A General Survey on NDT in the Chemical Industry

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Chemical Industry: Different Plants for all Sorts of Purposes
The BASF Site Ludwigshafen – the world’s largest integrated chemical complex
The “Chemis-Tree”
BASF Products

About 8,000 commercial products

Major basic products and intermediates
about 200

Raw materials
Crude oil
Rock salt
Phosphate
Sulfur
Ores
Natural gas
Water
Air
From Naphtha to Napkins: Superabsorbers from BASF

Naphtha → Propylene → Acrylic acid crude → Acrylic acid pure → Super-absorbers
Objects in Chemical Plants Subject to NDT

- Storage Tank
- Sphere for Pressurized Gas Storage
- High-Pressure Reactor
- Column
- Process Piping
Why are Inspections of Chemical Equipment Necessary?

- Economy (no down-time)
- Safety
- Legal Requirements
  - European
  - National
Focus on Pressure Equipment (Vessels, Process Piping)
Design and Manufacture

EU - Pressure Equipment Directive (PED)
- mandatory for the EU-member-states
- essential safety-requirements of PED
- harmonized standards: e.g. EN 13445-5
- national codes: e.g. AD-2000, CODAP 2000
- pressure vessels of cat. IV are subject of NDT in any case
  - typically good-workmanship criteria
  - 3rd party is involved
- responsibility of manufacturer
Focus on Pressure Equipment (Vessels, Process Piping)  
Operation (German View)

- Design
- Manufacture
- Operation

national BetrSichV (safe operation of plants)
- inspection periods established by owner
  - max. values by BetrSichV (e.g. 5 years)
- national accredited surveillance organizations
- experienced persons (e.g. owner)
- amount and type of NDT settled by owner and surveillance organization / experienced person
  - depends on type of potential damage

- responsibility of owner / operator
**Example 1**

**Shell & Tube Heat-Exchanger of Cat. IV**

**consists of**
- shell
- 2 end-covers (bonnet, hood)
- at least 4 nozzles
- 2 tubesheets
- tubes
NDT of Semi-Finished Products

- design & materials selection by manufacturer based on owner’s specs
- design - approval by notified body (3rd party)
- ordering of semi-finished products
  - rolled parts
  - forged parts (e.g. tubesheet)
  - tubes: seamless or welded
  - flanges, screws, etc.
- NDT carried out at steel-mill acc. to
  - EN-standards
  - customer specs. (manufacturer / operator)
- materials certificates & incoming goods inspection
- positive materials identification
NDT of Welded Vessel (shell, end-covers, nozzles)

- acc. to PED
- harmonized standard EN 13445-5
- national codes, e.g. AD-2000 HP 5/3
- NDT carried out at manufacturers site
- EN-standards for NDT of welds
- good workmanship criteria
- fitness for purpose criteria may be considered

- responsibility of manufacturer
- NDT results reviewed by notified body
Shell & Tube Heat-Exchanger

NDT of Tube-to-Tubesheet Welds

detection of porosity (potential leakage)
- NDT not required by codes or standards
- fitness-for-purpose NDT
  - to be specified by owner / operator
  - carried out at manufacturers site
  - RT
    - isotope
    - X-ray-tube
  - UT

- responsibility of owner / operator
Shell & Tube Heat-Exchanger

Leak Test (LT)

- not required by PED or by harmonized standard
- pressure test is no leak test
- fitness-for-purpose NDT
  - bubble test
  - tracer gas methods (e.g. He)

- it has to be specified early, if LT is under responsibility of
  - manufacturer
  - owner / operator
Final Inspection – Acceptance (cat. IV, Modul G)

- manufacturer provides
  - CE-marking on the heat-exchanger
  - declaration of conformity
  - technical documentation

- notified body carries out „unit verification“
  - examination of technical documentation
    - verify approval of NDT personnel
    - examine NDT test reports
    - ...........
  - final inspection
  - certificate of conformity

- final acceptance by owner
BetrSichV (safe operation of plants)
- internal inspection at least every 5 years
- internal inspection may be replaced or complemented by NDT

- amount and type of NDT depends on type of potential damage
- settled by
  1. owner
  2. owner and experienced person
  3. owner and surveillance organization (ZÜS)
Shell & Tube Heat-Exchanger

In-Service-Inspections (German View)

amount and type of NDT depends on type of potential damage

- LT of complete structure if necessary
- outer shell typically UT
  - wall-thickness measurement (corrosion)
  - main welds (cracking)
- tube-to-tubesheet welds typically PT or MT
- tubes typically ET, VT, UT-IRIS
  
  baseline inspection during fabrication recommended
Who carries out NDT?

