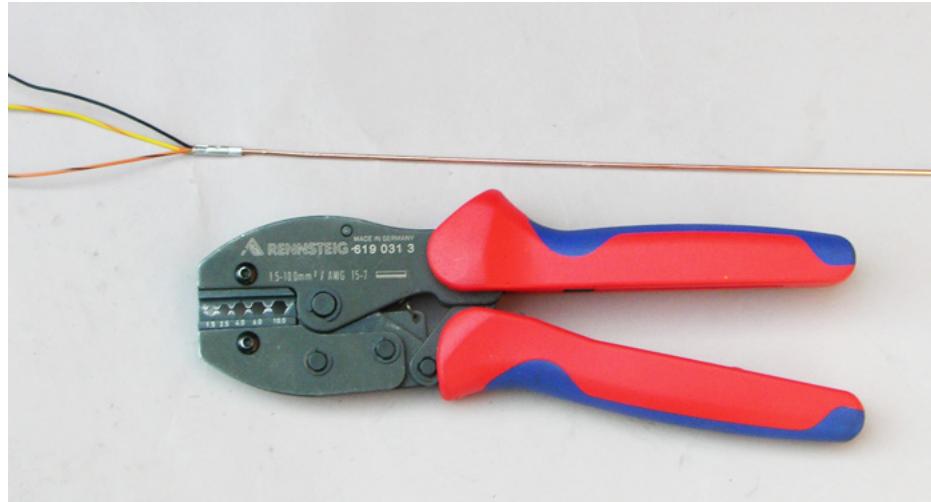
To choose a size of DR-25 for your harness sections choose the largest size that will shrink firmly to your wiring cross-section diameter. In other words if your wiring bundle is 3/8" in diameter you don't use 3/8" DR-25 as it has a shrink ratio of 2:1 (.375 start to .1875 final). The above dimensions are for several diameters of 20 gauge Spec55 wires, .058" in diameter.



An alternative to DR-25 is Raceline 150 from [Whitmor Wirenetics](#). Basically the same specifications you just don't get "DR-25" printed in yellow. We all know how important labels are these days.

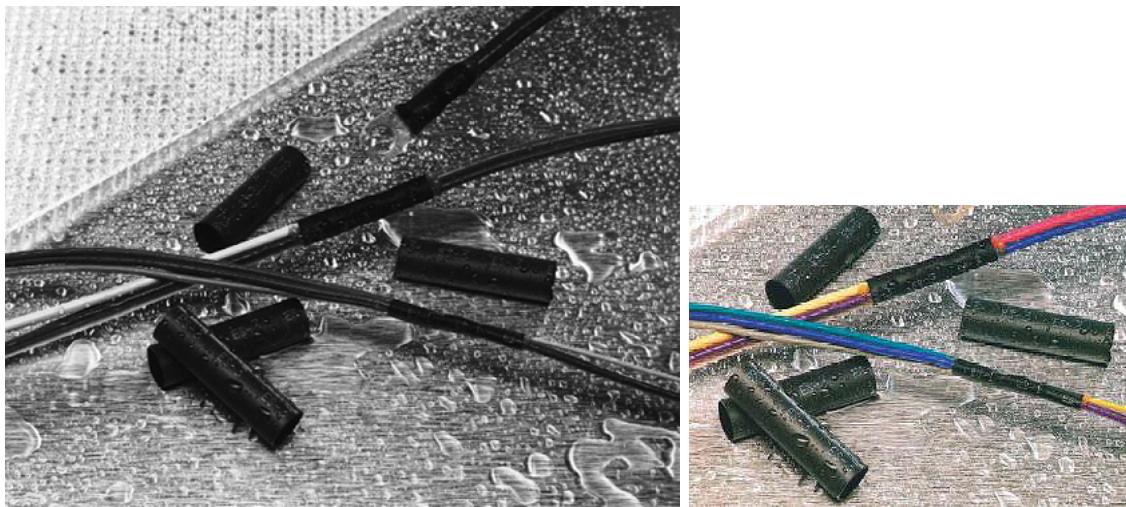
A second source for a less expensive alternative to Raychem DR-25 is [Deray V25](#) from [DSG-Canusa](#), which also has the same 2:1 shrink ratio as Raychem DR-25.

Pull don't Push



Trying to push some 22 gauge wires through 1/8" or 3/16" DR-25 is an exercise in frustration. Crimp the wires to something like a length of welding rod and pull them through.

Sealing DR-25 with Raychem ES2000



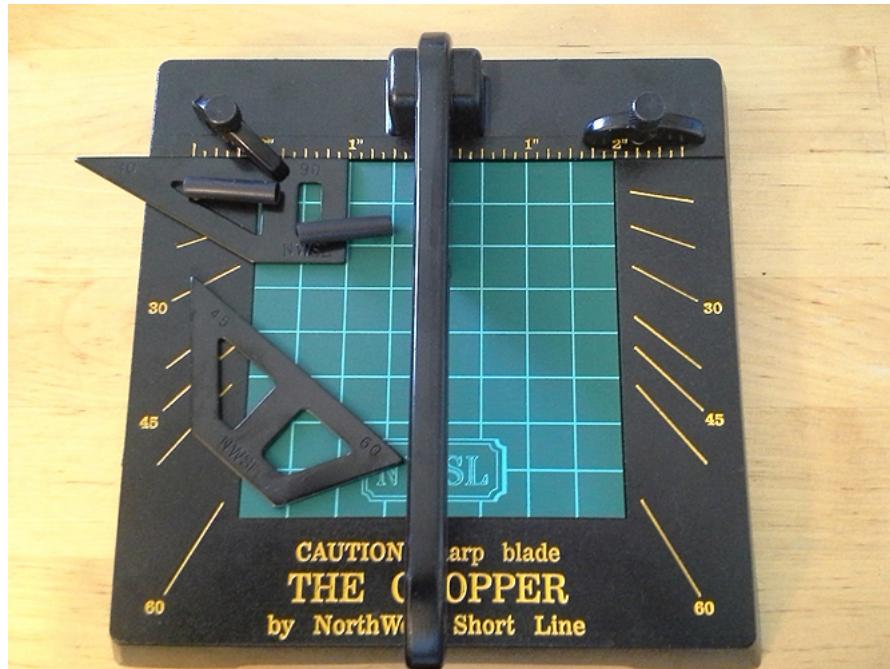
Semi-rigid 4:1 shrink ratio adhesive lined [Raychem ES2000](#) seals DR-25 to wires as well as serving as a strain relief for wire splices, terminals and other components.

Keeping Shrink Tubing...ES-2000 / SCL / ATUM / RBK



Shrink tubing typically comes in four foot long sticks. We cut these to fit McMaster Carr clear boxes 4629T2. For the most part this is rigid or semi-rigid adhesive-lined tubing, typically, for harnesses, cut in lengths less than 2.5" for connectors and sealing DR-25. It's easy to keep track of the various types and wall thicknesses as well as 2-, 1, 3-1 and 4-1 shrink ratios. You're always cutting parts and have lengths left over. It's easier to keep track of these in some form of compartments.

Cutting Shrink Tubing



Cutting small pieces of shrink tubing perfectly square with a pair of scissors simply does not work and a really sharp pair of Kershaw scissors can snip your hand (we've done that). This handy little cutter takes standard razor blades, has an adjustable stop and makes clean square cuts. The [Northwest Short Line Chopper II](#) is a hobby cutter that works perfectly.

At RB Racing we buy some pre-cut shrink tubes but we use this cutter for cuts of Raychem SCL 3-1 shrink tubing to terminate the ends of our Raychem DR-25 harness covering as well as trimming labels and clear RT-375. About \$50.00 shipped from various sources.

Small, effective, and handy for making precise, square cuts in all your types of shrink tubing...no more scissors.

Heat Guns and Heat Blowers



Heat Guns and Heat Blowers are different animals. The Steinel and the Snap-On to the left are Heat Guns whereas the Master Appliance pedestal mount is a Heat Blower. They all apply hot air but the Heat Guns are easier to work with, especially when dealing with Raychem Shrink Shapes and Boots as you must quickly rotate about the part to cause the controlled shrinkage. The larger Heat Blower is too unwieldy for this fine controlled shrinkage. Being able to regulate the temperature is also important.

DR-25 and various boots are rated at about 150C to 175C (350F) and will shrink at these temperatures. Heat guns and blowers can go to 1000F...that is too hot and can damage the DR-25.



When you are labeling individual wires with 1/8" heat shrink tubing and RT375 clear you sort of have to hold both ends of the wire and cook your fingers. We fabbed up a slotted cup to an old Master Appliance pedestal heat blower we have had for over 25 years. No more toasted fingers. Simple.



Probably the best value in a heat gun is the Ideal 46-204. Lots of bells and whistles. You can regulate the temperature and the blower. About \$200.00 as pictured above. We use both this "gun" and the Master Appliance pedestal blower.



Installing a 202K132 Raychem Boot on this Autosport Connector has to be done with a Heat Gun, not a Heat Blower. A Heat Blower will cause a too quick and uncontrolled shrinkage and ruin the Boot.

Concentric Twist Layers... Race-Spec

Concentric Cables

Smooth symmetrical cables can be built up about a core of more than one wire, though this is seldom done in practice.

