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TECHNICAL EXPERT OPINION

Investigation of the applicability of Resysten durable hygienic protective coating on the internal surfaces of railway vehicles from fire safety point of view

Client :

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This expert opinion consists of 9 numbered pages

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1. Assignment

Following previous verbal consultations, the client commissioned an expert opinion on the subject by e-mail on 02 June 2021. A summary of the work performed in accordance with assigned tasks via phone consultations is included in this document.

1. History

Resysten photocatalytic hygienic coating developed by the Client is a new generation, continuous-acting photocatalytic coating system. The coating system exerts its effect with the help of the energy of light reaching the surface, the substrate is bound to the surface at the molecular level, so it cannot be removed by traditional means. Resysten coating system does not contain biocides and is not covered by Regulation (EU) No 528/2012 concerning the marketing and use of biocidal products.

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Due to its antibacterial effect the coating system is an ideal hygienic coating for all critical surfaces that are used by people, and where the emergence of a plaque-promoting colonization, biofilm layer is possible. Based on its qualities the protective coating is a suitable protective surface treatment method for rail compartments.

The subject of this opinion is the analysis of the fire safety hazard of the finished hygienic protective coating applied to the interior surfaces of railway passenger vehicles , the determination of the applicability limits and the scope of fire safety tests that may be required according to EN 45545-2: 2020 standards [1].

2. The analysis of Resysten ® durable hygienic protective coating system

The coating system is applied to the surface to be treated by spraying. The raw material to be sprayed is a dilute, aqueous suspension which, when applied to the surface, forms a nanometer-sized polymer film after physical and chemical drying. The polymer film encapsulates and adheres the photocatalyst particles suspended in the raw material to the treated surface

1. Raw material to be applied to the surface

. The raw material to be applied to the surface is a dilute, aqueous suspension with the following composition according to the manufacturer's safety data sheet [2] :

name of the ingredient	CAS number	EC / ECHA number	REACH reg. number	concentration
water (solvent / diluent)	7732-18-5	231-791-2	-	> 97.0%
zinc oxide	1314-13-2	215-222-5	01-2119463881-32	0.8%
titanium dioxide	13463-67-7	236-675-5	01-2119489379-17	0.2%
2- [4- (2,4,4-trimethylpentan-2-yl) phenoxy] ethanol (surfactant)	9002-93-1	618-344-0		<0.5%

Table 1 Composition of raw material to be applied

2.2. Dry layer formed on the surface

After physical and chemical drying of the substrate applied by spraying on the surface, a nanometer-sized polymer film is formed on the surface. The carrier for the dry layer is an ethyl methacrylate / methyl acrylate copolymer which encapsulates and adheres the photocatalyst particles suspended in the raw material to the treated surface. According to the results of the laboratory analysis [3], the chemical composition of the dry layer is as follows:

name of the ingredient	CAS number	EC / ECHA number	REACH reg. number	material content [(m / m)%]
Poly (ethyl methacrylate-co-methyl acrylate)	26572-20-3	-	-	48.9%

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zinc oxide	1314-13-2	215-222-5	01-2119463881-32	39.12%
titanium dioxide	13463-67-7	236-675-5	01-2119489379-17	9.78%

Table 2. Chemical composition of the dry layer

2.3. Specific amount of material applied per surface

Based on the information of the Client, the raw material is applied to the surface by spraying. The coverage of the raw material per surface is 17 m^2/ l, ie 58.82 ml / m^2. No measurement data are available for the application efficiency, therefore 100% application efficiency was taken into account as the starting point of the calculation , ie the total amount of material calculated from the application remains on the treated surface after application.

As it cannot be stated from the safety data sheet of the raw material whether the concentration of the raw material was given in weight or y mixed percentage, the calculation of the specific amount of applied material was performed for both cases.

