Protective Coating system selection with ISO 12944

TRANSOCEAN
COATINGS
Since 1959

Introduction

Since 1959, Transocean Coatings is protecting structures at sea or on land, such as structural steel and roof constructions in buildings, bridges, storage tanks, water and fuel infrastructure, factories and energy installations on- and off-shore as parts of renewable energy or oil and gas assets. The fight against corrosion includes visible - as well as invisible parts like buried, immersed or non-accessible internal areas.

Painting is the most widely used method of providing protection against corrosion The ISO 12944 standard *"Paint and Varnishes: Corrosion Protection for steel structures by protective paint systems"* is an often used document in the selection of coating systems for steel protection.

The standard is a tool that can assist asset owners, operators and contractors in day-to-day work and give guidance on maintenance planning and other (investment) decisions, when it comes to protective coatings. As stated in this document's part 1: *"The type of environmental conditions and the durability of coatings systems are the main parameters for selecting the coating systems. The choice of coating system therefore is an important investment decision."*

Transocean Coatings can assist in using the standard for answering the question - which protective coating system is the right one for my project?

Scope

The focus of ISO 12944 is protection against corrosion. Protection against (damage by) microorganisms (such as marine fouling, etc.), chemicals, mechanical action (abrasion, etc.), and fire are not covered by the standard. Hence, coating the inside of a tank (lining) is not covered by this standard.

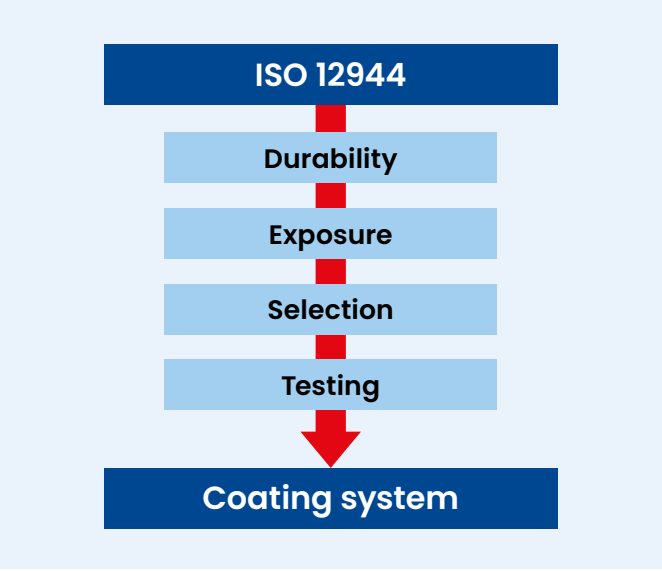
This brochure

In this brochure we summarise the different parts of the ISO 12944 standard but more importantly how to it can assist in the daily operations; from selecting coating systems to other considerations related to getting the best out of a Transocean Coatings protective coating system.

Product highlights of our tried and tested coating systems and a summary of our broad product portfolio show why you can trust the can with the smiling dolphin: it is unique.

The steps in coating selection

The exposure, or environment, where coated steel is used and how corrosive it is, has a major influence on how long a coating system will last: the durability. In the standard, durability dictates coating types and the minimum film thickness. In ISO 12944, four ranges of durability are used as period to first major maintenance: from low (<7 years) to very high (>25 years).



After identifying the exposure and deciding on the required durability, tables guide the user through the selection process for coating types and minimum required thickness per coat.

To back up the expected performance, the standard prescribes laboratory performance testing requirements.

Transocean's products are the building blocks for tested and certified coating systems meeting and surpassing the requirements of ISO 12944.

Environment

Atmospheric

Some locations are more aggressive with regards to corrosion than others. Consider rural or urban vs. coastal and industrial areas. Indoor and outdoor parts of the same steel structure are likely to corrode at a different rate due to more "wet time" and pollution outside. Steel in indoor spaces like a swimming pool or an airconditioned office is exposed different corrosion stress. Table 1 lists the external (6) and internal (5) atmospheric environments ISO 12944-2 describes. The corresponding corrosion pressure is estimated based on annual material loss in case bare steel would be exposed. Table 2 lists the immersion categories (4) in the standard.

Offshore

The off-shore part of the standard, 12944-9, replaces ISO 20340. Here the splash zone is described as a mix of atmospheric (using the CX category) and immersion scenarios linking to specific coating and test specifications.

Very low corrosivity, or is it?