Wires in Concentric Cables

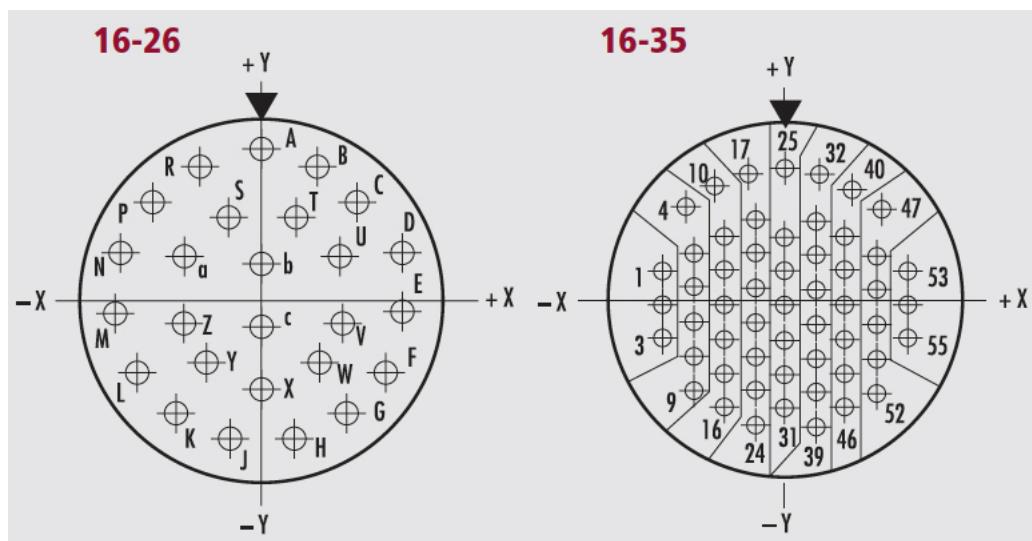
Number of Layers Over Core	Core of One Wire		Core of Two Wires		Core of Three Wires		Core of Four Wires	
	Wires per Layer	Total Number of Wires	Wires per Layer	Total Number of Wires	Wires per Layer	Total Number of Wires	Wires per Layer	Total Number of Wires
1	6	7	8	10	9	12	10	14
2	12	19	14	24	15	27	16	30
3	18	37	20	44	21	48	22	52
4	24	61	25	70	27	75	28	80
5	30	91	32	102	33	108	34	114
6	36	127	38	140	39	147	40	154
7	42	160	44	184	45	192	46	200

The stiffness of the harness will depend largely on how the underlying wires are arranged. The correct method is concentric twisting where successive layers are twisted in opposite directions...One wire surrounded by six wires, with each successive layer adding six additional wires i.e. 1-6-12-18. The twisting of the wires gives the harness additional flexibility and reduces strain on the wires. The above table provides some insight into the methodology. TE Connectivity offers a [PDF Guideline for Concentric Twisting](#).

The 1-6-12 etc is not inviolate i.e. you may have a central bundle of say, twisted pairs, that may approximate the diameter of six wires...Then the other layers 12 etc may follow.

This is a motorsports Race-Spec technique and is not an aerospace standard where weight is critical. Concentric twisting adds flexibility to the harness were routing and possible removal are involved. 22759 Mil-Spec wires are twisted internally for the same reason.

CW and CCW Twisting



Here we have the connectors on a Cosworth Pectel [SQ6M](#), pins facing out from the ECU, two 26 Pin Autosport and one 55 pin Autosport. Below is the sequence of twisting for the mating Autosport connectors. If you are planning on pretty Instagram pictures it will be time to plan your colors. Service loops can be done in a parallel fashion, held in place by 1/8" rods. We use 1/8" Aluminum welding rod for the most part.

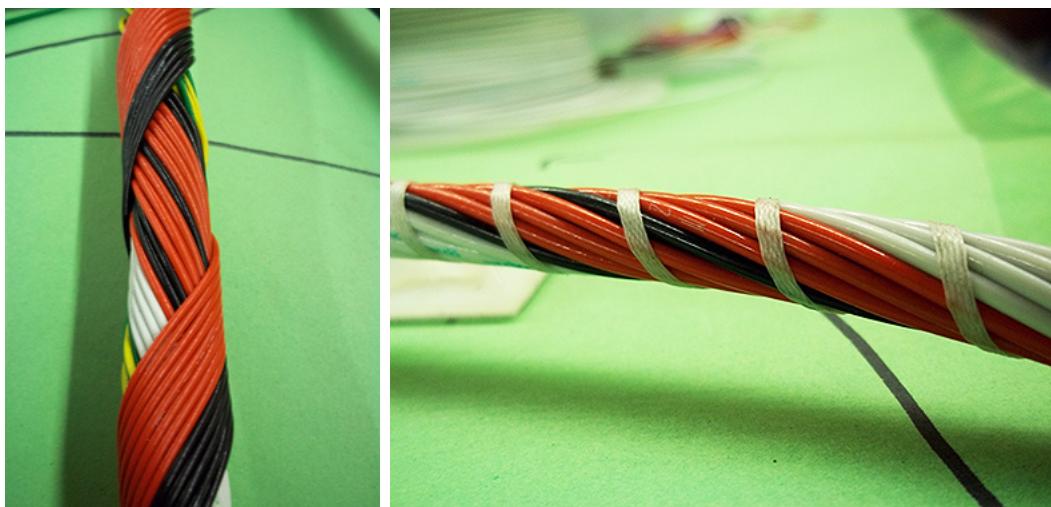
(2) 26 Pin Connectors C1 and C3: [Center wire: b](#); [Layer 2 CCW: T, S, a, Z, Y, c](#); [Layer 3 CW: U,V,W, X, K, L, M, N, P, R](#) [A, B](#); [Layer 4 CCW: J, H, G, F, E, D, C](#).

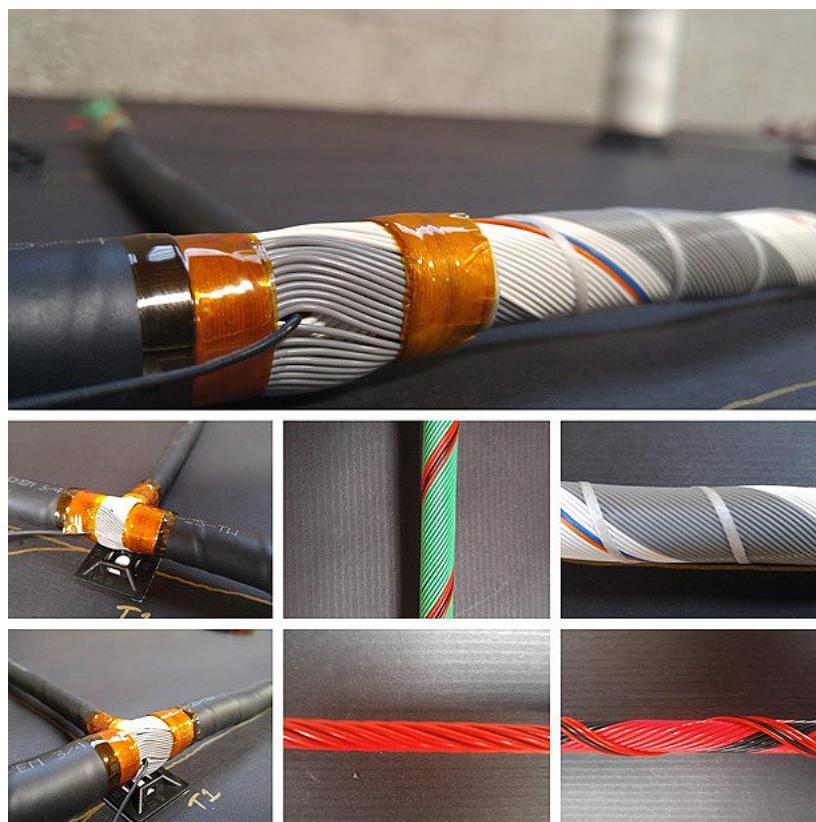
(1) 55 Pin Connector C2: [Center wire: 28](#); [Layer 2 CW: 27, 35, 36, 29, 21, 20](#); [Layer 3 CCW: 26, 19, 12, 13, 14, 22, 30, 37, 44, 43, 42, 34](#); [Layer 4 CW: 25, 33, 41, 48, 49, 50, 51, 45, 38, 31, 23, 15, 8, 7, 6, 5, 11, 18](#); [Layer 5 CCW: 17, 10, 4, 1, 2, 3, 9, 16, 24, 39, 46, 52, 55, 54, 53, 47, 40, 32](#).

Things get a bit more complicated where there are internal splice points in the harness i.e 1 into 2 wires or 1 into 4 wires such as in 5V supply or digital / analog grounds. Twisted pairs are often placed in the center.

Note: Unused positions in the harness must have the contacts installed and use either plugs or filler wires to maintain sealing integrity. Filler wires can be used to populate the concentric twisting.

Zac Perkins...Concentric Harness Construction





Concentric twisting of a motorsports harness requires a lot of planning when you have different gauge wires, multiple connectors, filler wires, splices, service loops etc. Here Zac Perkins (zac@motorsportselectronics.com) of [Motorsportselectronics](#) shows you how it should be done. Kevlar braided lacing cord secures the bundle. Zach is a master fabricator and motorsports electronics specialist. Check here to see his [portfolio](#). Zac can be reached via his website (or email) to schedule your project. BMW and Porsche 911 projects.



Zac doing M1 Series Motec integration in a [Porsche 911 project](#). A complete rewire of a [Porsche 911T](#) by Zac. Zac is currently working as a Senior Engineering Technician - Special Programs & Motorsport at Faraday Futures and holding a second hat at [motorsportselectronics](#) with Tim Whitteridge.

Tim Whitteridge



Center above, Tim Whitteridge, one of the good guys in Motorsports Electronics, working on the late Nissan LMP1 car. Tim did some top notch work for us at his previous employer before he joined the Nissan LMP1 effort and went to LeMans. [Tim's resume is lengthy](#) and we can vouch for his expertise. Besides his duties as an Electrical/Data Engineer at Magnus Racing he wears a dual hat at [Motorsportselectronics.com](#) doing wiring and systems integration with Motec, Pectel and other systems.



He has worked at the highest levels in motorsports. Tim can be contacted at tim@motorsportselectronics.com for your special projects. Tim at Petit LeMans in 2016. Nine 24 Hour Daytonas...does not get any easier.

In Tank Looms



Zach Perkins: "Building an in tank fuel cell loom. It's important to use the correct supplies, especially when dealing with ethanol or alcohol fuels. Pictured here: Deutsch hermetic fuel safe flange mount connectors, Raychem -12 chemical resistant boots, Raychem RW-200 viton shrink and Resinlab EP1385 epoxy- specially formulated for E85 and alcohol fuels. It's always better to test chemical resistance of what you're putting in your fuel tank BEFORE you gum up all your fuel pumps, luckily with these products I know they're up for it! [Motorsportselectronics](#).

Tying or Lacing Wire Harnesses



Braided Lacing Cord is commonly used, bound to the twisted cables in the opposite direction of the cable twist, secured at each end by tape. There are a wide variety of these in nylon yarn, polyester yarn, Teflon yarn, glass yarn, and aramid (Kevlar/nomex) yarn.

MIL-T-43435B Lacing Cord (Left Above): Braided nylon lacing cord meeting specification MIL-T43435B, Type I, Size 3, Finish B: Micro-crystalline wax with melting point above 55/ C ° 130° F and non flaking characteristics it is compounded to develop excellent knot retention, yet not giving a waxy feel to the user. Used to tie wiring bundles together. Less bulky than plastic tie wraps which can actually cut into wires and, when cut, leave a sharp edge that can cut your hands.

