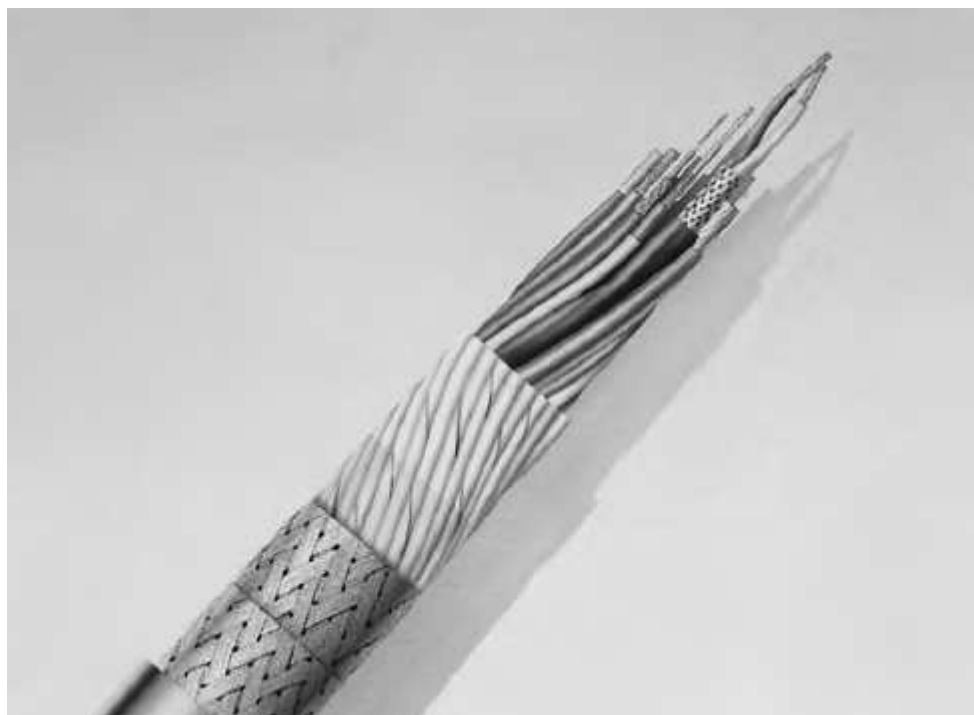


### Custom-designed and Standard Multiconductor (Multicore) Cables

#### Product Facts

- Temperature capability: -55°C to +260°C [-67°F to +500°F]
- Small size, lightweight
- System compatibility with other Raychem products
- Complete range of components
- Specially formulated jacket materials
- Special shielding to address EMI/EMC problems
- Custom designed and purpose built
- Fast response—design, pricing, and delivery
- Prototype length facility
- Raychem Dynalink extended flex-life and increased flexibility
- Fire-resistant: circuit integrity (IEC331, enhanced 950°C [1742°F], 3 hours)
- Small-size, lightweight, low-fire-hazard for modern high-speed vessels



#### Applications

Tyco Electronics is the leading manufacturer of Raychem custom-designed, small-size, lightweight, high-performance multiconductor (multicore) cables. Applications are found in the aerospace, commercial marine, naval, mass transportation, automotive, offshore, military ground vehicle, ground support, high-performance instrumentation, industrial, and commercial markets. Raychem multiconductor (multicore) cables have been approved to many standards demanding high performance criteria in service use.

#### Multiconductor (Multicore) Cables Purpose Built and Designed Using Raychem Components and Technology

Multiconductor cables are used in widely varying applications and environments. Careful consideration must be given to the selection of components with the right combination of physical, chemical, and electrical properties for specific applications.

Tyco Electronics' leadership in the technologies of polymer blending and subsequent radiation crosslinking has led to the development of a particularly broad range of Raychem cables. High-performance component wires and miniature coaxial cables are combined with unique cable jacket materi-

als to meet the requirements of demanding environments.

Established as one of the leading manufacturers of special purpose Raychem cables, Tyco Electronics has continued to develop both its design and manufacturing expertise.

