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## 1 Scope

This Linde Standard (LS) applies to workshop and site fabrication of metallic piping for process plants and contains basic requirements for radiographic testing (RT) and ultrasonic testing (UT) of welds (i.e. circumferential and branch welds, socket welds) on the basis of applicable construction codes and standards.

Applicable code requirements are mandatory. More stringent project- and component-specific requirements or specifications shall govern.

## 2 Abbreviations and definitions

### 2.1 Abbreviations

NDT	Non-destructive testing
PWHT	Post weld heat treatment
RT	Radiographic testing
TOFD	Time of flight diffraction
PAUT	Phased array ultrasonic testing
UT	Ultrasonic testing
WPS	Welding procedure specification

### 2.2 Definitions

COMPANY	LINDE AG, Engineering Division
CONTRACTOR	The party which is awarded a contract from COMPANY
CLIENT	Customer of COMPANY
Reference document	Document which defines method statements and design and/or installation requirements

## 3 CONTRACTOR

### 3.1 CONTRACTOR's responsibility

CONTRACTOR shall be responsible for the performance, interpretation, evaluation, and acceptance of NDT in accordance with the specified codes and regulations. CONTRACTOR may subcontract NDT services.

NDT shall be performed in due time consecutively after completion of welding and PWHT, if applicable.

CONTRACTOR shall observe applicable health, safety, and environmental requirements, in particular when using ionizing radiation sources. In this case, CONTRACTOR shall provide a local radiation safety responsible to ensure observation of applicable radiation protection regulations.

### 3.2 Qualification and certification

The NDT service provider shall be registered, accredited or certified acc. to code requirements and/or national regulations.

NDT personnel shall be qualified and certified acc. to the applicable code requirements. Satisfactory vision abilities of NDT personnel shall be ensured.

Accreditation, applicable procedures and NDT personnel list displaying only the personnel actually involved in the project incl. their qualifications with expiry dates, shall be submitted to COMPANY prior to start of work. The NDT personnel list shall be kept updated during the project indicating the start and termination dates of personnel.

## 4 Surface preparation

Prior to the commencement of any volumetric NDT, a visual examination by adequately trained and nominated personnel shall be performed. Any surface irregularities which could negatively affect the NDT interpretation shall be eliminated.

The surfaces of weld and heat affected zones on both sides of the weld shall be free from irregularities, which could either cover defects or lead to misinterpretations.

## 5 Radiographic testing (RT)

### 5.1 RT general requirements

For wall thicknesses up to 30 mm, RT shall be used; deviations therefrom shall be prior agreed upon in writing with COMPANY.

Double-wall exposures by using gamma ray outside a bunker shall be performed with collimator.

### 5.2 Weld-film correlation and marking

For obtaining a weld-film correlation, radiographic films and related welds shall be marked clearly and durably as defined below:

- Marking of weld, e.g. by stamping, engraving, or durable colour marking as minimum:
  - Construction area, line no., isometric sheet no., weld no. (or a test no. with direct link to weld location)
  - zero point,
  - direction of measuring;
- Film identification by exposed lead letters as minimum:
  - Construction area, line no., isometric sheet no., weld no. (or a test no. with direct link to weld location)
  - film no.,
  - special code letters:
    - F** Follow-up weld (also known as tracer or penalty shot)
    - G** Golden weld (also known as tie-in or closure welds not being pressure tested)
    - C** Control shot (testing or retesting of a weld for other reasons)
    - M** Modification weld (if already tests welds have been modified/re-welded for other reasons)
    - R** Repair weld (locally repaired or completely re-welded)
    - Q** Qualification weld (refer to par. 8a)
  - marking of the area to be interpreted (by means of an exposed lead measuring tape for welds > NPS 2 / DN 50; for welds ≤ NPS 2 / DN 50, lead letters shall be used),
  - date of testing;

When using test numbers, they shall be unique per project. A final list of all test numbers with reference to the respective weld location designation shall be part of documentation.

### 5.3 Selection of films and screens

To reduce number of films the film sizes shall correspond to the dimensions of the tested welds. The number of films depends on the diameter ratio, however as a minimum two films are required. Deviations therefrom shall be prior agreed with COMPANY.