MIL-T-43435B Lacing Cord size 4, Dacron, 2nd from Left, Finish C

MIL-T-43435B Lacing Cord size 3, Nylon, 3rd from Left, Finish C

MIL-T-43435B Lacing Cord (Far Right Above): Flat Braided Glass Yarn, Type IV, Size 1, Finish D: TFE-fluorocarbon coating, Black Color. Widest (size 1) .180" to .220". Stable to 427C (800 Deg F). [Gudebrod](#).



Continuous loops with the waxed MIL-T-43435B Lacing Cord (Left Above) should be tied in the above manner with continual lock stitches. Normally you just put a wrap and a square knot every 6-12".

Kevlar (Para-Aramid) and Nomex (Aromatic Polyamide) Flat Braided Lacing Tapes

MIL-T-43435 Type V | A-A-52084

Flat braided, electrical grade, continuous filament, aramid (aromatic polyamide) yarn

Finish:

- » *A: No finish
- » *B: Microcrystalline fungicide wax
- » *C: Synthetic elastomer
- » *F: F Silicone resin impregnated
- » *G: Liquid nylon

Temperature range: -55°C to 260°C

Standard colors: natural or black

Mil-spec #	Size	Width in Inches		Thickness in Inches		Breaking Strength
		Min.	Max.	Min.	Max.	
AA52084-*1	1	0.180	0.220	0.013	0.019	85
AA52084-*2	2	0.099	0.121	0.011	0.017	50
AA52084-*3	3	0.068	0.083	0.009	0.015	35
AA52084-*4	4	0.050	0.061	0.007	0.013	25

A-A-52084 Lacing Cord available in 250 or 500 yard rolls from suppliers like [Ryan Electronics](#), [Western Filament](#), or [Atkins & Pearce](#). Formerly known as MIL-T-43435 Type V it is available in four different sizes in natural or black finishes. Lacing tapes are wrapped in an opposite spiral direction from the last upper layer left-hand concentric twist. Lacing techniques are described in this [TE Connectivity Brochure](#).

[Boeing Specification](#) Nomex Lacing Tapes...Continuous Filament Yarn...Race-Spec



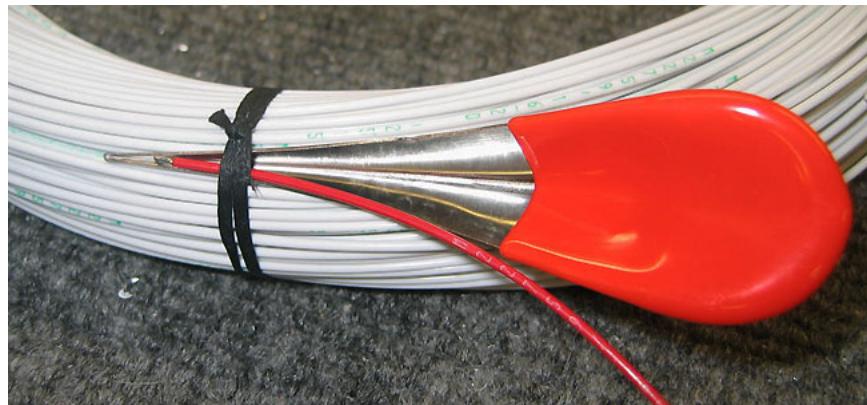
These are the **gold standard** in Nomex lacing tapes. Manufactured from continuous filament yarns in accordance to CID AA52080-AA52084 (formerly MIL-T-43435B). Keyword is "yarns".

BMS 13-54 Boeing Specification Nomex® Lacing Tape. [Western Filament Inc.](#)
Flat braided Nomex lacing tape. Type III, Grade D, Finish C, Class I with cross-tracer.

Available colors: White, Black, Blue, Brown, Green, Gray, Magenta, Orange, Pink, Purple, Red, Yellow.

Western Filament Inc. Part Number	Width Inches	Thickness Inches	PutUp (yds)
HOF40RTR	0.075"	0.012"	500
Western Filament Part Number	Width Inches	Thickness Inches	PutUp (yds)
HOF70RTR	0.110 "	.014	250

Wire Spoon



After you've laced your wire harness together with neat little square knots, how do you insert extra wires? The answer is a [Wire Spoon](#). Note that all the wires are white which is a normal practice in many applications. Spec 55 wire is available in up to 10 color and or color stripe combinations which makes keeping track of things much easier. Without laser-marking of each wire it can be a real chore to track down issues when all the wires are white. You can also label each wire (we do) as we have so many interruptions it's easy to lose track after numerous phone calls.

For your information a typical late model Harley-Davidson Touring bike uses about 77 different wire colors (color and stripes) in its wiring harness. 100 color and color/stripe combinations are delineated in this [Glenair MIL-STD-681 PDF](#). In aerospace applications wires are white and Ultra Vilolet (UV) laser marked.

Portable Shrink Tube Thermal Printers



You can, however, label each wire with 1/8" 3:1 heat shrink labels near the terminations to keep track of things and use one color mil-spec wire. Low end heat shrink printers can be purchased way under \$100.00 or you can spend many thousands of dollars on commercial units. We label all our wires anyway, even with different colors.

BEE3+ unit from K-SUN pictured above is about as cheap as it gets. Lists for about \$250.00 but sells for about \$150.00 or less. It prints on 1/8" (single MIL-SPEC wire), 3/16", 1/4", 3/8", 1/2" and up to 3/4" wire shrink tubing. It also prints labels in widths of 1/6"(4mm), 1/4"(6mm), 3/8"(9mm) 1/2"(12mm) and 3/4"(18mm) widths. The catch is the cartridges are expensive. There is always a catch. Expendables. Oddly the 3/8" shrink tubing is only available in white.

The lower priced BEE3 unit will only print up to 3/16" shrink tubing. Best get the BEE3+.

Use either KYNAR or Tyco Raychem RT-375 clear 2:1 heat shrink over your printed labels



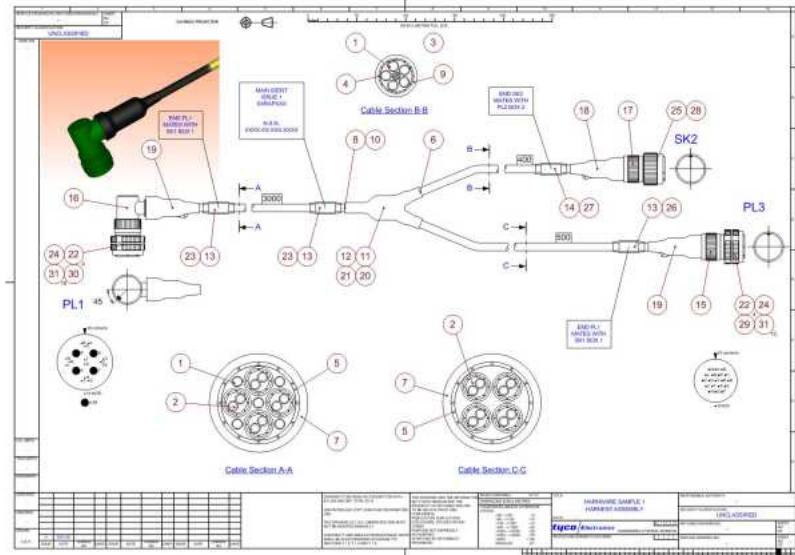
The Rhino 6000 will print wire shrink tubing up to 1" I.D. and flat labels up to 1" in width. These are in the mid to low \$200.00 range. For labeling individual wires they do not go down to the 1/8" size shrink tubing that the BEE3+ does.

Production Shrink Tube Printer Kroy K4350

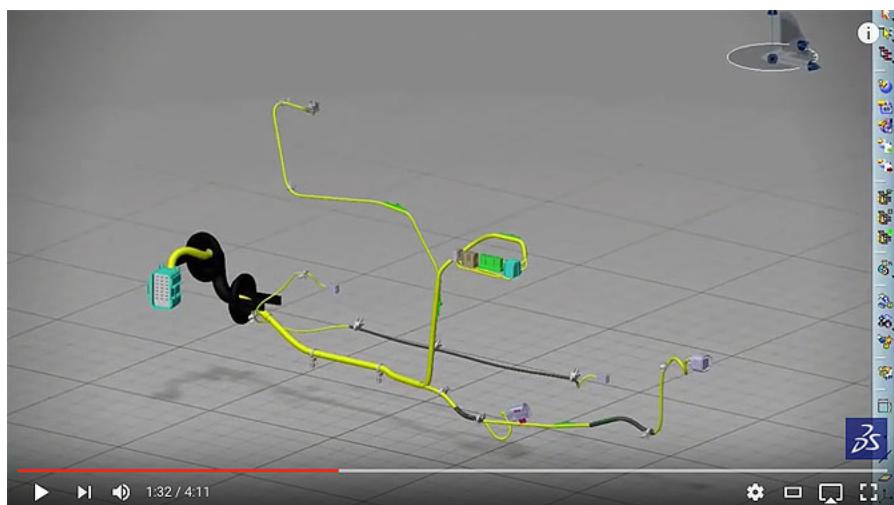


If you plan on doing production work the Kroy K4350 is a good bet...in the \$500.00 range. You use 100 foot reels of shrink tubing.

