



Corrosion protection by protective coating

Requirements and application

LINDE STANDARD

LS 148-06

Part 01

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Remarks on the current issue:

Revision: Completely revised.: corrosion protection of SS; surface imperfections; coating delivery status; inspection and testing; measurement of DFT;

Previous issues: 02.2004, 08.2004, 11.2008, 12.2008, 01.2009, 10.2011

Responsible functional unit(s) for the technical content: ENQM

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X	06	10.2011	LEDD/ ENM2/ Pohle	LEHQ/ ENM1/ Schwerdtfeger	LEHQ/ENM1- S/Alekseeva
X	05	01.2009	TME/ Schwerdtfeger	TME/ Rübel	TAW-N/ Alekseeva
Status	Issue	Date	Prepared	Reviewed	Approved

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LS 148-06.T01 (EN)

1 Scope

This Linde Standard (LS) applies to the engineering and construction requirements for passive atmospheric corrosion protection of metallic materials by protective coating.

It describes the surface preparation, application, testing, inspection and documentation of the following components:

- static equipment" e.g. vessels, columns, heat exchangers;
- "rotating equipment" e.g. pumps, compressors, motors, driver systems, machinery equipment;
- piping;
- valves, safety valves;
- tanks;
- structural steel;
- coldboxes;
- control valves, actuators;
- special equipment.

For coating systems LS 148-06 Part 2 applies.

For coldboxes supplied as package units LS 148-06 Part 3 applies.

For TSA (Thermal Spray Aluminium) application LS 148-06 Part 4 applies.

For preservation methods (temporary, transportation, site storage) LS 148-05 applies.

This LS does not cover the coating requirements for

- internal linings,
- concrete coating,
- protection of underground piping/ equipment.
- coating under passive fire protection.

2 Normative references

This LS contains undated references to incorporate provisions of other publications. The normative references are cited at the respective place in the text and the publications are listed below. Issues valid at the effective date of contract shall apply.

ISO 2409	Paints and varnishes - Cross-cut test
ISO 2808	Paints and varnishes - Determination of film thickness
ISO 4618	Paints and varnishes - Terms and definitions
ISO 4624	Paints and varnishes - Pull-off test for adhesion
ISO 8501-1	Preparation of steel substrates before application of paints and related products – Visual assessment of surface cleanliness - Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings
ISO 8501-2	Part 2: Preparation grades of previously coated steel substrates after localized removal of previous coatings
ISO 8501-3	Part 3: Preparation grades of welds, edges and other areas with surface imperfections
ISO 8501-4	Part 4: Initial surface conditions, preparation grades and flush rust grades in connection with water jetting
ISO 8502-3	Preparation of steel substrates before application of paints and related products - Test for assessment of surface cleanliness - Part 3: Assessment of dust on steel surface prepared for painting (pressure-sensitive tape method)
ISO 8502-6	Part 6: Extraction of soluble contaminants for analysis - The Bresle method
ISO 8502-9	Preparation of steel substrates before application of paints and related products - Tests for the assessment of surface cleanliness - Field method for the conductometric determination of water-soluble salts
ISO 8503-1	Preparation of steel substrates before application of paints and related products - Surface roughness characteristics of blast-cleaned steel substrates - Part 1: Specifications and definitions for ISO surface profile comparators for the assessment of abrasive blast cleaned surfaces

ISO 8503-4	Method for the calibration of ISO surface profile comparators and for the determination of surface profile - Stylus instrument procedure
ISO 11124	Preparation of steel substrates before application of paints and related products - Specifications for metallic blast-cleaning abrasives
ISO 11126	Preparation of steel substrates before application of paints and related products - Specifications for non-metallic blast-cleaning abrasives
ISO 11127	Preparation of steel substrates before application of paints and related products – Test methods for non-metallic blast-cleaning abrasives
ISO 12944	Paints and varnishes - Corrosion protection of steel structures by protective paint systems
ISO 16276-1	Corrosion protection of steel structure by protective paint systems - Assessment of, and acceptance criteria for, the adhesion / cohesion (fracture strength) of a coating – Part 1: Pull off testing
ISO 16276-2	Part 2: Cross cut testing and X cut testing
ISO 19277	Petroleum, petrochemical and natural gas industries - Qualification testing and acceptance criteria for protective coating systems under insulation
ISO 19840	Paints and varnishes - Corrosion protection of steel structures by protective paint systems - Measurement of, and acceptance criteria for the thickness of dry films on rough surfaces
ASTM D 4285	Standard test method for indicating oil or water in compressed air
SSPC-PA 1	Paint application specification No.1 - Shop, field and maintenance painting
SSPC-SP 1	Solvent cleaning
SSPC-SP 16	Brush-off blast cleaning of coated and uncoated galvanised steel, stainless steels, and non-ferrous metals
SSPC-SP-WJ-1	Waterjet cleaning of metals - Clean to bare substrate
SSPC-SP-WJ-2	Waterjet cleaning of metals - Very thorough cleaning
SSPC-SP-WJ-3	Waterjet cleaning of metals - Thorough cleaning
SSPC-SP-WJ-4	Waterjet cleaning of metals - Light cleaning
NACE SP 0508	Methods of validating equivalence to ISO 8502-09 on measurement of the levels of soluble salts
NACE SP 0198	Control of corrosion under thermal insulation and fireproofing materials - A systems approach
LS 148-06 Part 02	Corrosion protection by protective coating - Paint systems
LS 148-06 Part 03	Corrosion protection by protective coating - Package units - Coldboxes
LS 148-06 Part 04	Thermal spray aluminium

The following shall be observed in addition:

- national safety regulations valid for the site location,
- safety- and technical data sheets (SDS/ TDS) of PAINT MANUFACTURER.