Development of a sophisticated CAD system has allowed increasingly rapid response to any design request, followed by manufacturing to the highest quality standards.

#### Planar Film-Bonded Cables

Tyco Electronics can custom-design and build a variety of Raychem component wires and cables onto high-performance carrier films. Components and carriers are matched to ensure temperature and environmental stability.

#### Specifications/Approvals

Agency	Industry	Military	Raychem
Underwriters' Laboratories	Lloyd's Register of Shipping	Def. Stan. 61-12 Pt 25	WCD series
BSENISO9001	Det Norske Veritas	VG 95218 Pts 27 and 28	—
MSV 34410-34413, 34435,34436	—	—	—

**Multicore Cables****Design Flexibility****Components**

- SPEC 44 wire and cable
- SPEC 55 wire and cable
- Type 99 wire and cable
- 100 wire
- Coaxial cables
- ElectroLoss FilterLine cables
- Flexible power cables
- Optical fibers
- Special components

**Wraps and Braids**

- Fabric and film tapes
- KEVLAR or steel strength members
- Full range of electrical screens (including SuperScreens)

**Jacket Materials**

- FDR 25 - Fluid resistant, flexible, high temperature
- Thermorad - General purpose
- Thermorad HTF/ - Very high temperature, Fluoroelastomer fluid resistant
- Raythane C - Tough and flexible
- Raythane FR - Tough, flexible, flame-retardant
- Rayolin - Low moisture transmission
- Neoprene - Low-temperature flexibility
- Zerohal - LFH

KEVLAR is a trademark of E. I. DuPont de Nemours and Company.

Properties and Specifications

Specifications and Approvals (Components and Jacket Materials)

Specifications

UK Designation	FDR 25	Zerohal	Fluoro-elastomer	Thermorad	Rayolin	Raythane C	AFR	Neoprene	44 Wire	55 Wire	100 Wire	99 Wire	Hytrel
US Designation		Zerohal	Thermorad HTF	Thermorad F		Raythane FR		Thermorad NTFR	44 Wire	55 Wire	100 Wire		
Def Stan 61-12 Part 31 (NES 518)		X											
Def Stan 61-12 Part 25		X							X				
Def Stan 61-12 Part 18 type 1 (issue 4) (Maintenance range)									X				
Def Stan 61-12 Part 18 type 1 (issue 4)		X										X	
Def Stan 61-12 Part 25		X										X	
Def Stan 61-12 Part 26									X				
34435, 34436		X							X				
VG 95218 Part 20, 21, 22 and 23									X	X			
VG 95218 Part 24, 25 and 26	X												
VG 95218 Part 27 and 28	X	X							X		X		
VG 95218 Part 1000									X				
VG 95218 Part 1001 and 1002										X			
MIL-C-24640 (PMS 400)		X							X				
MIL-W-81044/MIL-C-27500									X				
MIL-W-22759/MIL-C-27500										X			
A014000		X											X
O2-517		X			X				X				
<b>Approvals</b>													
Lloyds Register of Shipping/DNV		X		X		X			X				X
Bureau Veritas	X	X	X	X		X	X	X	X	X			
UL				X		X (FR)	X		X	X			
CAA									X	X			
BWB	X			X					X	X			
VDE	X			X					X	X			
Det Norskeveritas													
Germanischer Lloyds		X										X	
American Bureau of Shipping		X										X	
Lloyds		X										X	
Bureau Veritas		X										X	

**Major Cable Specifications**

Country	Cable Specification	Specification Description	Approved Jacket
UK	Def Stan 61-12 Part 25	Royal Navy specification covering limited fire hazard thin-wall insulated electric cables using Def-Stan 61-12 Part 18 approved wire. Signal, control and light power circuits.	Zerohal
Germany	VG 95218 (parts 27 and 28)	Military ground systems specification for signal, control and power cables. Wire to VG 95218 Parts 20-23 and 1000.	FDR-25
USA	MIL-C-24640 (PMS 400)	Navy specification covering limited fire hazard thin-wall insulated electric cables for signal, control and light power circuits. Wire to MIL-W-81044.	Zerohal