Material loss in corrosivity category C1 is very low, no coating system for this environment is given. If painting is still required for aesthetic, (safety) marking or hygiene (cleanability) reasons, a system intended for corrosivity category C2 (with a low durability) may be used.

Steelwork destined for corrosivity category C1 may be exposed to more aggressive environment during transport, storage or construction stages. To prevent corrosion in these stages, the steel should be appropriately stored or given a suitable (primer) coat for the expected exposure time and corrosion pressure.

Note on C5M / C5I

In previous versions of ISO 12944, the C5 category was split in Marine (C5M) and Industrial (C5I). Therefore, in older documents C5 M may not refer to C5 medium durability. Similarly, C5I should not be mis-read as C5 low durability (C5 L, using the capital letter L instead of lower-case l).

Table 1: *atmospheric exposure categories (ISO 12944-2, ISO 9223)*

Corrosion category	Examples Exterior	Examples Interior
C1 (very low)		Heated buildings in rural areas such as offices, hotels, public buildings.
C2 (low)	Rural areas with low level of pollution.	Unheated buildings where condensation may occur such as warehouses.
C3 (medium)	Urban and industrial areas with moderate sulphur dioxide pollution. Coastal areas with low salinity.	Industrial facilities with high humidity such as food processing industries, breweries.
C4 (high)	Industrial and/or coastal areas with moderate salinity.	Chemical plants, swimming pools, boat yards, ship interiors.
C5 (very high)	Industrial areas prone to high humidity and chemical attack. Coastal areas with high salinity.	Facilities exposed to permanent condensation and chemicals.
CX (extreme)	Offshore areas with high salinity. Industrial areas exposed to extreme humidity, aggressive atmosphere and tropical areas.	Facilities exposed to extreme humidity and aggressive atmosphere.

Table 2: *immersion exposure categories*

Category	Environment	Examples
Im1	Fresh water	River installations, hydro-electrical power plants
Im2	Sea or brackish water	Immersed structures *without* cathodic protection (e.g. harbour areas with structures like sluice gates, locks or jetties)
Im3	Soil	Buried tanks, steel piles, steel pipes
Im4	Sea or brackish water	Immersed structures *with* cathodic protection (e.g. offshore structures)

Note: for corrosivity category Im1 and Im3, cathodic protection can be used with a paint system tested accordingly

Durability

A key consideration in decision making on protective coating systems, is the time that an asset is expected to be protected for. Durability, or the expected life of a protective paint system to the first major maintenance painting is categorised in four ranges:

Durability	Range
low (L)	up to 7 years
medium (M)	7 years to 15 years
high (H)	15 years to 25 years
very high (VH)	more than 25 years

The durability range is not a guarantee (time). As mentioned in ISO 12944: "guarantee time is a consideration that is the legal subject of clauses in the administrative part of the contract. The guarantee time is usually shorter than the durability range. There are no rules that link the two periods of time."

For certain exposure scenarios only high or very high durability is considered in the standard. For instance, part 9 only deals with high durability. For the Im1, Im2 and Im3 immersion scenarios, only high and very high durability class coating systems are proposed in the DFT tables. A lot of this has to do with the inaccessibility of the coated items which makes shorter maintenance intervals impractical and/or un-economical.

What is durability to first major maintenance?

Durability is a technical consideration/planning parameter that can help set up a coating maintenance programme between interested parties (involved in a project) based on for instance "about 10 % of the coatings have reached Ri 3, as defined in ISO 4628-3".

The durability range is not a guarantee (time). As mentioned in the standard "guarantee time is a consideration that is the legal subject of clauses in the administrative part of the contract. The guarantee time is usually shorter than the durability range. There are no rules that link the two periods of time."

Special stresses and scenarios

Mechanical stresses (both in atmosphere, erosion by particles blown by the wind) and in water (debris, ice, growth of algae or barnacles) are not included in the considerations of ISO 12944 and should be looked at separately if they are expected to be part of an exposure scenario.

In a similar way, the standard deals only with (atmospheric) exposure at ambient temperatures. Temperatures 60°C to 150°C and from 150°C to 400°C are described as medium and high respectively. These temperature ranges may require special coating systems not following ISO12944 or requiring dedicated testing.

Corrosion Under Insulation (CUI) is a special scenario for which a different standard was designed for the oil and gas industry which can be applied in other industries as well (ISO 19277-2018): *Qualification testing and acceptance criteria for protective coating systems under insulation.*

Although the standard does not cover all types of structures, surface and surface preparation, it suggests it can also be applied to those cases which are not covered by ISO 12944 if so agreed by interested parties. An example could be the use the use in the shipping industry (marine coatings) to come to standardised coating thickness specifications for certain parts of ships. Similarly, coating systems have been tested in line with the standard to show their suitability to perform on manually pre-treated or hydro-jetted steel.

