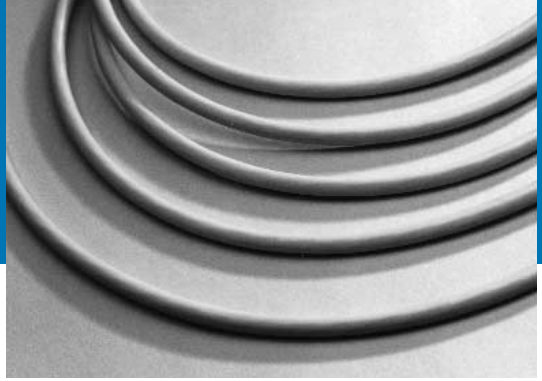


# FDR25

*Flexible,diesel resistant wire and cable jacket material*

## 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.

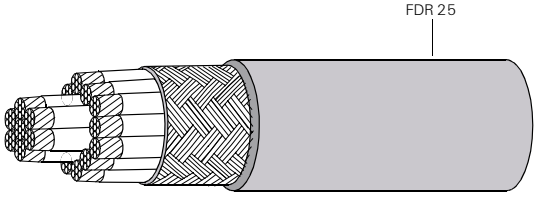
## Operating temperature range

-40°C to 150°C

## Features and benefits

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

| ***Available in:*** | Americas | Europe | Asia Pacific |
|---|---|---|---|
| | ■ | ■ | ■ |



***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) | 40 scrapes min. | |
| | Cold bend | -40°C | |
| Thermal ageing | Endurance IEC 216 | 2500 h 150°C | |
| | Heat ageing 120h, 175°C | TS 8 MPa (min). Eb 150% (min) | |
| | Heat shock 4 h at 225°C | 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 | 70 | 70 |
| | Hydraulic fluids 50°C | 70 | 70 |
| | Lubricating oils 100°C | 70 | 80 |
| | Cleaning fluids 23°C | 90 | 95 |
| | Deicing fluids 23°C | 90 | 95 |
| Electrical | Insulation resistance 20°C M ohm.km min. | 2 | |
| Other | 45° flammability | 30 s (max) afterburn<br>100 mm (max) burn length | |
| | Vertical flammability | Self extinguishing | |
| | Acid gas | 4% HCl equivalent (max.) | |


# Zerohal

*Low fire hazard performance wire and cable jacket material*

## 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.

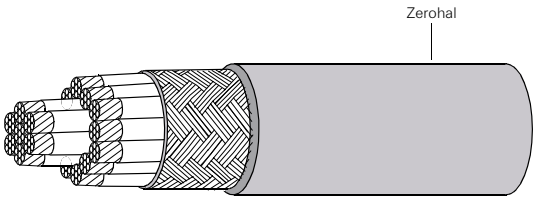
Zerohal jacket material is fully compatible with the low fire hazard harnessing system - System 100.

## Features and benefits

- Halogen free.
- Low smoke generation.
- Highly flame retarded.
- Low toxicity index.
- Low corrosive gas emission.
- Temperature rating -30°C to +105°C.

## System

- System 100.




| ***Available in:*** | Americas | Europe | Asia Pacific |
|---|---|---|---|
| | ■ | ■ | ■ |

***Product characteristics when tested in accordance with Raychem specification WCD 2015 and WC 2001 (Zerohal with Funguicide)***

| | | | |
|---|---|---|---|
| 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 | |
| Thermal ageing | Heat ageing 120 h 130°C | 60% min retention of TS and Eb | |
| | Heat shock 4 h at 225°C | No cracks, drips or flowing, | |
| | | 6 mm total shrinkage in 300 mm | |
| Fluid resistance | | Retention of properties | |
| | | Tensile strength | Elongation |
| | Diesel fuels 100°C/24 h | 85 | 75 |
| | IRM 902 24h, 100°C | 90 | 75 |
| | Lubricating oils 50°C/24 h | 80 | 75 |
| | Water uptake (ASTM D570) 70°C/28 days | 2% weight uptake (max) | |
| Electrical | Insulation resistance 20°C | 40 | |
| | M ohms km (min) | | |
| Other | 45° flammability | Self extinguishing | |
| | Vertical flammability | Self extinguishing | |
| | (Swedish Chimney) | | |
| | Acid gas | 1.2% HCl equivalent (max) | |
| | Limiting oxygen index | 32% | |
| | Temperature index | 275°C | |
| | 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 behaviour 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.