The sequence of the technical validation shall be as follows:

- national laws, regulations and standards,
- this LS 148-06,
- ISO 12944.

3 Terms, abbreviations and definitions

COMPANY	LINDE Aktiengesellschaft, Engineering Division and its subsidiaries
CLIENT	Potential client of COMPANY
MANUFACTURER	Manufacturer of coated or to be coated components, equipment, piping and structural steel
CONTRACTOR	Company performing corrosion protection work
PAINT MANUFACTURER	Manufacturer of coating systems
PFP MANUFACTURER	Manufacturer of PFP systems
Primer	Single prime coat or primer system consisting of shop-primer + single prime coat
shall	...indicates a mandatory requirement
1C	1 – component
2C	2 – component
ATEX	Atmosphère Explosible
C4/ C5	Corrosivity category in accordance with ISO 12944-2
CB	Coldbox
CCS	Coating concept specification (COMPANY Doc. No.: &AX-T-SS 2360)
CS	Unalloyed or low-alloyed carbon steel
CUI	Corrosion under insulation / PFP
DIN CERTCO	DIN tested and certified surface treatment inspector
DFT	Dry film thickness
EP	Epoxy resin (2C)
EP-MIO	Epoxy resin with micaceous iron oxide pigments
EPP	Epoxy phenolic-Novolac
FROSIO	The Norwegian professional council for education and certification of inspectors for surface treatment
HDG	Hot dip galvanized
IMM	Inert multipolymeric matrix or inorganic copolymer
IOZ	Inorganic ethyl zinc silicate
ISO	International standards organization
NACE	National association of corrosion engineers
NDFT	Nominal dry film thickness
OT	Operating temperature
PFP	Passive fire protection
PMa	Surface preparation grade (localized machine abrading) acc. to ISO 12944-4/ ISO 8501-1
PSa	Surface preparation grade (localized blast cleaning) acc. to ISO 12944-4/ ISO 8501-1
PUR	Polyurethane aliphatic
Rz	Roughness
Sa...	Surface preparation grade (blast cleaning) acc. to ISO 12944-4/ISO 8501-1

SDS	Safety data sheet
SS	Austenitic stainless steel (any type)
SSPC	The society for protective coatings (former: steel structures painting council)
tbd	To be defined
TDS	Technical data sheet
TSA	Thermal spray aluminium
WFT	Wet film thickness
Zn(R)	Zinc-rich

4 General

4.1 Basic requirements

For purposes not specified in this LS, ISO 12944 shall apply.

Steam-out service shall be recognized as operating condition.

All coating products shall be free from lead and chromium.

PUR coatings shall be aliphatic born. Aromatic PUR coatings shall not be used.

All coating products used for a specified coating system shall be made by the same PAINT MANUFACTURER. If this is not possible, tests for compatibility shall be performed prior to application.

The readability of all markings on piping and other items (e. g. material and piping identification, TAG No.) shall be guaranteed after final coating.

Coated tracing pipes and bundle tubes of tracing systems shall not be bent after coating.

Coated parts shall not be transported until the coating system is completely cured. An exception is inevitable for turning of single parts during the coating process or piling while drying at a suitable location. For any transportation and for installation of coated parts appropriate gear shall be used.

Flanges (except gasket sealing surfaces) including bolt holes shall be surface treated and coated in the same way as adjacent components.

Coating system selection for uninsulated parts protruding insulation shall be as follows:

- for pipe supports, vessel skirts and legs: coating system OT < 120 °C (as used for structural steel)
- for vessel brackets and saddles: coating system used for vessel

Items designated to be insulated for personnel protection with guards shall be coated identical to uninsulated items.

For equipment and items made from CS and SS, the coating system specified for SS shall be used on the entire surface. It is mandatory, that zinc containing coating materials shall not be applied to any stainless-steel substrates.

DFT of items specified with ATEX requirements or within an ATEX area shall be max. 200 µm. The DFT of corrosion protection layers shall be specified on a case by case basis by the responsible department of COMPANY.

All requirements specified in the TDS and SDS of PAINT MANUFACTURER shall be fulfilled.

All deviations from this LS require written approval of COMPANY.

4.2 Corrosion protection under PFP

For components to be fire protected by a spray-on PFP-system, only prime-coat systems explicitly approved by the PAINT MANUFACTURER / PFP MANUFACTURER and listed in a so called "Approved Primer List" shall be applied. The SDS, the TDS as well as the application manual of the PAINT MANUFACTURER / PFP MANUFACTURER shall be strictly adhered to.