Additional considerations

Design & specifications

ISO 12944-3 gives information on basic design criteria for improved resistance to corrosion. It gives examples of suitable and unsuitable structure designs. With diagrams, structural elements and combinations of elements are indicated that are likely to cause accessibility problems during surface preparation and coating applying as well as inspection and maintenance work.

Structural parts with differences in access and ease of coating

Prevent dirt or water building up within a structure by re-considering certain types of semi-closed structural members

Corrosion in box members and hollow components that are properly sealed from the external environment will be negligible. It is another design example that may need to be considered for coating if moisture cannot be kept out.

Substrate and surface

ISO 12944 deals with structures made of carbon steel (e.g. in accordance with EN 10025-1 and EN 10025-2) of 3 mm thickness and above, steel to reinforce concrete is not covered.

For pitted steel (rust-grade D) additional considerations are given: the dry film thickness or the number of coats shall be increased to compensate for the increased substrate roughness. Also, the paint manufacturer should be consulted for recommendations. Coatings with pit filling capacity are available, these are generally based on solvent free epoxy technology.

The standard mainly talks about coating bare (carbon)steel but includes references to metallised steel surfaces, thermally sprayed with zinc, aluminium or their alloys, hot-dip-galvanized surfaces etc. Surfaces painted with prefabrication (shop) primer and other painted surfaces (ISO 12944 covers both new work and maintenance) are also reference.

In the off-shore part of the standard, more clarity is given about excluded substrates: stainless steel and other metals such as copper, titanium or aluminium or their alloys, steel cables, pipelines and buried structures (Im3).

Unless otherwise specified, for carbon steel of any rust grade, the minimum surface preparation grade is ISO 8501-1 Sa 2½ (medium roughness). For galvanized steel sweep blasting is the minimum. Other substrate criteria should not be overlooked: removal of water soluble salts, dust, oil, grease, etc.

Execution and supervision of paint work

As many paint failures are related to what happens during surface preparation and application stages, the standard's part 7 deals with this phase. For more information about technical support and quality assurance, please contact your local Transocean Coatings representative.

Other industry standards

There are many corporate or industry standards that refer to ISO 12944 or parts of it. Sometimes additional requirements are added with regards to product or system pre-qualification (for instance impact or abrasion resistance testing).

The Norwegian oil and gas industry's Norsok M501, for example, was mainly known for its off-shore use and the link to ISO 20340. Their 2022 revision 7, refers to nearly every part of ISO 12944 at some point (except for part 8: Development of specifications for new work and maintenance). The International Association of Oil and Gas Producers (IOGP) has had their comments on that standard incorporated: a wider adoption of ISO 12944, directly or indirectly, is observed in multiple industries.

Coating selection

Zinc or no zinc

In most system descriptions in the standard, there is a choice to use a zinc-rich primer (abbreviated to "Zn(R)" primer). The key advantage of a zinc primer is its active corrosion protection that results in longer durability. ISO 12944 allows for lower film thickness when a zinc primer is used, in atmospheric systems the reduction is in the range of 20-60µm. The definition for this type of primer comes down to a minimum of 80% zinc dust pigment, by weight in the dry film. All other primer types, including those with lower amounts of zinc, are considered "miscellaneous" or "other primers".

Coating system and specification

A coating system is the combination of the different products and their individual thicknesses combining to a total film thickness. A specification also includes information about the substrate, surface preparation, overcoating times and other application related details.

More detailed coating selection information can be found in a more extensive guide that can be downloaded from www.transocean-coatings.com.

Scope

The ISO standard covers (liquid) coating products drying or chemically hardening (curing) at ambient conditions. Not covered by ISO 12944 are for products that require heat in their film forming or curing process such as powder coating and stoving enamels.

Single pack and water based options

For a number of coating types water based options are available and mentioned in the standard: Alkyd (single pack) Acrylic (single pack), Epoxy (two pack) and Polyurethane. The list is not intended to be exhaustive and other systems are also acceptable. For instance, water based (zinc-rich) silicates exist.

Innovative technology

Although the paint technology (binder chemistry) is shown in part 5 of the standard, new innovative technologies may be developed and brought to the market. With testing and experience they can also be proven to provide similar corrosion protection (possibly at lower number of coats or DFT).