High End Design: TE Connectivity HarnWare/HarnVis & Catia V6

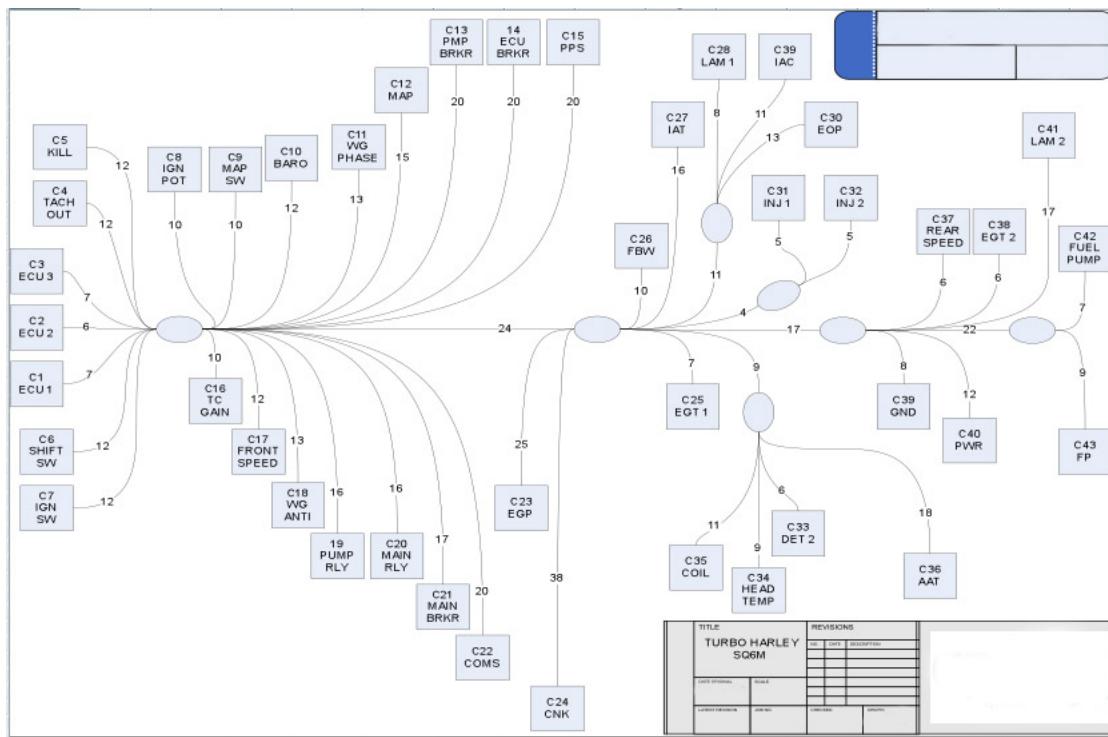


[HarnWare](#) Version 6 offers 2D and 3D modeling of harnesses. Complete libraries of all Raychem TE components. License must be purchased (dongle). Based on 32 bit Microsoft VISIO. [HarnWare \(2D\)](#) and [HarnVis \(3D\)](#) are developed and maintained by [ADE Analysis & Design Engineering LTD.](#)



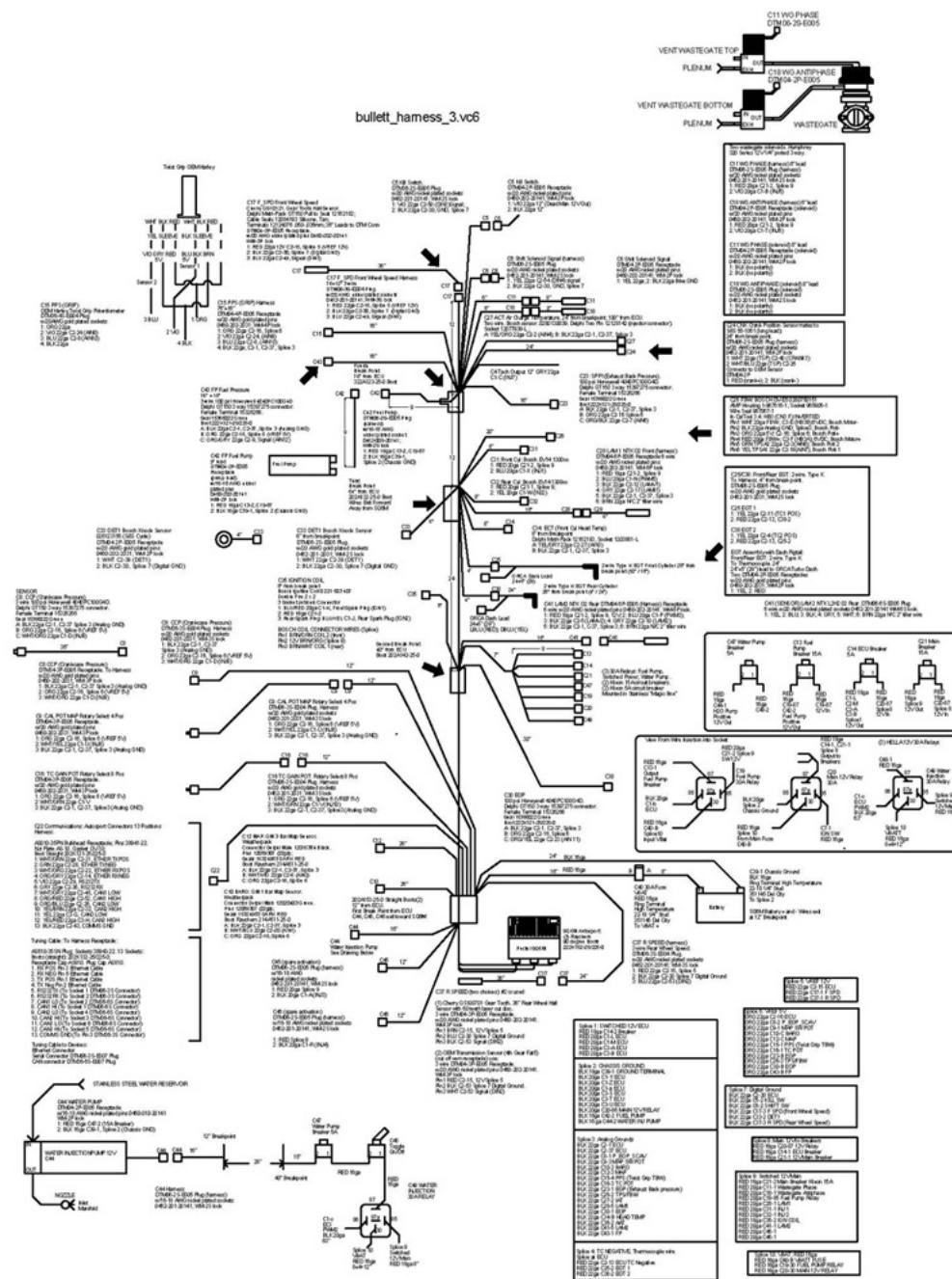
[Catia V6](#) is the high end OEM tool. Aircraft and OEM manufacturers. Way overkill.

Visio Professional 2013 for Motorsport Race-Spec Harness Design and Initial Layout



The above is a typical Microsoft Visio diagram for motorsports wiring and harness design. We can make an initial Visio drawing of the wiring diagram but this will only aid in planning purposes. The actual harness has to be measured on the application with all the hardware in place. It is critical that there be no strain or interference issues and that serviceability is planned for. This is often done in [Microsoft Visio Professional 2013](#). Template included on the Visio link.

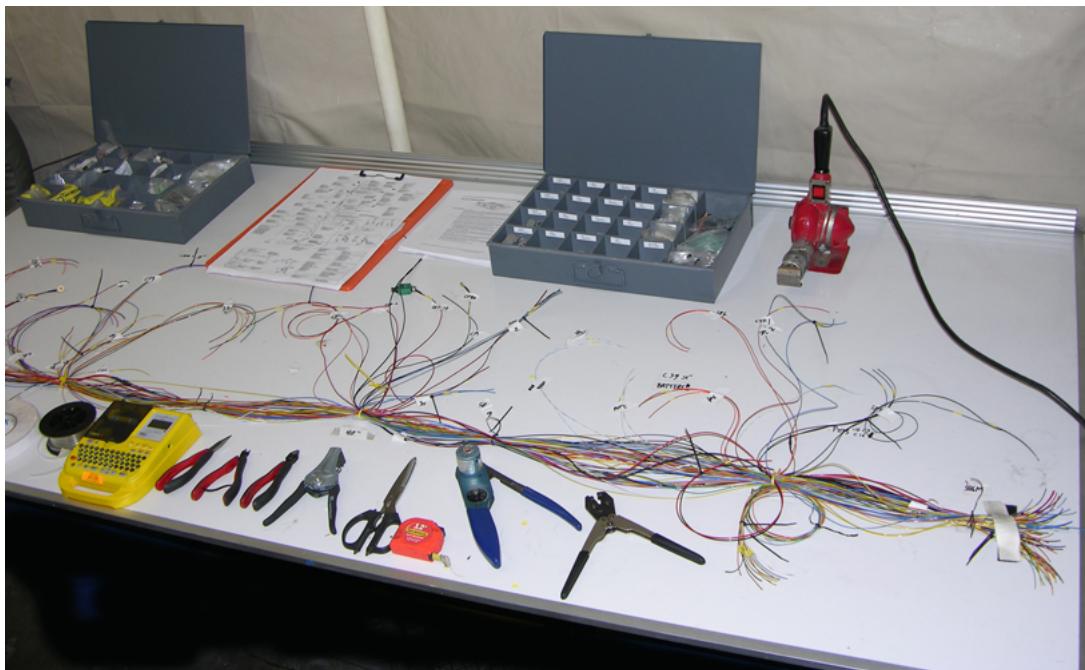
[Basic Visio Tutorial](#).



We also construct a detailed harness description in a CAD Program which lists every component in the system which can be printed out on a large format printer. This puts everything on one sheet to avoid looking through various documents. Lots and lots of details.

Wires in the above harness are MIL-22759/32 in 16/18/20 and 22 gauge. Deutsch DTM Plugs and Receptacles use a mix or gold and nickel plated pins and sockets. Deutsch Autosport Connectors are used for the [SQ6M ECU](#) on this harness. Different wire colors prevent confusion and we also label each wire. This particular harness has 49 outboard connectors. The SQ6M itself has 107 pins. In the case we are using 76 of them. Filler wires, also labeled, fill out the 107 pins.

We also do complete documentation in Excel and Pages (Mac) and Word listing every component, pin, socket, splice points, Raychem boots, wire lengths etc.