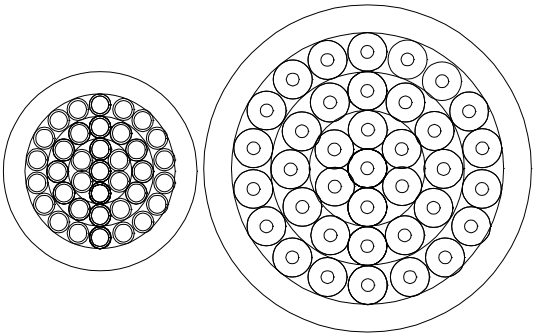
### Smoke

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



| | Raychem cable to Def Stan 61-12 Pt25 | Cable to DGS 212 |
|---|---|---|
| Diameter | 12.5 mm (nom.) | 21.3 mm |
| Weight | 328 g/m (nom.) | 526 g/m |
| Conductor | 0.60 $mm^2$ (nom.) | 0.5 $mm^2$ |

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, maneuvrability 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 ±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*

## 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 temperature of up to 200°C, 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.

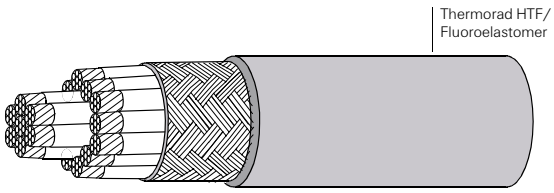
## Features and benefits

- High temperature capability -20°C to +200°C.
- Excellent chemical resistance.
- Flame retardant.
- Continuous aircraft fuel immersion.

## System

- System 200

| *Available in:* | Americas | Europe | Asia Pacific |
|---|---|---|---|
| | ■ | ■ | ■ |



***Typical characteristics when tested in accordance with Raychem specification WCD 51/1632***

| | | | |
|---|---|---|---|
| Mechanical | Tensile strength | 12 MPa | |
| | Elongation | 400% | |
| | Abrasion resistance (1.6 kg load) | 40 scrapes min. | |
| | Cold bend -0°C ± 3°C | No cracking | |
| Thermal ageing | Heat age | 168 h 250°C | |
| | Heat shock 4 h at 300°C ± 3°C | 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 | 60 | 60 |
| | ASTM No 2 oil 100°C | 60 | 60 |
| Electrical | Insulation resistance 20°C M ohms. km (min) | 10 | |
| Other | 45° flammability | 30 s (max) afterburn | |
| | | 100 mm (max) burn length | |
| | Vertical flammability | Self extinguishing | |

# Thermorad/Thermorad F

*General purpose wire and cable jacket material*

## Applications

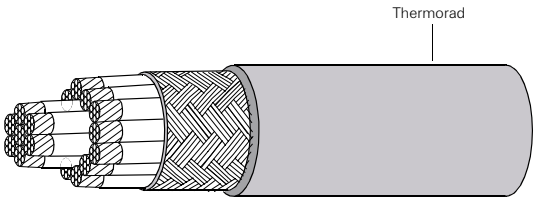
Thermorad is a general purpose jacket material which is unaffected by most common chemicals and solvents and is suitable for use during N.B.C. decontamination. Thermorad is highly flame retardant and has an overall balance of physical and chemical properties.

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.