Tables with system thickness for two component options

Environment/ Durability		Low		Medium		High		Very High	
Type of primer		Zn(R)	Misc	Zn(R)	Misc	Zn(R)	Misc	Zn(R)	Misc
C3	Min. nr. of coats	See note		1	1	2	2	2	2
	Thickness (µm)			60	120	160	180	200	240
C4	Min. nr. of coats	1	1	2	2	2	2	3	2
	Thickness (µm)	60	120	160	180	200	240	260	300
C5	Min. nr. of coats	2	2	2	2	3	2	3	3
	Thickness (µm)	160	180	200	240	260	300	320	360
CX	Min. nr. of coats	Not applicable		Not applicable		3	3	Not applicable	
	Thickness (µm)					280	350		

Note: For C3-low only alkyd/acrylic based systems are proposed in the ISO 12944 standard.

Abbreviated system selection table with ISO 12944 options for C3-C5 atmospheric systems of increasing durability. Systems based on (single component) acrylic and alkyd primers have not been included. dry film thickness goes up with durability requirements and the aggressiveness of the environment. Stepping up a corrosion category and down a durability class generally results in the same DFT requirements, for example: a system for C3-high (C3 H) will be the same as for C4-medium (C4 M). The systems for CX, (the standard only designs for high durability) have additional requirements vs. the C2-C5 systems that are not included here.

Testing

ISO 12944 parts 6 and 9 define laboratory tests to back up the expected durability for coating systems meeting the DFT requirements on the previous page. This accelerated testing is seen as an alternative for long-term field experience and helps new products to find acceptance.

In the tests, different scenarios are created that are known to affect the corrosion speed of (coated) steel. Some tests are relevant for all coating systems in the standard, others only for immersion or off-shore systems. By extending the test duration periods, higher durability classes are mimicked.

After the exposure, the panels are reviewed for corrosion in the coated area and from the scribe through the coating and in combination with adhesion testing before and after the test to classify them as passing the requirements (or not).

Test panels are exposed to (combinations of):

- water condensation
- neutral salt spray
- immersion
- cyclic accelerated weathering: neutral salt spray, freezer, UV-A(340nm) / condensation

Testing compatibility with cathodic protection systems, 4200hrs of cathodic disbonding testing is a specific requirement for Im4 and some of the buried Im3 and CX scenarios. Immersion testing in (salt) water, is a requirement for the Im1, 2 and Im3 systems, 3000hrs for high durability or 4000hrs for very high durability. For Im4 (high only), the test duration is 4200hrs.

Test / Environment	Duration / Durability				
Categories	C2 low/medium, C3 low	C2 high, C3 medium, C4 low	C2 very high, C3 high, C4 medium	C3 very high, C4 high, C5 medium	C4 very high, C5 high
Condensation	48 hours	120 hours	240 hours	480 hours	720 hours
Neutral Salt Spray	-	-	480 hours	720 hours	1440 hours

Cyclic accelerated weathering						
Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**
UV / Condensation cycle – ISO 1674-3 4h UVA 340nm 60°C - 4h condensation at 50°C			Neutral salt spray – ISO 9227 5% NaCl at 35°C			Low temperature -20°C

Environment	Duration
C4VH / C5H *	1680 hours = 70 days
C5VH	2688 hours = 112 days
CX and splash-zone	4200 hours = 175 days

The first table shows the duration of saltspray and condensation tests for C2 to C5 high exposures.
The second table shows the cycle optionally can be used for C4 very high and C5 high (*) and needs to be used for testing for C5 very high and CX / splash zone.
The final table indicates the duration of the cyclic tests.

Product highlights

In the ISO 12944 standard many coating systems are proposed and the possibility to combine different coating technologies makes the number of possible examples too large to show here. Below we show some references with comments on how they link to what is discussed in the standard.

Zinc silicate primers

Inorganic zinc primers Transozinc Silicate 147, Transozinc Silicate 152 and Transozinc Silicate 158 meet the 80% zinc-rich requirement of ISO 12944.

Product	DFT
Transozinc Silicate	TO 1.52
Transpoxy Masterbond	TO 4.67
Transurethane Finish	TO 3.43

At 280µm total DFT this system is in line with C5-H. With a single coat of Finish and DFT of 240µm this would be a C5-M system.

Zinc Epoxy primer

Several Transocean Coatings organic zinc primers like Transozinc Epoxy Primer meet the 80% zinc-rich requirement of ISO 12944.