**Summary of Typical Cable Jacket Properties**

UK Designation	US Designation	Property				Chemical Resistance		
		Temperature Range °C*	Abrasion Resistance	Flexibility	Flame Resistance	Acid	Alkaline	Hydrocarbon
FDR25	—	-40 to 150	Fair	Very good	Self-ext;ing	Good	Good	Very Good
Zerohal	Zerohal UK & US	-30 to 105	Good	Good	Self-ext;ing	Good	Good	Good
Fluoroelastomer	Thermorad HTF	-20 to 200	Good	Good	Nonburning	Excellent	Excellent	Excellent
Thermorad	Thermorad F	-55 to 125	Good	Good	Self-ext;ing	Good	Good	Good
Raythane C	—	-25 to 80	Excellent	Excellent	Self-ext;ing	Fair	Fair	Excellent
—	Raythane FR	-65 to 90	Excellent	Excellent	Self-ext;ing	Fair	Fair	Excellent
Neoprene	Thermorad NTFR	-55 to 110	Very Good	Excellent	Self-ext;ing	Good	Good	Good
Rayolin	—	-55 to 95	Very Good	Fair	—	Good	Good	Good
AFR	—	-40 to 105	Excellent	Good	Self-ext;ing	Good	Good	Good
—	Thermorad LS	-30 to 105	Good	Good	Self-ext;ing	Good	Good	Good
—	Thermorad O	-55 to 125	Good	Good	Self-ext;ing	Good	Good	Good
—	Thermorad 300	-65 to 200	Very Good	Fair	Self-ext;ing	Excellent	Excellent	Excellent
Polyvinylidene Fluoride	Thermorad K	-65 to 150	Very Good	Fair	Self-ext;ing	Excellent	Good	Excellent
Modified ETFE	Thermorad HT	-65 to 200	Very Good	Fair	Self-ext;ing	Excellent	Excellent	Excellent
Modified Flexible ETFE	Thermorad FL	-55 to 200	Very Good	Good	Self-ext;ing	Excellent	Excellent	Excellent

\*Operating temperatures for cables are application dependent. Figures shown are for guidance only. In many cases the limits shown may be extended at both ends of the temperature range. Consult Tyco Electronics for guidance.

**FDR25**

**Flexible, Diesel Resistant Wire and Cable Jacket Material**

**Product Facts**

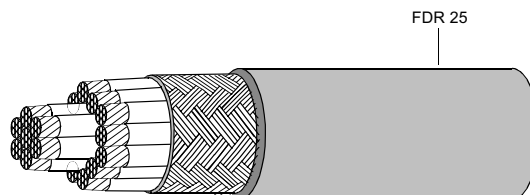
- Highly flame retardant
- Compatible with Raychem System 25 tubing, molded parts and adhesives
- Qualified to VG standards

**Applications**

FDR 25 cable jacket was originally developed for the Leopard II main battle tank to provide an exceptional range of properties. Used in compartments exposed to hot diesel fuels and vibration, FDR 25 resists a wide range of aggressive fluids and offers excellent low temperature flexibility. These properties have also led to a widespread use of FDR 25 on other military vehicles and in many applications such as test and communications equipment. FDR 25 is fully compatible with Raychem's high performance harnessing system — System 25.

**Operating Temperature Range**

-40°C to 150°C  
[-40°F to 302°F]