## Features and benefits

- Temperature rating -55° C to +125° C.
- Highly flame retardant.
- Resistant to fuels, oils and greases.
- Resistant to NBC decontaminant.
- UL approved.

| ***Available in:*** | Americas | Europe | Asia Pacific |
|---|---|---|---|
| | ■ | ■ | ■ |



**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 | |
| Thermal ageing | Heat ageing 120 h, 170°C | 60% min. retention of TS and Eb | |
| | Heat shock 4 hours at 225°C | No cracks, drips or flowing, | |
| | | 6 mm total shrinkage in 300 mm | |
| Fluid resistance | 72 hour immersion, 50°C | % Retention of properties | |
| | | Tensile strength | Elongation |
| | IRM 902 | 60 | 60 |
| | Skydrol | 60 | 60 |
| Electrical | Insulation resistance 20°C | 100 | |
| | M ohms km (min) | | |
| Other | 45° flammability | 30 s (max.) afterburn | |
| | | 75 mm (max.) burn length | |
| | Acid gas | 4% HCl equivalent (max.) | |

# Raythane, Neoprene, Rayolin, AFR

*Specialized wire and cable jacket material*

## 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.

## Features and benefits

Raythane C and Raythane FR

- -25°C to +80°C.
- Mechanically tough.
- Can be overmolded.

Rayolin

- -55°C to +95°C.
- Excellent long term water immersion.
- Can be overmolded.
- Compatible with Raychem's underwater cable splices.

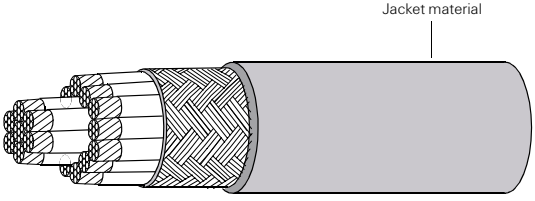
Neoprene (US designation Thermorad NTFR)

- -55°C to +90°C.
- Extreme flexibility.
- Highly flexible at low temperatures.

AFR

- -40°C to +105°C.
- Abrasion resistant.
- Fuel resistant.
- Flame retardant.

| ***Available in:*** | Americas | Europe | Asia Pacific |
|---|---|---|---|
| | ■ | ■ | ■ |



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

| | | WCD51/1625 | WCD3310 | WCD51/147 | WCD51/1601 | WCD51/1619 |
|---|---|---|---|---|---|---|
| | | Raythane C | Raythane FR | Neoprene* | Rayolin | 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 | -15°C | -55°C | -55°C | -40°C |
| Thermal ageing | Endurance (10000 h) | 80°C | 90°C | 90°C | 95°C | 105°C |
| Fluid resistance | 24 h immersion | | | | | |
| | Diesel fuels 50°C | Excellent | Excellent | Good | - | Good |
| | Skydrol 50°C | - | - | Excellent | Excellent | Excellent |
| | IRM 902 100°C | Excellent | Excellent | Good | Good | Good |
| Electrical | Insulation resistance 20°C 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.

# Electrical Screening (shielding)

*Interference - designing for the threat*

## Applications

In many applications, screening of cables is important, whether it be to minimize cross-talk within the cable, to prevent interference from external sources, or to eliminate radiation from the cable itself.

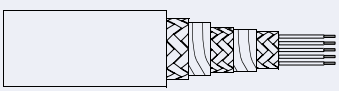
The design of cables to provide effective shielding over a broad frequency spectrum is complex, and cables must be tailored to specific electromagnetic environments. From simple aluminized Mylar that provides electrostatic screening, progressively more complex shielding can be designed incorporating plated copper braids and Mu metal wraps.

### Optimization

Performance of conventional braiding can be significantly improved by computer optimization. This tightly controlled process can give many times the screening performance of a basic braided screen without weight penalty or increase in optical coverage. Superscreened cables combine Mu metal wraps with optimized braids to provide even further enhanced performance, especially at low frequencies.

| ***Available in:*** | Americas | Europe | Asia Pacific |
|---|---|---|---|
| | ■ | ■ | ■ |

***Available screens***

| Screen type | Construction | Typical application |
|---|---|---|
| Aluminized Mylar |  | Electrostatic screening |
| Single Braid |  | Low level EMI<br>Low sensitivity |
| Single Optimized Braid |  | Sensitive lines<br>High EMI |
| Double Optimized Braid |  | Highly sensitive lines<br>Severe EMI |
| Superscreened |  | EMP/Tempest |
| Double Superscreened |  | Severest of applications |