4.3 Determination of corrosivity category

The environmental classification acc. to ISO 12944-2 shall be selected and defined according to the project-specific coating concept specification (CCS).¹

¹ Linde document &AX-T-SS 2360 "Coating concept specification"

4.4 Corrosion protection of CS

CS items shall be painted in general.

The zinc content of Zn(R)-primer shall be:


- > 80 % by weight for IOZ-primer
- > 65 % by weight for EP-zinc primer

4.5 Corrosion protection of SS

Table 1: Coating requirement of SS

chloride containing environment	not insulated	not insulated
	insulated	insulated
chloride free environment	not insulated	not insulated
	insulated	insulated***

-10** 60 200* OT [°C]

 ⇒ Protective coating required!

* for intermittent service 540 °C

** if OT < -10 °C, steam-out service shall not be considered

*** if OT > 60 °C **and** insulated with electrical tracing:
 - for piping: Al-foil wrapping (pure Al-foil, thickness 0.1 mm)
 - for equipment: protective coating

4.6 Corrosion protection of other metallic materials

For corrosion protection of other metallic materials not included in chapter 4.3 and 4.4 an individual assessment is required and shall be provided by COMPANY.

4.7 Coating procedure

CONTRACTOR / MANUFACTURER shall submit a detailed written coating procedure for surface preparation and coating application for COMPANY review and approval prior to start of work. Acceptable coating procedures shall demonstrate compliance with this LS and the PAINT MANUFACTURER's application instructions.

Acceptable procedures shall show minimum but not limited to the following:

- storage of coating products and thinners;
- the method of surface preparation and the degree of cleanliness and profile of the surface to be prepared;
- the type of abrasive to be used;
- identity of all coating materials, thinners and cleaners by PAINT MANUFACTURER and product;
- coating application sequence;
- NDFT of each coat;
- application equipment and method intended to use;
- environmental restrictions to be observed during surface preparation, coating application and curing;
- methods and equipment to provide ventilation during application and curing;
- inspection activities, methods and equipment (refer to chapter 8.2);
- touch-up and repair procedures;

- latest TDS, SDS and application instructions of PAINT MANUFACTURER / PFP MANUFACTURER for all products included in the procedure;
- daily inspection records/ logbook and verification forms.

5 Corrosion under insulation (CUI)

To avoid corrosion under insulation, the COMPANY standard approach is to apply protective coating systems under insulation materials and watertight insulation-cladding. Protective coating systems are given in LS 148-06 Part 02, the requirements for insulation are given in LS 151 - series.

Coating materials to be applied for CUI reasons shall be tested and approved acc. to ISO 19277.

In special cases with very high corrosion protection requirements, thermal spray aluminium (TSA) according to LS 148-06 Part 04 can be provided as an option.

6 Application

6.1 Surface preparation

6.1.1 General

Surfaces shall be checked for any contamination. This applies in particular to oil, grease, wax, salts of any kind, sulphates and dirt as well as dust residues and condensate.

Contamination on surfaces shall be removed or rinsed off prior to blast-cleaning e.g. sweet-water washing with min. temperature of 50 °C, water jetting acc.to SSPC-SP-WJ 1-4, washing with surface-active agents or solvent cleaning acc. to SSPC-SP 1.

If the functionality of parts like shafts, stems of valves, sealing surfaces of flanges as well as machines, motors and other components might be affected by blast-cleaning, these parts shall not be blast cleaned. If blast-cleaning work on site will be carried out adjacent to machines, motors, valves, level indicators, measuring and control devices or similar sensitive equipment, these components shall be properly shielded against the penetration of abrasive material and abrasive dust.

After blast-cleaning the adjacent areas shall be cleaned immediately from any abrasive-material or abrasive dust etc.

Compressed air shall be free from oil and any moisture and shall be tested by the "air-compressor-blotter-test" as per ASTM D4285 prior to use in every shift.

Blast-cleaned surfaces shall be free from contaminations such as dust, abrasive material, mill scale or welding spatters etc. according to Table 3. Dust contamination test shall be carried out on the blast cleaned surface according to ISO 8502-3. Dust contamination shall not exceed dust size class 1 or 2.

All bolt holes shall be at least cleaned by solvent before coating.

6.1.2 Salt content

The salt content of surfaces to be coated shall be tested acc. to ISO 8502-6 and ISO 8502-9. The values of max. total salt content acc. to Table 2 shall be observed and not exceeded. The test shall be conducted prior to and after blast cleaning.

Table 2: Max. total salt content for no or low risk

Corrosivity Category ¹⁾	C4		C5		CX		Im1-Im3	
Durability ²⁾	H	VH	H	VH	H	VH	H	VH
Total Salt Content [mg/m ²]	80	60	60	50	20	tbd	20	20
Conductivity ³⁾ [μS/cm]	67	50	50	42	17	tbd	17	17
¹⁾ acc.to ISO 12944-2 ²⁾ acc. to ISO 12944-1 ³⁾ based on an area of 12.5 cm ² and a volume of 3 ml (Bresle test)								

For internal linings and surfaces with permanent water contact the max. total salt content shall not exceed 20 mg/ m² (see Table 2; Im1 – Im3).