**FDR25** (Continued)

**Typical Characteristics when Tested in Accordance with Raychem Specification WCD 2002 (UK) and WCD 3304 (US)**

Mechanical	Tensile strength (MPa)	20	
	Elongation (%)	500	
	Tear strength (N/mm)	5	
	Abrasion resistance (1.6 kg load) Cold bend	40 scrapes min. -40°C [-40°F]	
Thermal aging	Endurance IEC 216	2500 h 150°C [302°F]	
	Heat aging 120h, 175°C [347°F]	TS 8 MPa (min). Eb 150% (min)	
	Heat shock 4 h at 225°C [437°F]	No cracks, drips or flowing, 6 mm total shrinkage in 300 mm	
Fluid resistance	24 h immersion	% Retention of properties Tensile strength      Elongation	
	Diesel fuels 70°C [158°F]	70	70
	Hydraulic fluids 50°C [122°F]	70	70
	Lubricating oils 100°C [212°F]	70	80
	Cleaning fluids 23°C [73°F]	90	95
	Deicing fluids 23°C [73°F]	90	95
Electrical	Insulation resistance 20°C [68°F] M ohm.km min.	2	
	45° flammability	30 s (max) afterburn 100 mm (max) burn length	
Other	Vertical flammability	Self extinguishing	
	Acid gas	4% HCl equivalent (max.)	

**Low Fire Hazard  
Performance Wire and  
Cable Jacket Material****Product Facts**

- Halogen free
- Low smoke generation
- Highly flame retarded
- Low toxicity index
- Low corrosive gas emission
- Temperature rating -30°C to +105°C [-22°F to +221°F]

**Zerohal****Applications**

Cables rarely initiate fires, but they could be involved in them and can significantly increase the damage caused should they propagate the fire. Until recently the flame retarding of cables was achieved by the use of halogenated flame retardants which are effective fire suppressants, but which unfortunately produce dense smoke and corrosive acid gases when burned. These effects are highly undesirable in a fire, hindering evacuation and fire fighting, endangering life and causing corrosion damage to expensive and vital equipment.

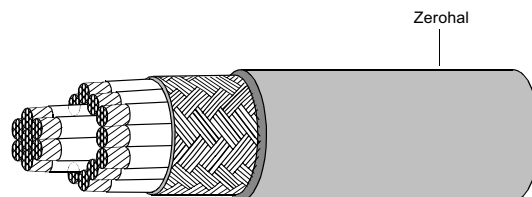
Raychem Zerohal is a halogen-free cable jacket material developed by Tyco Electronics and approved to the most exacting requirements for low fire hazard cables in many countries and, as such, is the most widely accepted material for these applications in the marine, process and mass transport industries. Combined with SPEC 44 wire or Type 99 and 100 wire, this jacket material provides small size, light weight cables (approximately 40% weight saving over conventional materials).

Zerohal combines the good mechanical and electrical features of some conventional cables with good flame retardancy, low smoke generation, low evolution of hazardous and corrosive gases, and good resistance to diesel fuel, lubricating oils and water.

Zerohal jacket material is fully compatible with the low fire hazard harnessing system - System 100.

**System**

- System 100



**Zerohal** (Continued)

**Product Characteristics when Tested in Accordance with Raychem Specification WCD 2015 and WC 2001 (Zerohal with Fungicide)**

Mechanical	Tensile strength (MPa)	8
	Elongation (%)	200
	Tear strength (N/mm)	5
	Abrasion resistance (1.6 kg load )	30 scrapes min.
	Cold bend	-30°C [-22°F]
Thermal aging	Heat aging 120 h 130°C [266°F]	60% min retention of TS and Eb
	Heat shock 4 h at 225°C [437°F]	No cracks, drips or flowing, 6 mm total shrinkage in 300 mm
Retention of properties		
Fluid resistance		Tensile strength      Elongation
	Diesel fuels 100°C [212°F] /24 h	85                      75
	IRM 902 24h, 100°C [212°F]	90                      75
	Lubricating oils 50°C [122°F]/24 h	80                      75
	Water uptake (ASTM D570) 70°C [158°F]/28 days	2% weight uptake (max)
Electrical	Insulation resistance 20°C [68°F] M ohms km (min)	40
	45° flammability	Self extinguishing
	Vertical flammability (Swedish Chimney)	Self extinguishing
Other	Acid gas	1.2% HCl equivalent (max)
	Limiting oxygen index	32%
	Temperature index	275°C [527°F]
	Toxicity index	2.5 per 100 g
	Smoke index	18
	Halogen content	None detected

**Low Fire Hazard Performance  
Flammability**

Current thinking on fire hazard defines the term 'Fire Risk'. This description recognizes that the risk in a fire situation is influenced strongly from several factors including, ignitability, heat release, smoke evolution and toxic gas emission together with flammability.