We use 4' x 8' whiteboard to layout the wiring harness. We use 3/4" adhesive tie wrap pads, plastic tie wraps, Velcro, and white gaffers tape to hold the main harness and connector leads in place. The adhesive pads can be removed or relocated without damaging the boards surface. No need to replace the surface.

wire_diameters_bullett.vc6

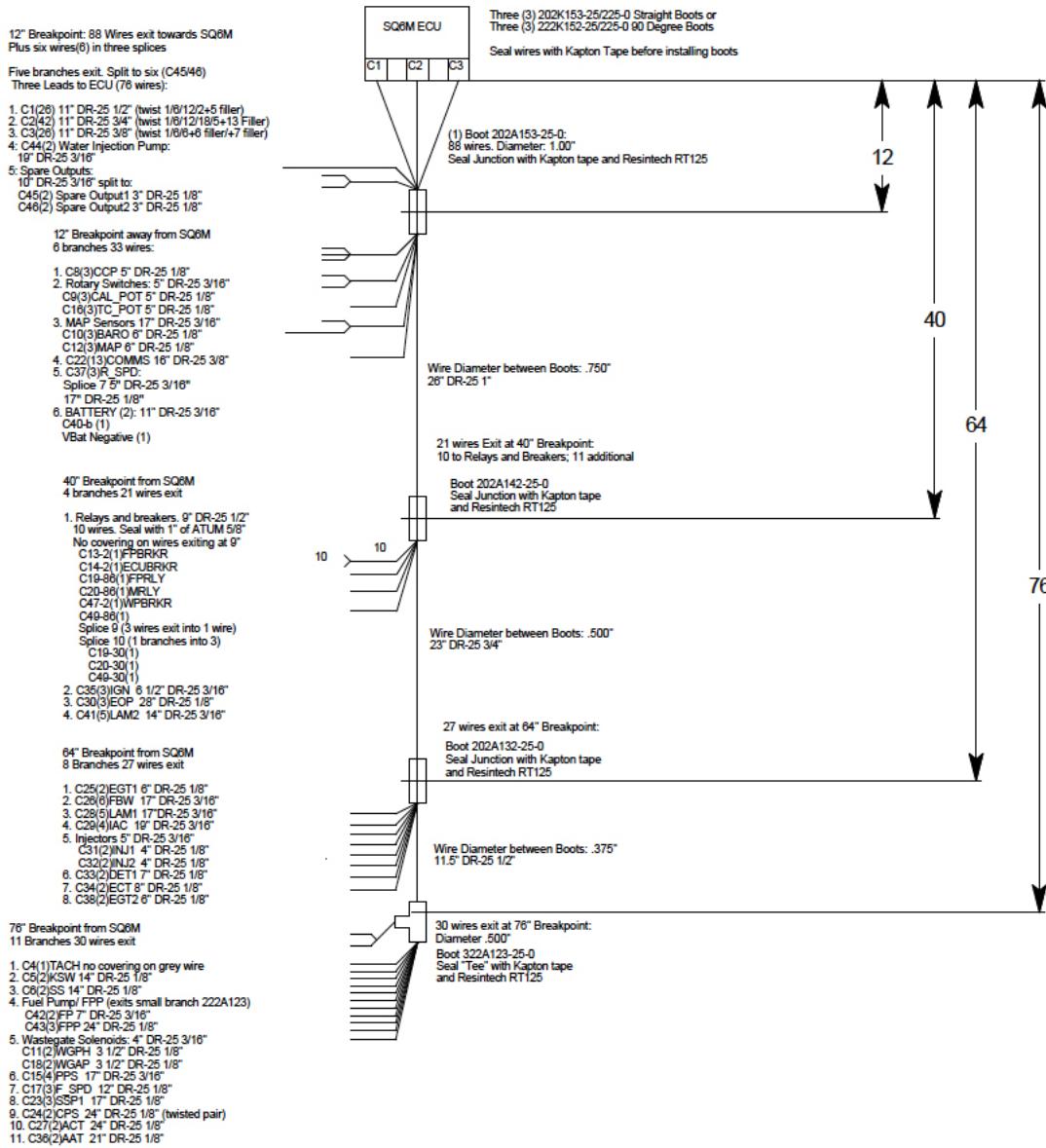
Note: Terminate DR-25 branches (Save C1, C2, C3) with appropriate size ES2000 adhesive shrink to seal wires and the "fix" the DR-25 in place before the connectors are installed.

Use MIL-T-43435B waxed braided nylon lacing cord on wire bundles.

76 wires are active at the SQ6M. 31 additional (Brown) terminated wires fill the unused terminals:
20 gauge filler wires on C1 (5 filler) and C3 (13 filler); 22 gauge filler wires on C2 (13 filler).

Filler wires are used for the unused pins so the total wires for the three connectors is $26+55+26 = 107$
88 wires exit to SQ6M at 12": 76 Wires Plus Minus 4-1(Splice 6); 4-2(Splice3) and
2-1(Splice 5). Add six wires $76-(4-1)+(4-2)+(2-1)+6 = 88$ wires
plus six wires exiting rearward (C44/45/46) equals 88 wires

All wires are labeled with yellow 1/8" heat shrink tube and covered with 1/8" Raychem RT375 clear. Branches are labeled with yellow or white shrink tubing and sealed with appropriate RT375 clear.



For planning purposes we determine which and how many wires exit the harness at each break point and also the diameter of the runs between the break points. Wire bundle diameter is important in choosing the correct diameter of DR-25 shrink tubing. 88 wires exit towards the SQ6M in this case with three separate leads going to each of the Deutsch Autosport connectors.

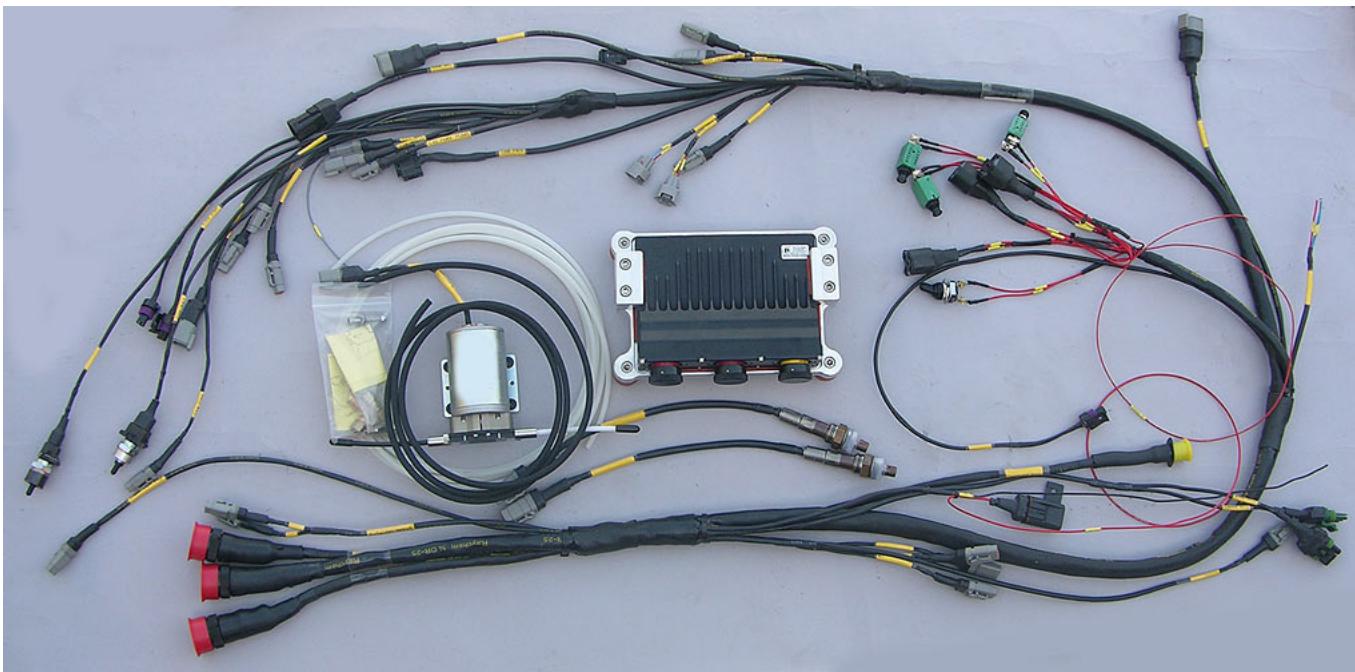


We twist the wires CW and CCW the best we can by the above format, but we always run into issues with 2-1 and 3-1 splices so we don't go the extra mile to put in dummy filler wires to get the 1-6-12-18 etc layers. We do the concentric twisting and secure the runs with Mil-T-43435B Lacing Cord. We label each wire with 1/8" yellow shrink tube covered by clear Raychem RT-375 clear shrink tubing.

We leave the exit branches about 4" longer than necessary and then trim the wires to length for the connector. You can slide the labels up and down the wire with a bit of force. Labels are necessary for us as we are constantly interrupted and brain fade sets in.

DR-25 1", 3/4", 1/2", 3/8". 1/4" and 1/8" is being used in this harness. Raychem 202A153, 202A142, 202A132 and 202A111 straight boots are being used with Resintech RT125 epoxy sealing the branches exiting the boots. Raychem ES2000-1, -2 and -3 tubing seals wires exiting the DR-25 on branch legs to sensors, circuit breakers, relays etc. Raychem ATUM is used to seal the back of connectors

Raychem DR-25 covers the main harness and the branches. Connectors are installed and sealed. Each branch is labeled with the connector number as well as the function. Kapton tape covers exposed wires before they have Raychem boots heat shrunk. In this application we have 49 outboard connectors to keep track of. Without documentation future issues as well as current assembly would be very difficult.



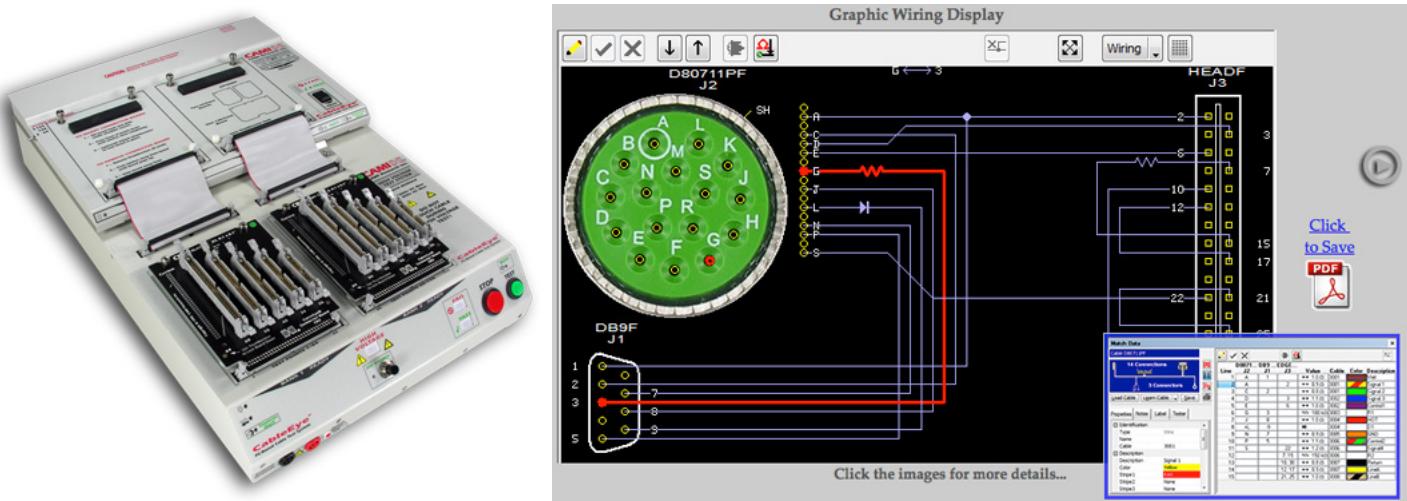
Labels on all connectors help keep track of things. Documentation is maintained on both the internal and external structure of the harness. [Pectel SQ6M ECU](#).