The values mentioned in Table 2 shall be observed. In case the TDS of the PAINT MANUFACTURER requires lower values, the values of the TDS shall be observed.

6.1.3 Surface imperfections

In general, all sharp edges on substrates shall be bevelled/smoothened and be free of burrs and fins. Welding joints shall be prepared free of coarse roughness, undercuts, pores, weld puddles or spatters. Table 3 shows in detail the minimum requirements for acceptable imperfections on substrates to be coated.

Table 3: Preparation requirements for surface imperfections

Sketch	Characteristic	Requirement
	Rolled steel profile edges	Edges shall be free of fins/ burrs.
	Thermally cut edges	Cut surfaces shall be removed by grinding and edges shall be bevelled and be free of fins/ burrs.
	Rolled edges	Edges shall be smoothened and be free of fins/ burrs.
	Edges arisen by drilling, punching, sawing, shearing	Sharp edges shall be removed, bevelled and be free of fins/ burrs
	Welding spatter	Loose and lightly adhered welding spatters shall be removed. Spatters as shown on the leftmost may remain
	Welding slag	Welding slag shall be removed completely
	Welding pores	Pores at the welding seam shall be sufficiently opened to allow penetration of protective coating or be grinded off
	Undercuts	Sharp and deep undercuts shall be chamfered.
	End craters	Sharp edges from end craters shall be removed
	Welding profile/ ripple	Sharp edged and irregular profiles shall be removed and smoothed/ dressed
	Slivers	Substrate shall be free from visible slivers
	Rolled-in foreign particles	Substrate shall be free from foreign particles
	Craters and pits	Craters and pits shall be sufficiently opened to allow penetration of protective coating. Craters and pits deeper than the corrosion allowance shall be closed by welding
	Rolling defects, roll-overs, roll laminations	Substrate shall be free from visible rolling defects
	Roll marks and indentations	Indentations and roll marks shall be bevelled and smoothened
	Gouges and grooves borne by mechanical work	The radius of gouges and grooves shall be minimum 2 mm

6.1.4 Surface preparation of CS

In general, only CS-substrates of rust grade A, B, or C acc. to ISO 8501-1 shall be used.

Components made from CS shall be blast-cleaned to achieve a surface preparation grade of Sa 2½ as per ISO 8501. For immersion service (Im1 – Im3) and internal linings the surface shall be prepared to grade Sa 3. The roughness R_{y5} of blast-cleaned surfaces shall be 40 - 65 µm or higher if required acc. to TDS of PAINT MANUFACTURER. However, roughness R_{y5} shall be less than the primer DFT. The blast-cleaned surfaces shall comply with profile grade "medium" (G) according to ISO 8503-1.

Only grit according to ISO 11124 (metallic blast-cleaning abrasives) and ISO 11126 (non-metallic blast-cleaning abrasives) is permitted as blast-cleaning abrasive. Due to the risk of silicosis the use of quartz sand is not permitted.

Abrasives shall be free from oil, grease, moisture, salt contamination etc. The salt contamination tested acc. to ISO 11127-1 and -6 shall not exceed 25 mS/m.

Prime coat shall be applied to the appropriate prepared surfaces immediately after completion of the surface preparation and before occurrence of any trace of corrosion. The acceptable duration between blasting and primer application depends on the climatic conditions and shall be defined by the CONTRACTOR.

For surface preparation of small areas a "rotary wire rebound method" (Bristle Blaster®) or equivalent techniques achieving an appropriate roughness shall be used.

6.1.5 Surface preparation of hot-dip galvanized surfaces

HDG components shall be sweep blast-cleaned (SSPC-SP 16) prior to coating. Alternatives such as water jetting or blast-cleaning methods require written approval of COMPANY prior to execution.

Suitable mineral blast cleaning abrasives free of ferrite and chromium shall be used at low pressure. The roughness R_{y5} shall be 40µm + 10 % or higher if required as per TDS of PAINT MANUFACTURER.

"White rust" shall be fully removed.

6.1.6 Surface preparation of SS

Surfaces of SS shall be roughened by sweep blast-cleaning. For this purpose, only square-edged, ferrite-free abrasive agents as per ISO 11126 are permitted. Alternative abrasive agents and methods (e.g. glass-peas) require written approval of COMPANY. The roughness R_{y5} shall be 40µm + 10 % or higher if required as per TDS of PAINT MANUFACTURER.

6.2 Application of coating

Coating materials shall be applied by brushing, rolling with short pile lamb's wool roller or airless-spraying.

Prime coats shall be applied by brushing or airless-spraying. Rolling is not permitted.

Application of intermediate and top coats by rolling is only permitted, when the coating material is suitable for this kind of application acc. to the TDS of the PAINT MANUFACTURER.

For hot-dip galvanized and SS surfaces the top coat may be applied by roller.