- Annex I, 3.1.3 of PED requires **approved personnel** for NDT of welds at cat. III - and cat. IV – vessels
- approval of personnel by recognized third-party organizations (article 13) actual list: http://ec.europa.eu/enterprise/newapproach/nando
- harmonized and supporting standards require personnel certified acc. to **EN 473**
- **no accreditation of NDT-company required**

- PED does not apply
- national regulations apply
- NDT based on
  - NDT EN-standards
  - NDT qualification procedure
- NDT personnel certified acc. to EN 473 if required
- accreditation of NDT-company based on EN ISO 17025 recommended / required?
Who carries out NDT?

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  - NDT qualification procedure
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Example 2

Process Piping

- transport of fluids, steam or gases
- typically pressurized, often hot and insulated
- 3 categories acc. to PED

- process piping consists of
  - tubes
  - bends
  - welded seams
  - flanges
  - valves
  - gaskets
  - ......
NDT of Pressure Equipment Parts

- materials selection by owner based on stresses and corrosivity of media
- ordering of pressure equipment parts by fabricator / manufacturer
  - tubes (seamless or welded, EN 10216 or EN 10217)
  - flanges
  - valve-housings
  - gaskets, etc.
- NDT carried out at steel-mill acc. to
  - EN 10246, part 1 - part 18 (UT, ET, MT,..)
  - customer specs → options of EN 10216/10217
- materials certificates & incoming goods inspection (e.g. PMI)
Process Piping

NDT of Welds (mainly circumferential)

- acc. to PED
- harmonized standard EN 13480-5
- national codes, e.g. AD-2000 HP 5/3
- NDT carried out at fabricators / manufacturers site
- EN-standards for NDT of welds
- good workmanship criteria
- fitness for purpose criteria may be considered

- fabricator(s) → manufacturer
- responsibility of manufacturer
Process Piping

Final Acceptance & Leak Test

<table>
<thead>
<tr>
<th>Design</th>
<th>Manufacture</th>
<th>Operation</th>
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**final inspection for acceptance**
- manufacturer provides
  - declaration of conformity
  - technical documentation
- for category III
  - notified body carries out
    - examination of technical documentation
    - verify approval of NDT personnel
    - examine NDT test reports
    - ..........
    - final inspection (incl. pressure test)
    - certificate of conformity
- final acceptance by owner

**LT not required by PED or by harmonized standard**
- pressure test is no leak test
- fitness-for-purpose NDT
  - bubble test
  - tracer gas methods (e.g. He)

**it has to be specified early, if LT is under responsibility of**
- manufacturer
- owner / operator
In-Service-Inspections (German View)

BetrSichV (safe operation of plants)
- visual inspection at least every 5 years
- pressure test at least every 5 years
- pressure test may be replaced or complemented by NDT

- amount and type of NDT depends on type of potential damage
- settled by
  1. owner
  2. owner and experienced person
  3. owner and surveillance organization (ZÜS)
Process Piping

In-Service-Inspections (Selection of Methods)

- **amount and type of NDT depends on type of potential damage** (ID or OD)
  - wall-thickness reduction
  - localized corrosion
  - cracking
  - deposits, blockage
  - .......

- off-stream methods require removal of insulation

- on-stream methods are applied during service (media, temperature, through insulation, etc.)
Process Piping

In-Service-Inspections (Methods)

- Detection of defective insulation by infrared – testing on-stream
- Detection of blockage by Acoustic Ranger Blockage Detector off-stream
- Verification of valve-seat position by RT and Phosphor Imaging Plate on-stream
Process Piping

In-Service-Inspections (on-Stream Methods)

Detection of corrosion under pipe-support
Magna-Tec

VT corrosion scanning
CorrScan

Detection of corrosion over long distances
Teletest

Detection of corrosion under insulation
Incotest

Design | Manufacture | Operation
Methods and NDT-Equipment used for In-Service-Inspections

Validation / Qualification

- **routine-NDT is typically based on EN-standards**
  - if an EN-standard applies, NDT-validation is not required or necessary

- **on-stream NDT methods / systems are typically not covered by standards:**
  - in this case:
    - validation / qualification of an NDT system is required acc. to EN ISO 17025
  - CEN technical report CEN/TR 14748:2004 Methodology for qualification of non-destructive tests
NDT in the Chemical Industry

Summary

- NDT in the chemical industry is NDT of equipment (e.g. vessels, tanks, piping)
- NDT during manufacturing is different from NDT during operation
- **NDT during manufacturing** has to follow provisions of European PED with respect to future operation conditions
  - good workmanship criteria apply
  - NDT acc. to well known codes and standards (RT, UT, PT, MT)
- **NDT during operation** has to follow provisions of national regulations
  - NDT depends on type of defect estimated
  - acceptance criteria depend individually from type of object
- Qualification / Validation of new methods required