Hi-Pot Testing



Hi-Pot testing is used in aerospace and high-end motorsports wiring houses to verify wiring harness integrity. Any poor connection, nick in wiring insulation, or short can be isolated and fixed. Simple continuity checks are OK but are not foolproof. [CH2 pictured above](#). A [PDF listing costs](#) for various cable testers.

The hipot test is a nondestructive test that determines the adequacy of electrical insulation for the normally occurring over voltage transient. This is a high-voltage test that is applied to all devices for a specific time in order to ensure that the insulation is not marginal. [An explanation of Hi-Pot testing is offered by Cirris](#). Cirris CH2 pictured.



Hi-Pot CableEye testers from CAMI Research. PC based i.e. software driven Hi-Pot testing makes isolating things a lot easier.

Wideband Sensor Wiring



The Bosch LSU-4.2 (left) or the NTK (right) wideband sensors are typically married with six position Deutsch DTM connectors. In that they are five wire sensors the sixth position uses a seal plug. LSU 4.9 is the newest version and is not compatible with 4.2 electronics. Wiring colors for the different sensors is as follows:

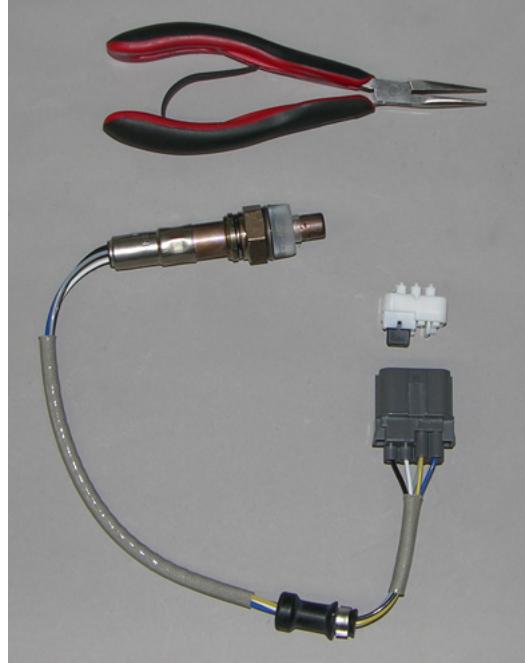
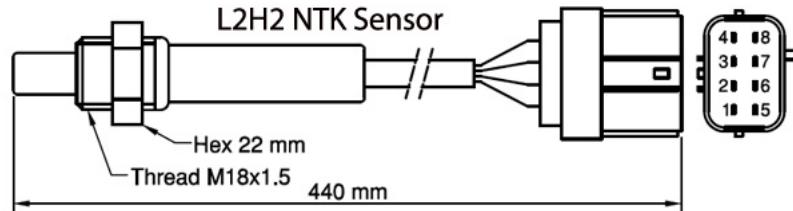
Bosch LSU-4.2 Typical DTM positions: DTM Terminal 1, Red Wire, WB_Pump; DTM Terminal 2, Black Wire, WB_Cell; DTM Terminal 3, Yellow Wire, WB_Com; DTM Terminal 4, White wire, WB_Htr-; DTM Terminal 5, Gray wire, WB_Htr+; DTM Terminal 6, seal plug.

Bosch LSU-4.9 Typical DTM positions: DTM Terminal 1, Red Wire, Pumping Current; DTM Terminal 2, Yellow Wire, Virtual Ground; DTM Terminal 3, White, Heater Minus (H-); DTM Terminal 4, Grey wire, Heater VBat (H+); DTM Terminal 5, Green wire, Trim Current; DTM Terminal 6, Black Wire, Nernst Voltage. LSU-4.9 Data.

[Interesting analysis of why Bosch Widebands fail.](#)

NTK L1H1 Wire Colors: Yellow Wire: Heater -; Blue: Heater Wire +; Black: Signal Ground; Grey: Nernst Cell Voltage; White: Ion Pump Current.

NTK L2H2 Wire Colors (8 pin Sumitomo H90 Connector): Pin1: Yellow Heater Wire -; Pin 2: Blue: Heater Wire +; Pin 3: Rc (cal resistor); Pin 4: Rc 0V; Pin 5: NC; Pin 6: Grey Wire Vs; Pin 7: White Wire Ion Pump; Pin 8: Black Wire Sensor 0V.



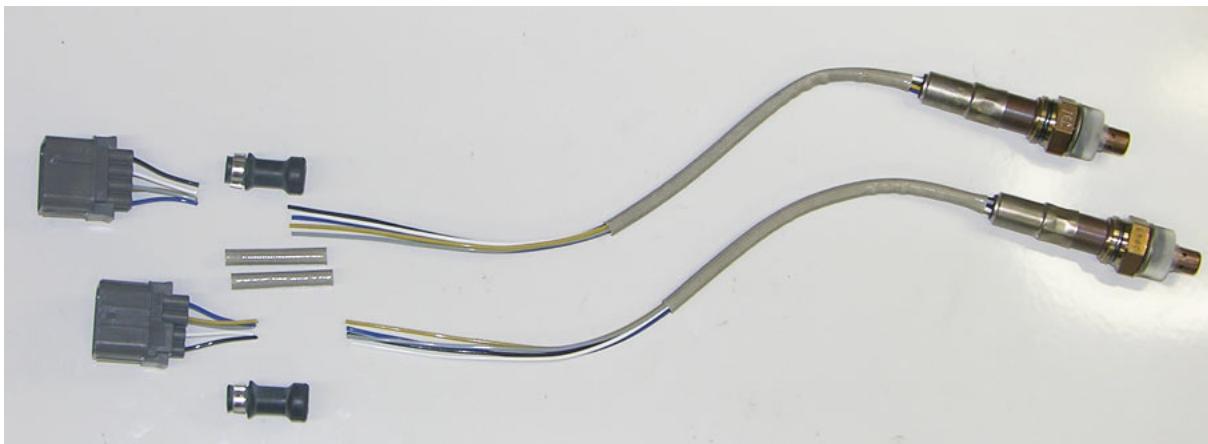
L2H2 Cal Resistor shown above between pins 3-4 which is read by oem application or devices like Motec PLM. These are individual to each sensor. High end ecus like the Pectel SQ6M do not use a Cal Resistor. NTK sensors are extremely accurate at Lambda 1.0 (14.57 AFR) but should be custom calibrated between Lambda 0.75 (10.92 AFR) and Lambda 1.25 (18.21:1 AFR). Nitrogen gas can be used to test for Lambda 1.0 (14.57:1). Calibration data can be entered into your ecu. Free Air has 20.95% Oxygen with a Lambda 1.43 (20.80AFR).

In general NTK sensors are higher temperature rated. We use them pre-turbo with pressure compensation tables as under rich conditions they show richer under boost pressure and leaner in lean conditions under boost pressure. Pectel SQ6 / SQ6M controllers are designed for the NTK sensors. NTK sensors are tolerant of leaded fuels whereas Bosch LSU-4.9 are not. Connectors for the L2H2 LZA-09-E1 sensors are available from Ballenger Motorsports.

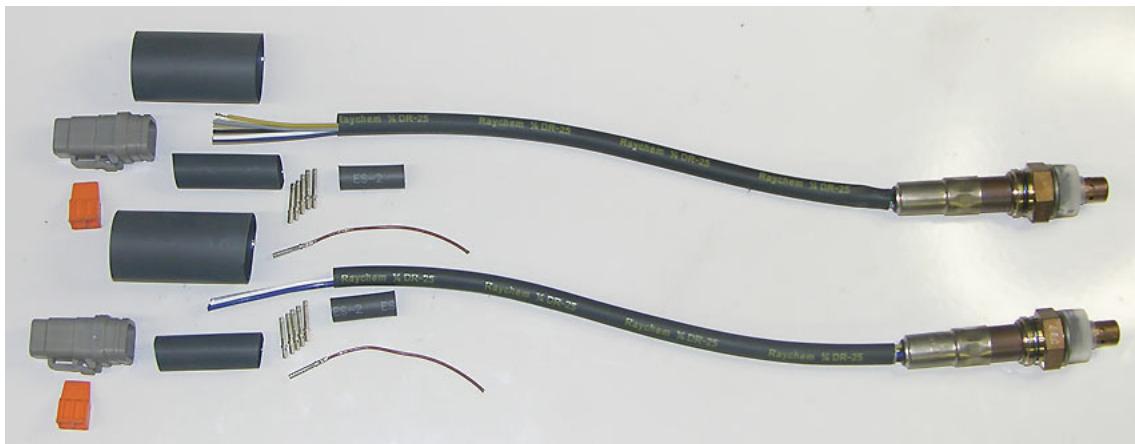
Another consideration is that the NTK sensors are about twice as fast as the Bosch 4.2 / 4.9 Sensors. No matter what anyone tells you the response times to correct injector output have a latency of 500Ms up to 980Ms which is why you do steady state step testing on a dyno. A fast dyno "sweep" can point out deficiencies but not

exactly pinpoint them. The base mapping has to be correct.

NTK L2H2 LZA-09-E1 Sensors



Cut and remove connector with calibration resistor. Leave longer silicone heat sheath.



Cover wires with 1/4" DR-25 overlapping the long NTK silicone heat sheath. Heat shrink the DR-25 and seal both ends with 1" ES2000-1.