There are several test procedures available used to assess flammability of wires and cables. Still in widespread use is Limiting Oxygen Index (LOI), but it is now generally recognized that because the test is conducted on a single specimen (of cable jacket or wire) in laboratory conditions, the results are, at best, only weakly correlated to actual fire situations. Critical Temperature Index (CTI), is a related test and assesses performance at elevated temperature but nevertheless it is still conducted on a single specimen. More recent evidence

and thinking places significantly greater importance on large scale flammability tests, such as IEC 60332-3, in which the sample consists of several bundles of wires. These tests predict more accurately the likely behavior of cables in actual fire scenarios. Raychem Zerohal cable jackets give very good results in small scale laboratory based tests (e.g. LOI, CTI) and Zerohal cables perform very well in large scale tests (e.g. IEC 60332-3). Overall Zerohal jacketed cables have been shown to exhibit excellent flammability characteristics.

**Corrosivity**

Under fire conditions, polymers containing halogens, sulphur and phosphorous all form corrosive acid gases or liquids. These acids can then attack items such as printed circuit boards, connectors, control relays and metal structures, including steel reinforcement bars embedded in concrete.

Test methods to evaluate corrosivity involve direct measurement of the amount of acid gas produced during pyrolysis, eg to British Rail Specification TDE 76/P/16 or measurement of pH and electrical conductivities of solutions.

**Toxicity Index**

The various gases given off by combustion of polymeric materials are toxic to differing degrees.

The Def Stan 02-713, assesses the concentration of each of the possible by-products and, by measuring the amounts of these materials, a Toxicity Index is assigned.

Zerohal jacket material has a typical Toxicity Index of 1.7, compared to a typical value of 6 for CSP and 20 for PVC jacketed cable. The Def Stan 61-12 part 31 specification requirement for a cable jacket is <5.

**Smoke**

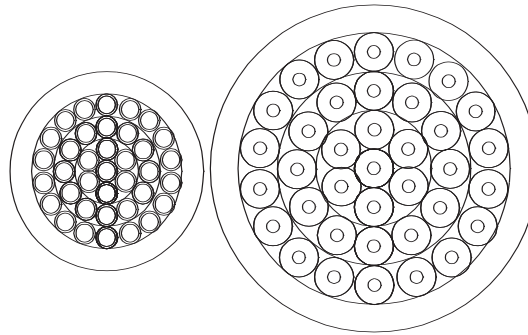
The problems of classifying flammability and corrosive gas generation equally apply to measuring smoke generation. The method accepted by most authorities involves the use of the NBS smoke chamber where optical density of the chamber's atmosphere is constantly measured during pyrolysis.

The 10% visibility line indicates the density of smoke which would cause human disorientation and confusion. The rate of change of smoke density can be summarized to a single numerical value, as in NES 711, to give a smoke index for a material and thus offers simple comparison of materials performance.



**Navy Applications**  
**37 Component Cable**  
**Comparison**

**Zerohal** (Continued)



	<b>Raychem Cable to Def Stan 61-12 Pt25</b>	<b>Cable to DGS 212</b>
Diameter	12.5 mm (nom.)	21.3 mm
Weight	328 g/m (nom.)	526 g/m
Conductor	0.60 mm <sup>2</sup> (nom.)	0.5 mm <sup>2</sup>

Ships are becoming smaller and more sophisticated, with an ever increasing complexity of electronic systems, sensors and weapons. As technology advances shipbuilders are called upon to update and modify existing systems or fit completely new ones. The proliferation of electronic hardware requires more and more communication systems to transfer data from one place to another. To provide all the necessary interconnections, hundreds of multicore cables have to run throughout the ship. These, along with cables for power, lighting and other basic services, create a severe space problem within ducts and hangers. For the vessel to achieve maximum speed, maneuverability and range, it is vital to

keep the "top weight" to a minimum and since most of the equipment is located on the upper decks, system weight must be kept as low as possible.