Resysten raw material			
abundance	17 m^2/ l 0.05882 l / m^2		
component	concentration [(m / v)%]	specific weight [mg / l]	specific surface weight [mg / m^2]
water (min)	97%	970	57.0588
water (max. extra)	1.50%	15	0.8824
ZnO	0.80%	8	0.4706
TiO_2	0.20%	2	0.1176
surfactant	0.50%	5	0.2941
Altogether	100.0%	1000	58.8235

Table 3 Specific weight of components applied to the surface based on a mixed percentage concentration

Resysten raw material						
abundance	17 m^2/ l 0.05882 l / m^2					
component	concentration [(m / m)%]	density [kg / m^3]	weight conc. [mg / kg]	component volume inthe mixture [ml / kg]	specific weight mg / l	specific surface weight mg / m^2
water (min)	97%	1000	970	970	978.22	57.5425
water (max. extra)	1.50%	1000	15	15	15.13	0.8888
ZnO	0.80%	5680	8	1,408	8.07	0.4746

TiO_2	0.20%	3900	2	0.513	2.02	0.1186
surfactant ag.	0.50%	1070	5	4,673	5.04	0.2966
Altogether	100.0%		1000	991.59	1008.48	59,3222
resulting density		1008.5				

Table 4 Specific gravity of the components applied to the surface based on concentration by weight

Based on the calculations, there is no significant difference between the two amounts of material calculated at different concentrations. As the amount of substance calculated on the basis of the percentage by weight is - to a negligible extent - bigger this result is used for further calculations.

2.4. Specific amount of material in the dry layer

The amount of material in the dry layer must be calculated on the basis of those components of the raw material which do not undergo any changes during the chemical and physical drying. For Resysten, these are the materials of the photocatalyst. The calculation is based on the assumption that the suspended components in the surface-applied material are evenly distributed and that the total amount of applied material remains on the surface during drying. The weight of the components of the dry layer, based on the composition according to Table 2 , is as follows:

Dry layer						
component	material content [(m / m)%]	ZnO ???calculated from the content [mg / m²]	Based on?? ? TiO_2 content [mg / m²]	density [kg / l]	species volume [l / kg]	theoretical layer thickness [mm]
ZnO	39.12%	0.4746	0.4746	5.68	0.1761	$8.355 \cdot 10^{-7}$
TiO_2	9.78%	0.1186	0.1186	3.9	0.2564	$3.042 \cdot 10^{-7}$
copolymer	48.90%	**0.5932**	**0.5932**	1.06	0.9434	$5,596 \cdot 10^{-6}$
other	2.20%	0.0267	0.0267	1	1	$2,669 \cdot 10^{-7}$
	100.00%	1,2131	1,2131	-	-	$7.003 \cdot 10^{-6}$

Table 5 Specific gravity of the components of the dry layer relative to the surface

3. Fire safety assessment of Resysten® protective coating system

1. Determination of combustible components

Of the materials listed in Tables 2 and 5, zinc oxide [4] [5] and titanium dioxide [6] [7] are non-flammable and non-combustible. Ethyl methacrylate / methyl acrylate copolymer [8]

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is not flammable but combustible and decomposes on exposure to heat. Therefore, in the case of a fire safety test, it is only necessary to test this component.

According to the calculations made in point 2.4, the specific gravity of the combustible material present in the dry layer, in the case of regular application:

$$m \; 593.2 \; \mu g \; m$$

2. Evaluation of the combustible content of the dry layer according to EN 45545-2: 2020 standards

The dry layer is considered to be a coating on the surface of materials / products used in the vehicle. As the coating alone cannot be considered as a listed product, an assessment was made according to the grouping rules to determine the test requirements, given the low weight of the coating.

1. Protective layer applied to "listed" product (s)

If the protective layer is applied directly to a qualified material belonging to the product groups listed in Tables 2 and 3 of EN 45545-2: 2020 standards, it shall be taken into account according to clause 4.3.1 of this standard if its total combustible mass within a vehicle or fire compartment exceeds the value of a m_{max} = 10 grams . Taking into account the amount of material specified in section 3.1, the combustible mass of the coating system exceeds the assessment limit if the treated surface is greater than

$$m \; 10 g$$

$$m \; m \; 593.2 \; \mu g \; 16\,857.1 \; m \; m$$

If the surface treated is smaller than this, a separate analysis of the fire safety and combustion properties of the protective layer is not necessary. In practice, the internal surface of a railway vehicle is two orders of magnitude smaller than the specified value.