Heat shrink 11mm label and seal with RT375 clear. Slip over 1.5"ATUM 12-3. Strip wires, crimp pins or sockets and insert these in the connector. Filler wire with pin or socket for the unused pin 6. Heat shrink the ATUM 12-3. Slip 2" ATUM 24-6 over the sensor and heat shrink to the DTM six position connector.

When mounting the NGK/NTK wideband lambda sensor pre-turbo you need to create pressure compensation tables in your ECU. We made a [Back pressure Lambda Calculator](#) that shows how lambda reading are skewed under exhaust back pressure....Or simply change your aim.

New Bosch LSU ADV... Pre-Turbo Lambda



New [Bosch Lambda ADV Sensor](#) for pre-turbo installation. Previous LSU 4.2 and 4.9 sensors could not be placed pre-turbo.

NTK L2H2 Lambda Test Stand Calibration



NTK L2H2 Test Stand for sensor linearization: Propane with a variable air bleed and three 18mm x 1.5 ports. Used for calibrating two NTK L2H2 Lambda meters against a known calibrated meter. Flowing Nitrogen gives Lambda 1.0 (14.57:1 AFR). Free Air at one end of the scale 100% propane on the other and propane/varying air mixtures for in-between. We burn the propane as so as not to vent unburned propane.

Pectel SQ6M engine controllers have 33 points to linearize or calibrate for each of the two NTK sensors. The SQ6M has internal NTK amplifier and heater circuits, so no external devices are required. Alternatively you can purchase a \$1,200.00 drum of test gasoline and a \$1,200.00 bottle of Lambda calibration gas to do your testing.

Keep in mind although NTK sensors are fast responding, around 1.3Ms, your fuel map must be correct as sensor latency in fast closed loop sweeps is an issue. Step tests on Dynamometers is recommended.

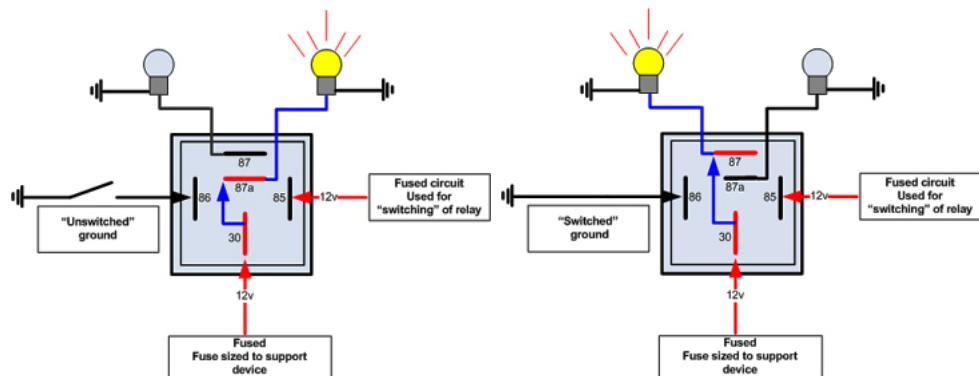
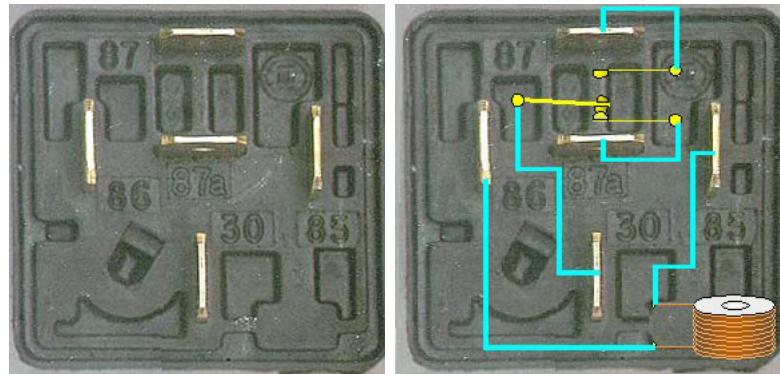
Pectel offers specifically calibrated five wire [NTK "Band 10"](#) wideband sensors for their engine control systems that come with Deutsch Autosport Connectors.

Viper Specialty Regulator



Viper Specialty Performance designed a nifty [fuel regulator](#) that incorporates differential pressure and temperature sensing which are then inputted to your engine controller...This simplifies things in terms of wiring, sensor placement and data acquisition.

Automotive 30A Relays



We use Hella or Bosch 30 Amp relays in our wiring harnesses. This is a pictorial reference as to how they work.

Corrosion Protection



At the Bonneville Salt Flats the salt air and salt eats everything. Internal cavities in relays turn into green gardens. Starter relays and switches die sooner or later. Cadmium plated hardware corrodes quickly. Battery terminals and any metal exposed that isn't stainless or chrome plated begins its ugly descent to mother earth from whence it came. [Boeshield T-9](#) is the best thing we've found to protect metal surfaces. WD-40 seems to disappear after a time. This stuff stays.

[Saltproofing USA Fluid](#) sounds a bit like snake oil but it really works. Protects about everything including alternators, relays, switches, and electrical motors.

Literature

Motorsport Wire:

[Raychem Spec 55 Wire](#) (XLETFE Polymer) The standard for high end motorsports wiring.

[Mil-STD-861 Color Codes](#) For Mil-Spec Wiring. 100 possible combinations. 10 colors are normally available.

Master Catalog Raychem Heatshrink Products:

[Raychem Heatshrink Products](#) Covers everything including tubing, all molded shapes (with dimensions), tools, and materials

Wire Covering:

[DR-25 Heat Shrink](#) Used to cover XLETFE wires in wiring harnesses. Has a 2-1 shrink ratio. Single Wall. Motorsports std. Yellow or White Lettering. [Available from Prowire USA](#).

[DSG-Canusa Deray V25](#) a less expensive alternative to DR-25

[Raychem RT-375](#) Clear heat shrink tubing. Use to cover your yellow/black wire heat shrink labels. [Available by the foot from Prowire USA](#).

[Kynar](#) Clear Heat Shrink Tubing to cover wire and cable heat shrink labels.

Adhesive-Lined Shrink Tubing:

[Raychem ES2000](#) Adhesive heat shrink. Semi Rigid 4-1 shrink ratio. Sealing wire transitions. Strain relief.

[Tyco RBK_Dual Wall](#) Adhesive heat shrink. Used to seal wire transitions and connectors. Less flexible than ATUM. Strain relief.

[Raychem SCL Heat Shrink](#) Used to seal shapes like switches and relays in lieu of specific "boot". Adhesive lined. 2.5:1 shrink ratio. [Available in 4 foot lengths from Prowire USA](#).



[Tyco ATUM semi-flexible Adhesive-lined heat shrink](#). Sealing Boots and transitions and shapes. 3-1 and 4-1 shrink ratio available. Here a three wire Cherry Hall Sensor has 1/4"DR-25, Resintech RT125 epoxy sealing the DR-25 ends, and 16mm ATUM semi-flexible adhesive shrunk to the assembly. [Available in 4 foot lengths from Prowire USA](#). Last digit is Color Code. Black is "0" (Zero).

3-1 Shrink Ratio	4-1 Shrink Ratio
ATUM-3/1-0	ATUM-4/1-0
ATUM-6/2-0	ATUM-8/2-0
ATUM-9/3-0	ATUM-12/3-0
ATUM-12/4-0	ATUM-16/4-0
ATUM-19/6-0	ATUM-24/6-0
ATUM-24/8-0	ATUM-32/8-0
ATUM-40/13-0	ATUM-52/13-0

[DSG-Canusa CDR](#) Adhesive lined shrink tube. 4:1 shrink ratio. Semi-rigid. More rigid than Tyco ATUM. Splice covering.

[DSG-Canusa CPA](#) Adhesive lined shrink tube. 3:1 shrink ratio. Connector sealing.

Molded Parts:

[Raychem Heatshrink Products](#) Covers everything including tubing, all molded shapes (with dimensions), tools, and materials

[Raychem Molded Parts](#) Heat Shrinkable, adhesive or non-adhesive lined, for wiring harness transitions and connectors.

[Hellermann-Tyton Molded Shapes](#), Heat shrinkable up to 5-1 ratio shapes for transition and connector sealing.

[Resintech RT125](#) Wiring Harness Epoxy.

[Molded Parts \(Boots\) Cross Reference](#) Raychem, Hellermann-Tyton etc.

Wire Stripping:

[Tyco Wire Stripping Guide](#)

[Teledyne Stripall Thermal Stripper](#)

[Ideal Wire Processing \(Stripper\) Catalog](#)

Motorsport Connectors:

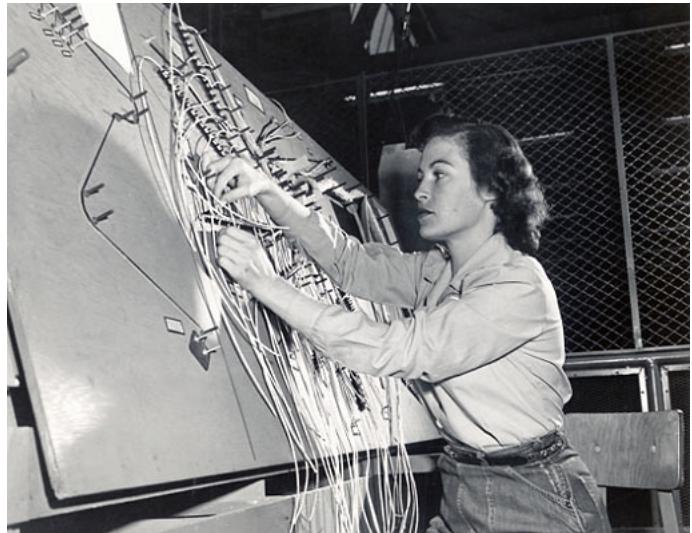
[Deutsch Autosport \(connectors\) Catalog](#)

[Deutsch DTM Series Connectors \(thermoplastic\)](#)

[Sureseal Rubber Connector](#)

[Souriau](#) Equivalent parts to Deutsch Autosport

[Delphi Metri-Pack GT150 Connectors](#) used for various sensors like Cherry Hall etc. (See Page 22: Pull to seat)

Circuit Breakers:[ETA 483 Circuit Breaker](#)[Tyco W23 Circuit Breaker](#)[Klixon 2TC14 Circuit Breaker](#)[Bussman 227 Manual Reset ATC](#)**Standards:**[NAVAIR Aircraft Electrical and Electronic Wiring](#) (Over 1000 pages) 12.8 Mb. Lots of mil-spec reference #'s, data and techniques.[Wire Harness Lacing Techniques](#)[NASA wiring and Harness Standards](#)[NASA Pictorial Standards](#)[IP Protection Ratings Chart](#) Explains "IP" or Ingress Protection ratings of connectors from water, dust, etc..Not a military specification.**WWII Wiring Harnesses**

In WWII we were cranking out bombers and fighter aircraft faster than they could be shot down. Extremely high crew losses were backed up by a system of production and training not seen since. Women were a major part of the work force and kicked butt. After the war their jobs were taken away from them. There went 50% of the talent.