## Measuring screening efficiency

### Surface transfer impedance (Zt)

To assess the effectiveness of a shield, Tyco Electronics has adopted the line injection method as described in IEC 1196-1 to measure the surface transfer impedance (Zt) of a cable shield. This relates the open circuit voltage generated on a component wire inside the cable to the current injected on the overall shield. The unit of Zt is Ohms per meter, thus the voltage coupling is length dependent and long cables exhibit more leakage than similar but shorter length ones. To determine the surface transfer impedance across a range of frequencies, a drive signal is generated by the internal tracking generator of a spectrum analyzer, and amplified. The voltage is induced on the center conductor of the sample which is amplified and returned to the signal generator for measurement. The understanding of leakage mechanisms has enabled Tyco Electronics to design Raychem cables with guaranteed minimum Zt values for the desired operating environment.

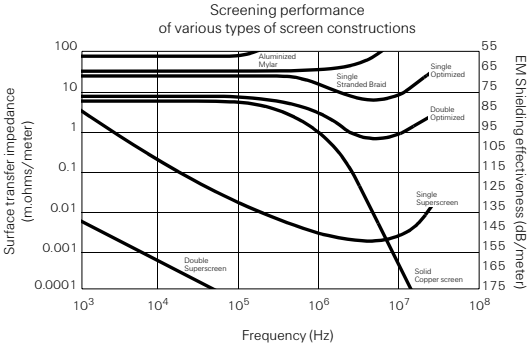
## Superscreening

### EMP hardened cables

The requirements for nuclear hardened cables present the engineer with a range of problems. The waveform of the EMP is such that the majority of power is dissipated in a frequency band between 1 KHz and 5 MHz, where little protection is given by conventionally screened cables. Tyco Electronics has solved this problem with a range of superscreened cables which give screening performance at these frequencies by incorporating materials which change the inductance of the shield and lower the transfer impedance. Raychem superscreened cables have a sandwich construction of Mu metal tapes between optimized braids. Mu metal is a ferro-magnetic material which has a high permeability over a wide range of field strengths. It is applied to the cable in a way which maintains cable flexibility and minimizes work hardening and any consequent reduction in permeability. Superscreened cables not only give protection against EMP but also other major interference modes, Surface transfer impedance (m. ohms/ meter)

## Screened cables

### Controlling the threat




### Testing

Tyco Electronics EMC test facilities have the capability for bulk current injection and radiation field testing in addition to surface transfer impedance measurements. The installation is a proven facility in characterising new design parameters.

### Design and manufacturing expertise

The problems of shielding cables are complex. However, with the introduction of optimized braids and superscreened cables, Tyco Electronics has the capability to solve the most difficult shielding problems. Shielding of cables without degrading cable flexibility can be provided for coaxial and multiconductor cables for all EMC and EMP conditions. To complement this range of cables, Tyco Electronics manufactures Raychem cable terminations and connector back fittings to give total interconnection system screening performance.

# Computer-Aided Design

*Custom design capability*

## Applications

Every year, Tyco Electronics designs and builds several thousand custom, high-performance, multiconductor cables that meet unique product needs.

Design staff can draw on an extensive range of high-performance cable components and jacket materials, while incorporating both color-coding and alphanumeric marking techniques for component identification. These options, combined with a full range of EMI shields (screens), lead to a huge variety of construction possibilities.

Tyco Electronics developed computer-aided design tools to provide a fast response to design requests. The software, used by factory engineers or product specialists in the field, can generate cable design proposals with drawings and quotations in minutes. A design drawing details all the cable data and can be used as the input to harness or cable splice (joint) design. The resulting cable is tailored to customers' exact needs in an efficient design that is superior to the compromise cable selected from a product catalog.

## Quality Assurance

Raychem WCD and WSD cable specifications ensure that performance and quality standards are maintained to the highest level. Tyco Electronics manufacturing sites have obtained the highest available quality system approvals, including ISO 9000 and QS9000. Raychem cables are manufactured to meet the requirements of several major specifications.

| ***Available in:*** | Americas | Europe | Asia Pacific |
|---|---|---|---|
| | ■ | ■ | ■ |