In order to obtain the specified coverage and thickness, a stripe coating shall be applied by brush on all edges, corners, welds, bolt holes and behind angles and edges of beams or other components. All areas not fully reachable by spraying shall be stripe coated by brush as well.

If Zn(R)-coating is used as prime-coat, stripe coating shall be applied on primer with the intermediate coating material.

In general, the requirements given in SSPC-PA1 shall be observed.

Requirements as per TDS of PAINT MANUFACTURER for storage, mixing of coating material, induction time, pot life, overcoating intervals, drying times etc. shall be strictly adhered to.

6.3 Coating of components acc. to MANUFACTURER's Standard

Due to justified exceptions, components like actuators, gear boxes, machines, electrical motors, etc. as well as items listed in table 4 under "Manufacturer Standard" may be coated acc. to MANUFACTURER's standard if the following minimum requirements are fulfilled:

- Providing of an application procedure with a detailed description of the coating system/products intended to use incl. TDS and SDS for review and approval by COMPANY prior to application;
- Surface preparation shall be minimum grade Sa 2½;
- Coating system shall consist of two layers (prime and top coat) minimum;
- Coating system shall be suitable for corrosivity category and durability defined for the project acc. to ISO 12944-1 and -2;
- Colour code shall be acc. to Table 6 or Table 7 (depending on the kind of project),
- Temperature resistance of the coating system shall be suitable for the OT of the item shall be coated,
- QA/QC – requirements according to Para. 8:

6.4 Coating of components on site

6.4.1 Inspection of MANUFACTURER standard coating (material receiving inspection)

Components delivered to site with MANUFACTURER's standard coating shall be subject to a material receiving inspection on site. The obtained results shall be documented in the Acceptance Sheet "Corrosion protection - Components- Material receiving inspection" (attached in Annex A, LS 148-06 Part 01 Form 02). If MANUFACTURER-Standard - coating does not offer a stable substrate for further coats it shall be removed completely, and the components concerned shall be coated with a new suitable prime coat.

6.4.2 Coating at site prefabrication (piping)

External surfaces of pipes, spools and fittings shall be blast-cleaned and prime-coated at the blast/coating shop prior to installation.

After blast-cleaning but before applying any coats, pipe ends shall be masked off over a length of 50 mm. Piping shall be blown out accurately before it is hauled-off from the coating shop and ends shall be closed up acc. to project specific requirements. Pipe ends are subject to heat treatment and shall remain uncoated over a length of 200 mm.

6.4.3 Coating at construction area (piping)

After completion of installation but prior to any further coating the previously applied coating shall be inspected. Required cleaning and repair work shall be defined and accomplished. After that the coating work shall proceed according to the specified coating system.

If damages are detected on the previous coating, a complete reconstitution of all coats at the damaged areas is required. The surface to be repaired shall be prepared according to the requirements of the coating system.

For repair work only the already applied brand shall be used. If this shouldn't be possible, the use of an equivalent coating product or a compatible tie coat requires a test application to ensure the compatibility of the products as well as a written approval of COMPANY prior to final application.

6.4.4 On site welded components (tanks, reformer, cracker, coldboxes ...)

After installation and welding of components delivered with a prime coat, a partial blast cleaning respectively mechanical grinding and roughing of the welding seams and welding bevels is required.

Surface preparation grade shall be PSa 2½ respectively PMA. In case of PMA, a surface roughening with grit size 60-80 is required prior to the application of the coating.

After installation of components delivered with a shop primer (welding primer) and welded on site, the welding joints and installation damages shall be blast cleaned prior to any further coat application.

6.4.5 Structural steel

On stairs, catwalks or platforms all coatings on top flanges of the beams of structural steel shall have been applied and fully cured prior to installation of gratings.

After installation of primed bolted steel structures, the joints at the flanged connections shall be filled and sealed using a 1C permanent elastic acryl resin joint filler. Silicone based sealants are not permitted.

Welded steel structures shall be treated according to the coating requirements of the coating system specified.

6.4.6 Repair of hot dip galvanizing

Damages on hot dip galvanized surfaces shall receive a surface preparation acc. to PSa 2½. If blasting is not an option, surface preparation may be performed acc. to PMA after written approval of COMPANY only.

After surface preparation the repair areas shall be coated with a 2C EP Zinc coating or a 1C PUR Zinc coating. The top coat shall be 2C PUR coating in a shade like the galvanized finish. Zinc sprays or other coating materials are not permitted.

7 Coating delivery status

Table 4 specifies the scope of coating that shall be applied by the MANUFACTURER prior to delivery to site or module yard. Items delivered to site/module yard without a complete coating system shall receive the final coating on site/module yard.