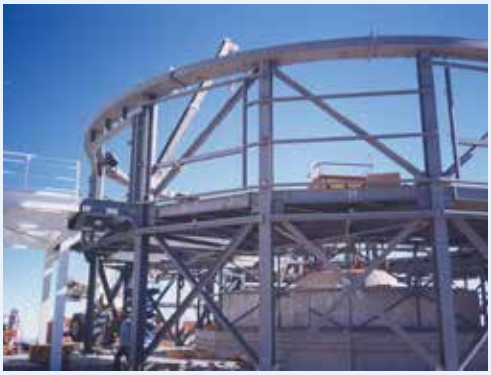
Product	Product nr.
Transozinc Epoxy Primer	TO 1.55
Transpoxy Masterbond	TO 4.67
Transurethane Finish	TO 3.43

Besides use in new construction, zinc epoxy primers are often used as a repair of areas coated with a zinc silicate primer as the first coat. The picture shows the use as a coating repair system for (weld) joint areas. This replacement, of inorganic by organic zinc primers in maintenance, is generally not possible where zinc silicates are used as linings or as part of a high heat resistant system.

Miscellaneous primers

Zinc Phosphate primers, often specified for C2-C4 environments, especially internal/structural steel, do not contain metallic zinc and hence are part of the “Miscellaneous” primers category. The actual salinity and pollution would be the key factor in deciding on the DFT for a C2, C3 or C4 system for the different internal and external parts.

Product	DFT
Transpoxy ZP Primer	TO 1.61
Transpoxy Barrier	TO 2.16
Transothane Finish	TO 3.43



Glass flake

Glass flake reinforced epoxy coatings, as used in this example as second and third coats, are referred to in ISO 12944-5 but not separately specified. These floating structures were inspected after 5 years and required only 2 drums of paint to touch up.

Product	Product nr.
Transpoxy Masterbond	TO 4.67
Transpoxy Glascote	TO 4.40
Transpoxy Glascote	TO 4.40

Water based

Specifying water-based products is only mentioned as a possible option in a footnote for certain categories of products. Both single and two component products are included. ISO 12944 does not have specific set of requirements for these types of products. In this example piping and ducts coated with water based products.

Product	Product nr.
Transaqua Primer 1.36	TO 1.36
Transocean Aquapox 4.50	TO 4.50

Single pack topcoats

For corrosivity exposures up to C4 high, the standard gives coating systems based on single pack alkyd and acrylic products such as used here.

Product	Product nr.
Transogard Primer	TO 1.22
Transunilac Finish	TO 3.31

Poly Siloxane

In a wide variety of projects, from infrastructure to off-shore, the use of very high solid iso-cyanate free siloxane topcoats is becoming more popular.

Product	Product nr.
Transozinc Epoxy Primer	TO 1.55
Transpoxy Mio Sealer	TO 1.65
Transpoxy Mio Sealer	TO 1.65
Transpoxyl PX 370	TO 13.70

Transocean Coatings Product Range

The Transocean Coatings product portfolio comprises a wide range of technologies and product types, designed to be used in all of the environments and uses described in ISO 12944 and more. Note that products are always part of a coating system and hence need to be combined at the right thickness for a specific application.

The tables below show a small selection from our portfolio, please contact your local Transocean company for obtaining more information on our products and for advice on appropriate coating systems.

Zinc Rich primers

Product	Number	Type	Volume solids	Nr. of components
Transozinc Silicate 147	TO 1.47	Zn(R), silicate primer	55%	2
Transozinc Silicate 152	TO 1.52	Zn(R), silicate primer	55%	2
Transocean MC-Zinc	TO 1.60	Zn(R), polyurethane primer	75%	1
Transozinc Epoxy Primer 155	TO 1.55	Zn(R), epoxy primer	50%	2

Miscellaneous / other primers (not Zinc Rich)

Product	Number	Type	Volume solids	Nr. of components
Transpoxy Uniprimer	TO 1.71	Misc., epoxy primer	54%	2
Transozinc Epoxy Primer 179	TO 1.79	Misc., zinc epoxy primer	55%	2
Transpoxy Masterbond Alu 466	TO 4.66	Misc., epoxy primer	78%	2

Primer / Coatings (self-priming)