2. Protective layer applied to "grouped" products

If the protective layer is not applied directly to a listed material belonging to the product groups listed in Tables 2 and 3 of EN 45545-2: 2020 standards; but to other combustible or not listed materials, the grouping rules according to section 4.3 of the standard shall apply to the products, in which case:

For an exposed surface area $_{exp}$ > 0.2 m ^{2}, the dry layer shall be tested according to EN 45545-2: 2020 requirement group R1 for indoor use and R7 for outdoor use. The summary of most stringent tests belonging to R1 requirement group is in tables 6 and 7

Requirement group R1 according to EN 45545-2: 2020					
Test procedure reference (EN 45545-2: 2020 Table 6)	**parameter and unit of measurement**	**maximum or minimum**	**risk level i**		
			HL1	HL2	HL3
T02 ISO 5658-2	CFE [kWm $^{-2}$]	Minimum	20	20	20
T03.01 ISO 5660-1: 50 kWm $^{-2}$	MARHE [kWm $^{-2}$]	Maximum	-	90	60
T10.01 EN ISO 5659-2: 50 kWm $^{-2}$	Ds (4) [without ME]	Maximum	600	300	150

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T10.02 EN ISO 5659-2: 50 kWm $^{-2}$	VOF4 [min]	Maximum	1 200	600	300
T11.01 EN 17084 Method 1 50 kWm $^{-2}$	CITG [without ME]	Maximum	1.2	0.9	0.75

Table 6 Requirement group R1 and limits of parameters to be tested

Tests belonging to requirement group R1						
investigation	**standard**	**short description**	**parameter**	**ME**	**requirement**	**comment**
T02	ISO 5658-2	lateral flame spread	*CFE*	kWm $^{-2}$	Minimum	*CFE (Critical Flux at Extinguishment)*
T03.01	ISO 5660-1	fire behavior - heat dissipation, smoke generation , mass loss factor - Part 1 specific heat emission (conical calorimeter method)	*MARHE*	kWm $^{-2}$	Maximum	*MARHE (highest average heat emission factor)* Data collection time was 20 minutes with a sampling frequency of 2 s. Heat flow should be 50 kW / m ^{2}. *ARHE* and *MARHE* results must be given in kW/ m ^{2}. (heat output per surface area)
T10.01	EN ISO 5659-2	Plastics - smoke generation, . Part 1: Optical density definition of single chamber examinatio n	Ds (4) l. 3.1.3	without ME	Maximum	Heat flow 50 kW / m ^{2}without ground flame. Test duration 10 minutes. *D* s (4) is the optical density measured in the test chamber after 4 minutes, multiplied by a coefficient depending on the characteristics of the apparatus and the size of the sample.
T10 .02	EN ISO 5659-2	Plastics - smoke generation, Part 1: Optical density definition of single chamber examinatio n	VOF4 l. 3.1.4	minute	Maximum	Heat flow 50 kW / m ^{2}without ground flame. Test duration 10 minutes. VOF4 is the cumulative value of the specific optical density during the first four minutes of the study.
T11.01	EN 17084 Metho d 1	Gas analysis in a smoke chamber according to EN ISO 5659-2 by FTIR procedure	CITG at 4 and 8 minute s	without ME	Maximum	CIT is the standard toxicity index Heat flux 50 kW / m ^{2}without ground flame. Test duration 10 minutes.

Table 7 Description of tests for requirement group R1

For $A_{exp} \leq 0{,}2$ m ^{2} exposed surface area, the grouping procedure shall be followed for the products included in the grouping. Due to the fact that the amount of combustible material belonging to the exposed surface area of the dry layer is several orders of magnitude below the classification limit (m_{max} = 10 g), so the material can be ignored in practice during grouping.

4. Fire safety inspection when using the product

Before using the product, first it must be decided whether the product will be used on a new vehicle, which is not yet type- approved, or on an existing, approved vehicle.

1. Application to a new vehicle

In the case of a new vehicle, if the fire safety test and qualification of the vehicle is performed according to the EN 45545 series of standards, the provisions of subsection 3.2 shall apply to the qualification of the coating system. The data in Table 2 and the mass per unit area (according to section 3.2.1) of the combustible components in the technical data sheet of the raw material and the coating system should be indicated so that the low combustible mass of the coating system can be immediately identified by fire safety experts.

In practice, the fire safety rating of the dry layer is only required separately if the exposed surface of the dry layer exceeds 0.2 m ^{2} and the protective layer is applied to an unlisted product or group of products.

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4.2. Application to an existing vehicle

As a general rule, in the case of the incorporation of combustible materials into existing vehicles, the newly incorporated combustible material (s) shall be assessed according to the standard originally used for the fire safety assessment of the vehicle. The vehicle operator or the organization responsible for maintenance should provide this piece of information If no other data are available, the EN 45545 series of standards shall be taken into account for the assessment.