Table 4: Coating delivery status

	N/A	Uncoated	Shop primer	Primer	Primer + intermediate coat	Primer + intermediate + top coat	Manufacturer standard	Hot dip galvanized
Structural steel						X		
Grating, stair treads, ladders, cages, handrails, guard rails, kick plates, platforms								X
Structural steel to be passive fire protected				X ¹⁾				
Piping (bulk material)		X						
Pipe supports						X		
Special pipe supports						X		
Underground piping (PE-coated)	X							
Bulk valves (as per pipe class) including strainers, steam traps and nozzle check valves ...				X ²⁾				
Actuators, gearboxes, electrical motors, etc.							X	
Control valves, tagged valves						X		
Vessel / Column						X		
Coldbox inside			X					
Coldbox outside (stick built CB)					X			
Heat exchanger						X		
Air cooler						X		
Filter						X		
Silencer						X		
Compressor						X		
Pump						X		
Modules/ package units incl. corresponding steel structure/ CB see LS 148-06 part 3						X		
Electrical items							X	
Instrumentation items							X	
¹⁾ only primer approved by PFP MANUFACTURER ²⁾ - For CS-valves and similar prime-coated items: IOZ as per LS 148-06 part 2 shall be applied. - For SS-valves and similar items: no coating shall be applied at vendor.								

8 Quality assurance, testing, final inspection and documentation

8.1 Quality assurance / quality control (QA/QC)

CONTRACTOR shall include in its proposal a short description of its QA/QC procedures for protective coating.

CONTRACTOR shall use suitable, certified and calibrated testing devices for quality control of the surface preparation and coating.

Quality control shall be done by experienced and qualified personnel (min. level – 2/B of NACE, FROSIO, DIN-CERTCO or equivalent). Justified exceptions shall be audited and approved by COMPANY's department for corrosion protection.

Coating application shall be in accordance with the principles of good workmanship practise described in SSPC-PA 1.

COMPANY reserves the right to perform inspections at any time.

Inspection and certification according to acceptance sheet "Corrosion protection by manufacturer" (acc. to LS 148 Part 01 Form 01) shall be performed prior to shipment of coated items.

8.2 Testing

8.2.1 Execution of tests

Testing by destructive test methods to determine the quality of the coating systems applied on items shall be carried out on test plates² (appr. 150 x 150 x 4 mm) coated identically and simultaneously³ together with the item itself.

Due to HSE-reasons testing of IOZ-coatings by MEK-test shall be executed in justified exceptions only.

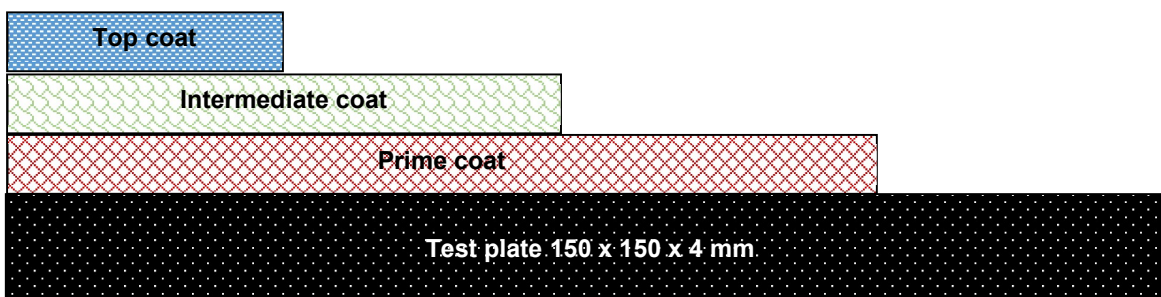


Figure 1: Principle sketch of test plate containing each coating layer incl. blast cleaned substrate.

² Possibly made from the same material of the original item to be coated.

³ „simultaneously“ means the test plates shall be coated under exact the same application conditions as the item itself (same surface preparation, same time and the same location), so as if they would be a part of the item to be coated!

Table 5: Inspection and testing during coating work execution

Test definition	Method	Extent/ frequency	Acceptance criteria	Consequence if not passed acc. criteria
Environmental conditions	ISO 8502-4	Prior to start of each shift/ and twice a day	Rel. humidity $\leq 85\%$; amb. temp. $\geq 3^\circ$ above dew point; substrate and amb. temp betw. $10 - 40^\circ\text{C}$	No blasting, No coating
Pre-cleaning	SSPC-SP 1	100% of surface	Free of oil, grease and other contaminants	Recleaning until acceptable
Water soluble salts	Brestle-test acc. to ISO 8502-6 or NACE SP 05 08	Bulk valves (irrespect. of size): 1 test/every 50 items; equipment (vessel, heat-exch., compressors, etc.): 1 test/ item and every further 100 m ² surface to be coated	See Table 2	Recleaning until acceptable
Examination of substrate	Visual ISO 8501-3	100% of surface	See Table 3	Repair and retesting
Abrasive blast cleaning	SSPC-VIS 1 ISO 8501-1 ISO 8501-2 ISO 8503-4	100% of surface	See Para. 6.1.4 -6.1.6: CS: min. Sa 21/2	Re-blasting until acceptable
Roughness	NACE RP 02 87 ISO 8503-1	100% of surface min.1 test/ 100 m ²	As required by coating system acc. to TDS or CS: $R_z 40 - 65\ \mu\text{m}$ SS: $R_z 40 \pm 10\% \mu\text{m}$ HDG: $R_z 40 \pm 10\% \mu\text{m}$	re-blasting until acceptable
Dust test	ISO 8502-3	100% of surface min.1 test/ 100 m ²	Dust size class 1 or 2	Recleaning until acceptable
WFT	Comp gauge ASTM D 4144	100% of surface min.1 test/ 100 m ²	As per TDS of PAINT MANUFACTURER	Removal
DFT	ISO 19840	100% of surface Frequency as per ISO 19840 Para. 6.1	LS 148-06 part 2 (max. DFT)	Repair, additional coating or recoating as appropriate
DFT (HDG items)	ISO 2808	100% of surface Frequency as per ISO 1461	As per ISO 1461	Rejection/ renewal
Final examination of coating	Visual	100% of surface	Evenness; no sagging, cracking, blistering, rust, mech. damages, or any other defects; colour code	Repair, additional coating or recoating as appropriate
Adhesion (at test plates only!)	Pull-off test: ISO 4624/ ISO 16276-1 Cross cut test: ISO 16276-2 ISO 2409	Bulk valves (irrespective of size): 1 test/every 50 items; equipment (vessel, heat-exch., compressors, etc.): 1 test/ item and every further 100 m ² surface to be coated	IOZ, EP, PUR-systems: $> 5\ \text{MPa}$ IMM-systems: $> 2\ \text{MPa}$ Classification 0 or 1	Rejection/ renewal