Production and aerospace wiring harness construction is still largely done by women whether in the USA or elsewhere. Seems to be an ego deal in motorsports for males to twist and glue motorsport harnesses....probably Instagram wiring photos aren't part of the Defense contractor routines. Would you have the patience?

F1 Wiring



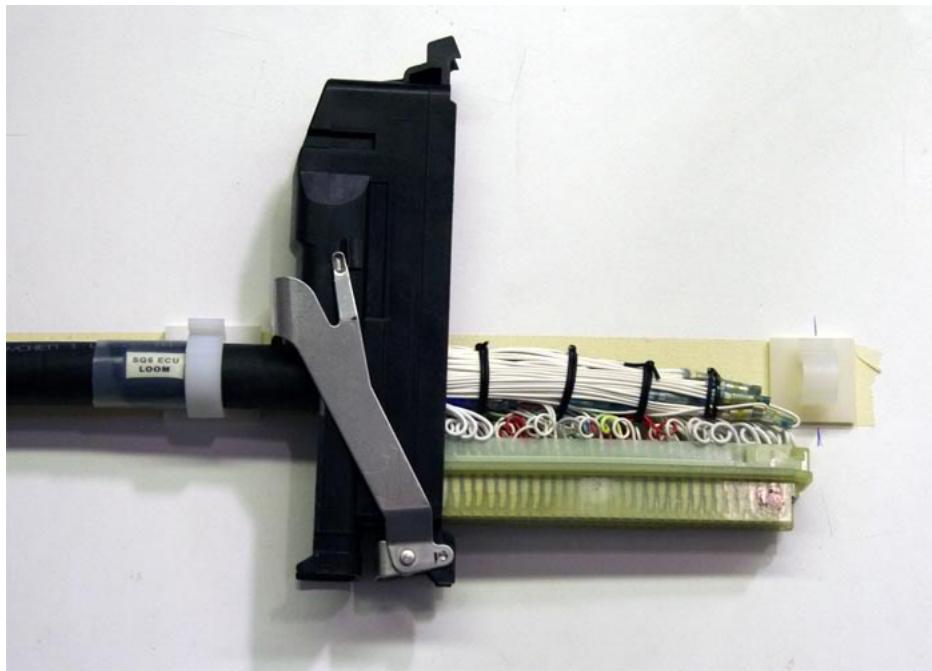
[Renvale Ltd.](#) (Formerly Tony James Wiring) in the United Kingdom is a specialist in high end motorsports wiring. [This is a video](#) of their work for the now defunct USA F1 Team. Let's hope they got paid. HAAS is up and running these days.

Prodrive



Production of a World Rally Car Wiring Harness at [Prodrive](#) is shown [starting at 4:08 in this video](#). You can see at this level of motorsport they use a large vertical assembly board per aircraft/aerospace use and also use Raychem Spec 55Mx4x4 (450 volt) white wires, not multi-colored wires. All wires are labeled and assembled into Deutsch Autosport connectors. Full [Cosworth Pectel electronics](#) and [displays](#) are used. [Cosworth Multi Function Display](#).

Motorsports Pectel SQ6 Wiring Example



Here we have an 88-way Cosworth Pectel SQ6 connector with service loops twisted just before the connector sockets. Follow the construction of a [Cosworth Pectel SQ6 Wiring Harness](#).

It requires a lot of money, time and supplies. In this case all the wires are all white in color...This makes servicing things down the road as well as construction much more difficult. If you label each wire and use colors codes it's easier.

An excellent source for your wiring supplies for you go it alone types is [ProwireUSA](#) as they stock about everything you need and sell in small quantities. It a good place to pick up your MIL-W-22759/32 wire and supplies. They have 140 Mil-Spec wire color combinations in stock. Quick service and excellent prices.

Costs: A Reality Check



The simple fact is that a professional motorsports wiring harness costs a lot of money. Unless it is some kind of production item, which it never is, these are going to be expensive whether you like it or not and a rule of thumb is that it is going to cost as much as your engine controller of choice and almost certainly likely more. One of the people we know typically spends about 200 man hours designing and fabricating a custom wiring harness. If you were a lawyer that would be about \$70,000.00 billable hours...If you were only charging a minimum burger slinging wage of \$10.00 per hour, the labor costs alone would be \$2000.00. That's a wide spread.

Even at a proposed minimum wage of \$15.00 per hour the labor alone for a 200 hour plan and build would be \$3,000.00 not including parts. Sort of depends on what you think your ass is worth after years and years of experience. Do you work for minimum wage? Do you expect your harness supplier to? Instagram photos and glory does not pay the bills, nor does a pat on the back. Hobby versus business, the eternal struggle.

What can you expect to pay? Well for a garden variety Mil-Spec sealed harness that is a semi-production item by some experienced specialist figure \$3,000.00 minimum. Normal costs are in the \$4,000.00 to \$6,000.00 range. For more complex harnesses involving firewall bulkhead connectors and multiple sub-harnesses figure \$8,000.00 and up...An experienced specialist who has everything in stock and is efficient in his / her production methods might complete a complex harness in 150 hours. Complete

vehicle wiring...\$25,000.00 and up depending on the complexity.

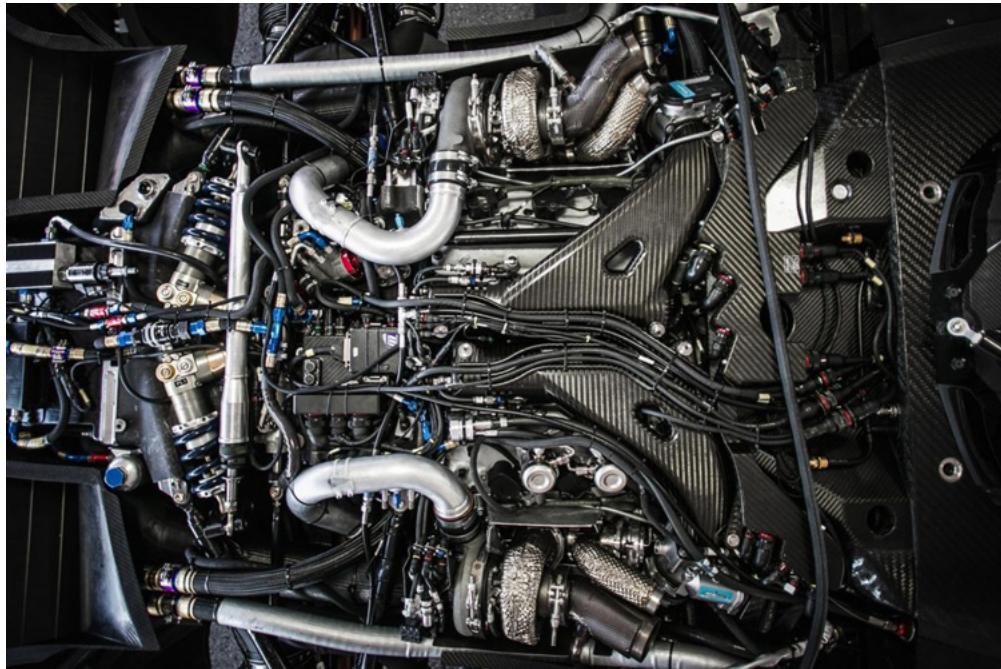
A person we know used to wire high end off the road racing vehicles where the total wiring bill was often North of \$25,000.00 for parts and labor and he did not want to do it anymore as it was tough getting paid for the work, not to mention all the travel and fighting clients. He cut back on that work and just sells parts these days and deals with clients who he can bill and get paid.

It's the old adage "Time is Money". Add up all the hours in planning, ordering and stocking parts, buying tooling, plus the actual fabrication and write yourself a fat check...Or let someone else do it. Letting someone else do it implies there is a solid design template or that person is going to have access to the project where it can be planned and executed in place. Travel expenses may be involved as remote designing is a bit of a risk. Sometimes it's best to pay and get on with your life.

We do our own harnesses and have for over 25 years as we have our projects in-house and don't like running around...and these days life is a lot more complicated. Time is money as they say.



[Sakata Motorsport](#) (1-714-446-9473 1241 N. Patt St., Anaheim, CA, 92801) has been making Mil-Spec Motorsports wiring harnesses on a contract basis for a long time. There are many others but you can research these out. Professional Motec Tuners like [Shane Tecklenburg](#), [John Reed](#), [Electron Speed](#), [Racegrade](#) (Motec East/West), and Pectel Specialists like [Dan Lesser](#) have solid reputations and are well versed in harness construction. UK/USA based [dce](#) builds the highest quality harnesses. The new firm of Zac Perkins and Tim Whitteridge (tim@motorsportselectronics.com) at [Motorsportselectronics](#) does excellent wiring, ecu calibration and systems integration work.



Jeremy Gibson at Indy Wiring Services LLC does the highest level of motorsport wiring and provides full documentation and Cirris Hi-Pot testing of every harness. Jeremy can be reached by phone at 1 (317) 371-7044 and by e-mail at indywiring@gmail.com. Jeremy provides Formula 1 level quality and adheres to all current Mil-Spec testing standards and specifications. He is familiar with the wiring requirements for the Cosworth Pectel SQ6, SQ6M and MQ12 series of engine controllers as well

as Bosch Motorsport controllers. Jeremy does Indy Car, NASCAR as well as complete harness construction for club racing. Jeremy did harness design, construction, and repair for Cosworth/Pi Research/Pectel for 9+ years. He has more than 15 years experience in motorsports wiring. Nissan LMP1 above work by Indy Wiring Services LLC.

[Home](#)[Products](#)[Part# / Price](#)[Contact](#)[Oscars](#)[Calculations](#)[Secrets](#)[Hot News](#)[Eat Shit](#)[About RB](#)[Orders](#)[Cinema](#)