The data in Table 2 and the mass per unit area of the combustible components (according to section 3.2.1) should be indicated in the technical data sheet of the raw material and the coating system so that the low combustible mass of the coating system can be identified immediately by fire safety experts.

5. Material testing institutes

At the request of the client , some of the test laboratories suitable for carrying out the tests according to 3.2.2 are listed below :

testing laboratories			
name	address	phone	e-mail
Sychta Laboratorium Sp.J.	ul. Ofiar Stutthofu 90 72-010 Police Poland	+48 502078855 +48 914210214	biuro@sychta.eu
DMT GmbH & Co. KG Plant & Product Safety	Tremoniastraße 13, 44137 Dortmund Germany	+49 231 5333-240	aps@dmt-group.com
Warringtonfire Frankfurt GmbH	Industriepark Höchst, Geb. C 369, 65926 Frankfurt am Main Germany	+49 69 943 23075	-

Table 8. Testing laboratories

Table 8 is not exha*ustiv*e, but lists only a few examples with references. Accreditation to perform tests according to the standards listed in Table 7 is in the selection of testing laboratories.

6. Summary

This document summarizes the preliminary fire safety assessment related to the application of Resysten ® hygienic protective coating to the interior surfaces of railway passenger vehicles; the analysis of the fire safety hazard of the applied, hygienic protective coating , the determination of the applicability limits and the scope of fire safety tests that may be required according to EN 45545-2: 2020 [1]. The document also includes an indicative list of accredited laboratories that may be used to test the fire resistance and combustion properties of the finished coating .

The document also contains a proposal to supplement the technical-technological documentation of the product.

7. Resources

1 EN 45545-2: 2020 Railway applications - Fire protection on railway vehicles - Part 2: Requirements for fire behavior of materials and components [Railway applications. Fire protection of railway vehicles, Part 2: Requirements for the combustion properties of materials and components]

2 Resysten ® permanent hygienic protective coating - safety data sheet v1, Resysten Hungary Kft., Biatorbágy, 13 March 2020.

3 Certificate of Conformity, ResYST Dry Composition Chemical Composition, Nanocolltech LLC, Szeged, 18 June 2020.

[4] Zinc Oxide Material Data Sheet , ECHA European Chemicals Agency, https://echa.europa.eu/registration-dossier/-/registered-doss ier / 16139/9 access: 27 June 2021.

5 ICSC 0208, Zinc Oxide, International Chemical Safety Card, Intenational Labor Organizaton, World Health Organization, April 2017

6 Titanium Dioxide Material Data Sheet , ECHA European Chemicals Agency, https://echa.europa. eu / registration-dossier / - / registered-dossier / 15560/4/5 and https://echa.europa.eu/registration-dossier/-/registered-dossier/15560/9 access: 27 June 2021.

7 ICSC 0338, Titanium Dioxide, International Chemical Safety Card, Intenational Labor Organizaton, World Health Organization, November 2019

8 26572-20-3 (POLY (ETHYL METHACRYLATE-COMETHYL) Product Description [poly (ethyl methacrylate-co-methylacrylate) product data sheet] https://www.chemicalbook.com/ChemicalProductProperty_US_CB8504135.asp x , Chemicalbook, 2017 , accessed: June 27, 2021.

9 ELVACITE ® 4072 MSDS [Safety Data Sheet], Lucite International Inc., Cordova TN, USA, 16 November 2010.

8. Limitation of Liability

This document was carried out on behalf of Resysten Hungary Kft. and summarizes the assessment required for the application of the Resysten ® hygienic protective coating system developed and manufactured by Resysten Hungary Kft. on railway vehicles. This expert opinion is based on the data, product descriptions and product test reports provided by the Client , taking into account the applicable European and international standards. Data on individual material properties are derived from database of reliable international professional organizations accessible for public on the internet.

Fundamentally it is the responsibility of the vehicle manufacturer and its maintenance organization to determine the safety conditions of the vehicle; check the fulfillment of the specified conditions of conformity when ordering the production and conversion of vehicles, on receipt of, and during the further operation of the vehicles. Accordingly, the vehicle manufacturer, operator and maintenance organization may, on the basis of their own change management and risk assessment system, diverge from the essential standards in the direction of safety or set additional requirements, which may be sought from the competent body before the product is used.

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END