8.2.2 Measurement of dry film thickness

For measurement of DFT, ISO 19840 shall apply.

Only measurement devices working on magnetic inductive or eddy current techniques acc. to ISO 19840 shall be used.

Any single measurement⁴ of DFT shall be not less than 80% of NDFT. The average value of all single-readings shall not be less than the specified NDFT. The number of readings in the range of 80-100% of the NDFT shall not exceed 20%.

To consider the variations of the surface profile (as per ISO 8503-1) a correction value shall be subtracted from the DFT. Unless otherwise specified (e.g. due to possibly required determination of correction value), the correction value shall be 25 µm (= "medium" acc. to ISO 19840) independent of the number of coating layers.

The DFT of IOZ-coatings shall not exceed 75 µm⁵ (or max. DFT specified by the PAINT MANUFACTURER) due to a possible lack of cohesive strength.

The DFT of PUR top-coats shall not exceed 100 µm.

8.3 Reference areas

COMPANY recommends the preparation of reference areas in coordination with PAINT MANUFACTURER.

In this case all applications shall be documented, and the records shall be submitted to COMPANY. Reference areas shall be prepared in areas allowing access without need for lifting platforms, scaffolding, ladders or other auxiliary equipment.

COMPANY reserves the right to perform spot checks at any time.

8.4 Final inspection and documentation

CONTRACTOR shall maintain a complete construction logbook with regular (daily) entries from the start of work and during the whole duration of surface preparation and coating activities. The logbook, records and plans shall be submitted to COMPANY unrequested, regularly (weekly) and as part of the documentation.

The following data shall be recorded at least:

- consecutive page numbering,
- date,
- items worked on,
- surface preparation,
- surface roughness,
- execution time and duration of all single work steps,
- air- and object/ substrate temperature,
- relative air humidity,
- coating material details,
- tests performed incl. results,
- names of staff carrying out the work,
- progress (daily and cumulated).

After completion of coating activities, a final inspection together with COMPANY shall take place in accordance with acceptance sheet "Corrosion protection – final acceptance on site" (Form 3). COMPANY shall be invited to the final inspection min. 1 week in advance.

All acceptance sheets (LS 148-06 Part 1 Forms 01-03) shall be included in the final documentation.

9 Colour coding

Each layer of coating shall be applied in a different colour. Prior to coating work those colours shall be submitted to COMPANY to show the planned layer structure.

⁴ Single measurement = the arithmetic mean of 3 single readings within a circle area of 40 mm.

⁵ Thickness indication reduced by correction value.

The colour-codes of top coats shall be according to Table 6.

In air separation plants the top coats shall be applied in the colour-codes shown in Table 7.

Table 6: Colour-code of top coats for industrial plants

Item/ equipment	RAL-No.	Colour
Piping and equipment OT $\leq 120^{\circ}\text{C}$	7001	silver grey
Piping and equipment OT $> 120^{\circ}\text{C}$	9007	grey aluminium
Pumps and motors	5010 or manufacturer's standard	gentian blue
Turbines	6019 or manufacturer's standard	pastel green
Compressors OT $\leq 120^{\circ}\text{C}$	6019 or manufacturer's standard	pastel green
Compressors OT $> 120^{\circ}\text{C}$	9007 or manufacturer's standard	grey aluminium
Furnaces / boilers	9007	grey aluminium
Structural steel	6011	reseda green
Pipe supports	a) like associated piping b) parts sticking out of the insulation: like structural steel	
Air-cooled heat exchangers	9007 or manufacturer's standard	grey aluminium
Screwed plate-fin heat exchangers	5010 or manufacturer's standard	gentian blue
Steel tanks (not insulated), shell of coldbox	9016	traffic white