Product	Number	Type	Volume solids	Nr. of components
Transpoxy Tankguard 118	TO 1.18	Epoxy primer / coating (chemical linings)	68%	2
Transpoxy Barrier FF	TO 2.16FF	Fast curing epoxy primer / coating	68%	2
Transpoxy Barrier 218	TO 2.18	Epoxy primer / coating	80%	2
Transpoxy Glascote DTM	TO 4.40	Glassflake epoxy primer / coating	92%	2
Transpoxy Mastermio	TO 4.46	MIO pigmented epoxy primer / coating	78%	2
Transpoxy Masterbond	TO 4.67	Epoxy primer / coating	84%	2
Transpoxy Masterbond BT	TO 4.68	Epoxy primer / coating (IMO PSPC)	78%	2
Transpoxy HB	TO 4.73	High build, epoxy primer / coating	80%	2

Topcoats

Product	Number	Type	Volume solids	Nr. of components
Transurethane Finish	TO 3.43	Polyurethane topcoat	52%	2
Transurethane Shield	TO 3.45S	High Solid polyurethane topcoat	65%	2
Transothane Finish	TO 3.63	General purpose polyurethane topcoat	50%	2
Transpoxyl PX	TO 3.70	Polysiloxane topcoat	95%	2
Transocean FC Coating	TO 93.80	Fluorcarbon topcoat	50%	2
Transocean NISO Finish	TO 3.60	Epoxy acrylic, iso-cyanate free topcoat	50%	2

Other coating functionality: special stresses and scenarios

As described earlier, certain exposure scenarios and environments are outside of the considerations of ISO 12944, Transocean Coatings offers a wide range of specialty products, from abrasion, chemical and heat resistant products to shop-primers for temporary protection of new steel (plates and profiles). In addition we offer anti-fouling and fouling release coatings to prevent/reduce growth of marine fouling on the immersed parts of ships and off-shore structures.

Chemical Resistant tank and pipe linings

Chemical resistant linings are designed for use in contact with for instance crude oil, jet-fuel and/or other chemicals. Specific certifications exist for some of these exposures. They can also be specified for use for immersion exposure as described in ISO 12944 (Im1, Im2, Im3 or Im4), check with your Transocean Coatings representative which lining is suitable for the specific steel protection scenario you require.

Product	Number	Type	Volume solids	Nr. of components
Transpoxy Tankguard 458	TO 4.58	Polyamine cured phenolic epoxy	68%	2
Transpoxy Deep Tanks	TO 4.62	Polyamine cured epoxy (Jet Fuel)	52%	2
Transpoxy Novacure 488	TO 4.88	Solventless phenolic epoxy	98%	2
Transpoxy Resin system 7900	TO 4.42	Epoxy coating for reinforced laminate	100%	2
Transpoxy Guard 475	TO 4.75	High build epoxy, immersed or buried service	100%	2

Heat resistant (atmospheric coatings)

Product	Number	Type	Volume solids	Nr. of components
Transpoxy Novacure HR	TO 4.82R	Heat & chemical resistant phenolic epoxy	69%	2
Transosil Finish	TO 5.14	Silicone Acrylic (≤250°C)	36%	1
Transosil HR	TO 5.17	Silicone (≤450°C ~ 550°C)	45%	1
Transosil Aluminium	TO 5.15	Silicone (≤600°C)	40%	1

Abrasion resistant

Product	Number	Type	Volume solids	Nr. of components
Transpoxy Masterbond N GF	4.67GF	Glass flake high solids epoxy	82%	2
Transpoxy Novacure GF	4.88GF	Glass flake solventless phenolic epoxy	98%	2
Transpoxy ARC	2.24	Reinforced, polyamine cured epoxy	80%	2
Transocean X-ARC	3.90	Polyurethane/urea hybrid	100%	2

Visit **www.transocean-coatings.com** for more information or contact your Transocean Coatings representative for system advice.

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The smiling dolphin guarantees local service around the world. It's unique!

Since 1959, Transocean Coatings is active in the manufacture and supply of anti-fouling, anti-corrosives and other coatings for commercial ships, pleasure crafts and steel structures onshore as well as offshore.

The Transocean Coatings association has member companies in 20 countries who export to over 70 countries worldwide. With their joint research and development capacity, coordinated from the central office in the Netherlands, Transocean Coatings offers a wide range of products which have been selected and trusted by professionals around the world.

Manufacturing takes place using stringent formulation control. Whether a product is supplied in Europe, Asia, North- or South America, in Africa or Australia, the quality is guaranteed to be identical. At any shore therefore, wherever in the world, you can rely on Transocean Coatings.
Local service assures quick delivery of factory-fresh products at competitive prices.

That's unique!

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