The diagram shows a lightweight cable compared with a traditional Navy cable having the same cross-sectional area of copper. Both cables have the same number of conductors. A saving in size has been made on the insulation material, but without sacrificing the mechanical or electrical characteristics of the cable. A typical saving in cable tray volume could be as high as 40%. Lightweight cables can also save in excess of twenty tons on a typical frigate and three to five tons on a fast patrol boat.

Raychem lightweight, small size cables are giving reliable service in frigates, corvettes, fast patrol boats, hydrofoils and submarines in many major Navies.

Due to recent improvements in manufacturing, Raychem can now offer an even tighter tolerance of  $\pm 2.5\%$  on cable diameter. This is well within the limits imposed by specifications such as Def Stan 61-12 part 25, and offers significant benefits to system designers, particularly where cable glanding is involved.

Weight savings within "maxima allowed" by existing specifications are also achievable.

**Other Applications**

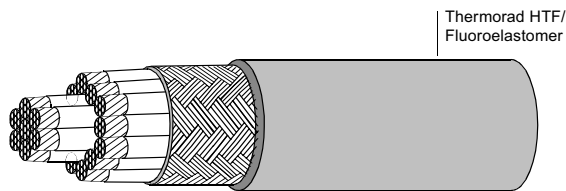
The increasing awareness of many areas of industry of the need to minimize fire hazard risk is leading to a rapid growth in the use of Zerohal jacketed cables. Applications include rail and mass transit, offshore platforms and other enclosed areas where a fire would present a significant threat to people or equipment.

Thermorad HTF/ Fluoroelastomer

High Temperature Performance Wire and Cable Jacket Material

Product Facts

- High temperature capability  
-20°C to +200°C [-4°F to 392°F]
- Excellent chemical resistance
- Flame retardant
- Continuous aircraft fuel immersion



Applications

Thermorad HTF/ Fluoroelastomer is a material specially formulated for use in applications where exceptional performance is required.

It displays excellent stability during continuous high temperature exposure to adverse chemical environments.

Thermorad HTF/ Fluoroelastomer has a continuous operating tempera-

ture of up to 200°C [392°F], and finds applications in aircraft fuel tanks and on high performance engine cables. Thermorad HTF/ Fluoroelastomer cable jackets are compatible with the Raychem high temperature harnessing systems — System 200.

System

- System 200

Typical Characteristics when Tested in Accordance with Raychem Specification WCD 51/367

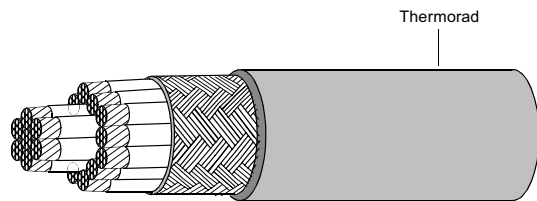
Mechanical	Tensile strength	12 MPa	
	Elongation	400%	
	Abrasion resistance (1.6 kg load)	40 scrapes min.	
	Cold bend -0°C ± 3°C [37°F]	No cracking	
Thermal aging	Heat age	168 h 250°C [482°F]	
	Heat shock 4 h at 300°C ± 3°C [572°F ± 37°F]	No cracks, drips or flowing, 6 mm total shrinkage in 300 mm	
Fluid resistance	72 h immersion	% Retention	
		Tensile strength	Elongation
	Diesel oil 100°C [212°F]	60	60
	ASTM No 2 oil 100°C [212°F]	60	60
Electrical	Insulation resistance 20°C [68°F] M ohms. km (min)	10	
Other	45° flammability	30 s (max) afterburn 100 mm (max) burn length	
	Vertical flammability	Self extinguishing	

### General Purpose Wire and Cable Jacket Material

#### Product Facts

- Temperature rating -55°C to +125°C [-67°F to 257°F]
- Highly flame retardant
- Resistant to fuels, oils and greases
- Resistant to NBC decontaminant
- UL approved

## Thermorad/Thermorad F



#### Applications

Thermorad is a general purpose jacket material which is unaffected by most common chemicals and solvents and is suitable for use during N.B.C. decontamination. Thermorad is highly flame retardant and has an overall balance of physical and chemical properties.