Table 7: Colour-code of top coat for air separation plants

Item/ equipment	RAL-No.	Colour
Casing of air compressor and piping	3000	flame red
Casing of oxygen compressor	5012	light blue
Oxygen piping	5012	light blue
Refrigeration plant except drivers	5012	light blue
Argon piping	6010	grass green
Water piping	7000	squirrel grey
Steam piping	1011	brown beige
Oil piping and oil tanks	8001	ochre brown
Acetylene piping	1004	golden yellow
Hydrogen piping, normal	2001	red orange
Casing of nitrogen compressor	1018	zinc yellow
Nitrogen piping	1018	zinc yellow
Safety piping	8011	nut brown
Crane	2000	yellow orange
Electrical drives $\geq 1 \text{ kV}$	2000	yellow orange
Krypton, xenon, helium piping	6011	reseda green
Equipment / tank farm, shell of coldbox	9016	traffic white
Electric-motors, low voltage, distributors, instrument boards	7032	pebble grey
Steel structures, ladders, stairs, railings, supports, handrails, etc.	9016	traffic white
Hand wheels of valves	9005	jet black
Character/ Logo "LINDE"	5017	traffic blue

Annex A (informative) – Acceptance sheets

Table 8: Overview of acceptance sheets

Form	Title	Issue
Form 01	Corrosion protection by manufacturer	03 / 01.2020
Form 02	Corrosion protection - Components - Material receiving inspection	03 / 01.2020
Form 03	Corrosion protection - Final acceptance on site	02 / 01.2020

	Acceptance sheet	LINDE STANDARD
	Corrosion protection by MANUFACTURER	LS 148-06 Part 01 Form 01

Issue 03/01.2020

Page 1 of 1

Project No.:		Project Code:	
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For components with protective coating. To be filled in by MANUFACTURER and to be submitted for approval for shipment.

MANUFACTURER:		Order No.:	
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Item description:		TAG No. / Item No.:	
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Coating system:	
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A) Surface preparation:

Standard preparation grade:		Roughness R _z acc. EN ISO 8503-1:	
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Period of coating application from _____ to _____

B) / Composition of coating:

	PAINT MANUFACTURER	Product	DFT, µm
Prime coat			
Intermediate coat			
Top coat			

Other coatings of add-on parts:

Add-on:		Coating system:		DFT:		µm
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Parts without corrosion protection are treated as follows: _____


Declaration of conformity:

This is to certify that coating of above-mentioned item has been carried out according to LS 148-06, Part 01 – Part 04.

	PAINT MANUFACTURER *	MANUFACTURER	CONTRACTOR	COMPANY* <input type="checkbox"/> reviewed <input type="checkbox"/> noted <input type="checkbox"/> witnessed	CLIENT *
Name / Dept:					
Date:					
Signature:					
* optional					

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LS 148-06.T01-F01 (EN)

	Acceptance sheet	LINDE STANDARD
	Corrosion protection - Components - Material receiving inspection	LS 148-06 Part 01 Form 02

Issue 03/01.2020

Page 1 of 1

For coated components delivered to site or to manufacturer of package equipment, where touch-up and / or additional coating shall be applied.

Project No.:		Project code:	
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Item description:		TAG No. / Item No.:	
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Declaration of conformity:

This is to confirm, that the coating on above-mentioned component is executed in accordance with LS 148-06 Part 01 – Part 04 and it is suitable for further coating.
Coating system, dry film thickness and appearance of coating has been inspected.

Coating system:		DFT:		μm
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Signature CONTRACTOR:		Date:	
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Areas of non-conformity:


Required corrective actions:

Signature CONTRACTOR:		Date:	
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	PAINT MANUFACTURER *	MANUFACTURER*	CONTRACTOR*	COMPANY <input type="checkbox"/> reviewed <input type="checkbox"/> noted <input type="checkbox"/> witnessed	CLIENT *
Name / Dept:					
Date:					
Signature:					
* optional					

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LS 148-06.T01-F02 (EN)

	Acceptance sheet	LINDE STANDARD
	Corrosion protection - Final acceptance on site	LS 148-06 Part 01 Form 03

Issue 03/01.2020

Page 1 of 1

Project No.:		Project code:	
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CONTRACTOR:		Order No.:	
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Invitation to final acceptance by CONTRACTOR:

Item description:		TAG No. / Item No.:	
Proposed date:			

The coating on the above-mentioned component has been executed in accordance with
LS 148-06, Part 01 – Part 04.

Date:		Name / Dept:	
Signature:			

Acceptance by COMPANY and/ or CLIENT

Acceptance given:

Yes, no punch points	<input type="checkbox"/>
Yes, with punch points	<input type="checkbox"/>
No, with punch points	<input type="checkbox"/>

Punchlist:

	PAINT MANUFACTURER *	MANUFACTURER*	CONTRACTOR	COMPANY <input type="checkbox"/> reviewed <input type="checkbox"/> noted <input type="checkbox"/> witnessed	CLIENT *
Name / Dept:					
Date:					
Signature:					
* optional					

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LS 148-06.T01-F03 (EN)