Fluorescent screens are not permitted.

A correlation of common manufacturer trademarks to film system classes per code serves as information, see Table 1.

**Table 1: Equivalent film systems (informative)**

Manufacturers film systems			Film system classes		
Agfa / GE	Fuji	Kodak	ISO 11699-1	ASTM E 1815	JIS-K7627
D2	IX 25 IX 50	DR	C1	Special	T1
D3	IX 25 <sup>2)</sup> IX 50	M 100	C2	I	T1
D4	IX 50 IX 80	MX 125	C3	I	T2
D5	IX 80 <sup>2)</sup> IX 100 <sup>1)</sup>	T 200	C4	I	T2
D7	IX 100 <sup>2)</sup>	AA 400	C5	II	T3
D8	IX 150	CX	C6	III	T4
1) Manual development					
2) Automatic development					

## 5.4 Image quality indicators (IQI)

The requirements shall be acc. to the applicable codes and standards. Wire type IQIs are to be preferred. For aluminium materials, Al wire IQIs shall be used.

## 5.5 Gammagraphy of steel

The requirements of the applicable codes and standards with regard to the allowable thickness range for the gamma source used shall be adhered to.

Any exemption concerning the reduction of the minimum values for the radiographed thickness shall be prior agreed upon with COMPANY. In this case, the following conditions shall be fulfilled in addition:

- source dimensions: max. 2.0 x 2.0 mm;
- high density film class to be selected (minimum quality e.g. Agfa D5 film or equivalent), films shall be vacuum packed;
- film screens: for wall thicknesses  $\leq 10$  mm: Pb 0.1/0.1 mm;  
for wall thicknesses  $> 10$  mm: Pb 0.02/0.02 mm;
- exposure time  $\geq 30$  s.

## 5.6 Gammagraphy of aluminium

Wall thicknesses  $< 12$  mm shall be radiographed by means of an X-ray tube.

For wall thicknesses  $\geq 12$  mm, an isotope (preferably Se 75 or Yb 169) may be used if all of the following conditions are met:

- code requirements regarding sensitivity and density are fulfilled;
- fine grain film (e.g. for X-ray Agfa D4 Pb film and for Gamma radiography Agfa D2 Pb film);
- use of backing rings for welds;

# 6 Ultrasonic testing (UT)

## 6.1 UT general requirements

For wall thicknesses  $\geq 30$  mm, UT may be used. The application of UT (incl. techniques TOFD, PAUT) below 30 mm wall thickness shall be prior agreed upon with COMPANY in writing.

## 6.2 Calibration of equipment

UT shall only be performed by using equipment with time base adjustment and sensitivity setting in accordance with the applicable requirements.

# 7 Magnetic particle testing (MT), dye penetrant testing (PT), hardness testing (HT), positive material testing (PMI), Ferrite number testing (FN)

There are no requirements on MT, PT, HT, PMI, FN defined by this Linde Standard. Applicable code and project specific requirements shall be followed.

# 8 Extent of volumetric NDT

The extent of NDT shall comply with the requirements acc. to the relevant specifications and regulations. However, welders shall be tested on a regular basis by ensuring that welders are not permanently welding on areas with assignment of 0% RT/UT.

The selection of the welds to be tested shall be performed and / or approved by responsible quality personnel considering construction cost and schedule.

The extent of random NDT shall be randomly spread over piping pre-fabrication and site assembly welding; all welders involved shall be covered.

- For site welds, the first three welds of each welder shall be radiographed 100%.
- For dissimilar welds (e.g. austenitic to ferritic steel), the extent of NDT shall be 100%.
- In case of detection of unacceptable imperfections:

- ca) For  $\leq$  DN 300, two further welds welded by the same welder shall be completely tested for each weld to be repaired.  
For  $>$  DN 300, two further welds shall be tested in a critical area over a seam length of min. 20% per rejectable defect.
- cb) If unacceptable imperfections are found again, ca) shall be followed.
- cc) If defective welds are found again, every weld of the involved welder in the scope of the applicable WPS shall be tested.
- cd) Retesting shall be performed after repair welding.
- d) Prior to a pneumatic pressure test, the extent of NDT shall be as follows:
  - da) for circumferential and branch welds, acc. to code or specified requirements, but not less than 10%;
  - db) 100% for T-joints with longitudinal welds if longitudinal welds have not been non-destructively or pressure tested at the manufacturer's/supplier's workshop.
- e) For underground piping which cannot be subject to a hydrostatic pressure test prior to back filling of the pipe trench, the extent of NDT shall be min. 25%.
- f) For connections to already existing plant piping, the extent of NDT shall be 100%.
- g) For welds of material X10CrMoVNb9-1 (1.4903, P91), the extent of NDT shall be min. 20%.
- h) NDT shall be performed after PWHT.
- i) Socket welds shall be randomly tested 2% per welder for verification of specified gap (one exposure).

## 9 Evaluation and reporting

### 9.1 Evaluation

The evaluation of radiographic films and UT shall be performed by qualified and certified personnel acc. to applicable code and specifications. Any repair marking on defective welds shall be performed by trained and nominated personnel.

Radiographic films shall be kept available by CONTRACTOR on site for review by COMPANY and CLIENT. Films and related reports shall be presented together.

The radiographs shall be evaluated in a darkened facility on an area of the viewing screen with an adjustable luminance. The viewing screen shall be clean and film size-adjustable.

When NDT services are sub-contracted, CONTRACTOR's competent quality personnel shall review and approve radiographs and NDT reports prior to COMPANY or CLIENT review.

### 9.2 Contents of reports

Any relevant indication shall be recorded regardless of its acceptability. As a minimum, the type of indication (i.e. porosity, slag, film mark, etc.), location, and extent (i.e. length) shall be recorded.

The NDT reports shall contain the following information as a minimum:

**Table 2: Content of reports**

<b>General content, RT and UT:</b> <ul style="list-style-type: none"> <li>- name of NDT service provider</li> <li>- name of CONTRACTOR;</li> <li>- object;</li> <li>- material;</li> <li>- geometry of the weld incl. weld edge preparation;</li> <li>- material thickness;</li> <li>- time of testing (e.g. reference to heat treatment, if any);</li> <li>- surface condition;</li> <li>- NDT procedure and/or instruction, or specification;</li> <li>- acceptance criteria;</li> <li>- extent of testing;</li> <li>- test results incl. location of indications;</li> <li>- testing date, name, qualification level of person who performed NDT;</li> <li>- evaluation date, name, qualification level, signature of person who evaluated NDT</li> </ul>	
<b>Technical content RT:</b> <ul style="list-style-type: none"> <li>- required image quality (IQ);</li> <li>- system of marking used;</li> <li>- film position plan incl. location of radiation source;</li> <li>- radiation source, type and size of focal spot and identification of equipment used;</li> <li>- film type and system, screens and filters;</li> <li>- tube voltage used and current or source type and activity;</li> <li>- time of exposure and source-to-film-distance;</li> <li>- processing technique: manual or automatic, and development conditions;</li> <li>- type and position of IQI;</li> <li>- film density and IQI readings.</li> </ul>	<b>Technical content UT:</b> <ul style="list-style-type: none"> <li>- identification of UT instrument used: manufacturer, type, and ID no.;</li> <li>- identification of probes used: manufacturer, type, nominal frequency, angle of incidence, and ID no.;</li> <li>- search unit cables used: type and length;</li> <li>- couplant used: brand name or type;</li> <li>- method and values used for sensitivity setting;</li> <li>- time base range;</li> <li>- calibration blocks and/or reference blocks used;</li> <li>- scanning positions;</li> <li>- special equipment, if used: e.g. wedges, shoes, automatic scanning equipment, recording, equipment;</li> <li>- computerized program, if used: identification and revision.</li> </ul>

### 9.3 Storage of reports and films

Films related to a specific weld shall be kept together. This includes repair films, films from cut and re-welds etc. as well as their reports.

Storage conditions with regard to temperature, humidity, dust etc. shall ensure prevention from deterioration of films. Films shall always be stored systematically, e.g. in sequential order.