Thermorad cables find widespread use in industrial, commercial and military applications. This includes railways, commercial vehicles, medical equipment, communication equipment and commercial electronics. Thermorad cable jackets are compatible with Raychem polyolefin tubings, molded parts and adhesives.

#### Typical Characteristics when Tested in Accordance with Raychem Specification WCD 51/1602 (UK) and WCD 3310 (US)

Mechanical	Tensile strength	22 MPa	
	Elongation	550%	
	Abrasion resistance (1.6 kg load)	300 scrapes min.	
	Cold bend	-55°C [-67°F]	
Thermal aging	Heat aging 120 h, 170°C [338°F]	60% min. retention of TS and Eb	
	Heat shock 4 hours at 225°C [437°F]	No cracks, drips or flowing, 6 mm total shrinkage in 300 mm	
Fluid resistance	72 hour immersion, 50°C [122°F]	% Retention of properties	
		Tensile strength	Elongation
	IRM 902	60	60
	SKYDROL	60	60
Electrical	Insulation resistance 20°C [68°F] M ohms km (min)	100	
Other	45° flammability	30 s (max.) afterburn 75 mm (max.) burn length	
	Acid gas	4% HCl equivalent (max.)	

SKYDROL is a registered trademark of Monsanto Company.

### Raythane, Neoprene, Rayolin and AFR

#### Specialized Wire and Cable Jacket Material

##### Product Facts

##### Raythane C

- -25°C to +80°C  
[-13°F to +176°F]

##### and Raythane FR

- -65°C to +90°C  
[-85°F to +194°F]
- Mechanically tough
- Can be overmolded

##### Rayolin

- -55°C to +95°C  
[-67°F to +203°F]
- Excellent long term water immersion
- Can be overmolded
- Compatible with Raychem's underwater cable splices

##### Neoprene (US designation Thermorad NTFR)

- -55°C to +90°C  
[-67°F to +194°F]
- Extreme flexibility
- Highly flexible at low temperatures

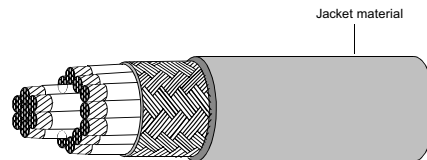
##### AFR

- -40°C to +105°C  
[-40°F to +221°F]
- Abrasion resistant
- Fuel resistant
- Flame retardant



#### Applications

In addition to the preferred cable jacket materials, Tyco Electronics offers a variety of Raychem cable jackets for specialized applications. For example, specialized materials are available for extreme low temperature flexibility or for enhanced abrasion resistance, or non-cross-linked materials for cable splicing or overmolding.



#### Typical Characteristics when Tested in Accordance with Raychem Specification WCD

		WCD51/1625 Raythane C	WCD3310 Raythane FR	WCD51/147 Neoprene*	WCD51/1601 Rayolin	WCD51/1619 AFR
Mechanical	Tensile strength (MPa)	45	45	12	14 12	
	Elongation (%)	400	400	400	250	150
	Abrasion resistance (1.6 kg load)	500 scrapes	500 scrapes	30 scrapes	300 scrapes	200 scrapes
	Cold bend	-25°C [-13°F]	-15°C [5°F]	-55°C [-67°F]	-55°C [-67°F]	-40°C [-40°F]
Thermal aging	Endurance (10000 h)	80°C [176°F]	90°C [194°F]	90°C [194°F]	95°C [203°F]	105°C [221°F]
Fluid resistance	24 h immersion Diesel fuels 50°C [122°F]	Excellent	Excellent	Good	—	Good
	SKYDROL 50°C [122°F]	—	—	Excellent	Excellent	Excellent
	IRM 902 100°C [212°F]	Excellent	Excellent	Good	Good	Good
Electrical	Insulation resistance 20°C [68°F] M ohms. km (min)	1	1	5	100	100
Other	45° flammability	Pass	Pass	Pass	—	Pass

\* In the US use Thermorad NTFR to WCD 3314.

SKYDROL is a registered trademark of Monsanto Company.