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# Heat Exchangers in Pharmaceutical Water Systems

– Guidance, Challenges & Solutions
8th November 2021

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– Introduction of speaker

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Responsible for development of heat exchangers to Pharma. Expert in heat transfer and pharma demands, and has been a speaker at several BioPharm conferences and seminars in Asia, America and Europe.

MSc, Chemical Engineering, Food and pharma engineering, University of Lund, Sweden 1990-1995
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# Agenda

– What will be covered

**Part 1:**

- Introduction to water storage & distribution loops
- What are the challenges and what does the guidance say about heat exchanger for water storage & distribution loop?
  - FDA guide to inspection
  - ISPE
  - ASME BPE

**Part 2:**

- How Pharma-line S&T and Pharma-line Point of Use fulfil the guidance and solve the challenges

# USP water specification

| | WFI | PW |
|---|---|---|
| Conductivity µS/cm @ 25 °C* | 1,3 | 1,3 |
| TOC, ppb | < 500 | < 500 |
| Microbial, cfu/100ml | 10 | 10 000** |
| Endotoxin, max | 0,25 EU/ml | Not spec. |

** Conductivity levels depending on measured temperature*

*** Purified water specified as 100 cfu/ml*

**Water For Injection Monographs**

| Attribute | USP | EP | JP | ChP | IP |
|---|---|---|---|---|---|
| Source water | US, EU, Japan, WHO drinking water | Human consumption | JP water specification | Potable water or Purified water | Potable water or Purified water |
| Production Method | Distillation or suitable processes | Distillation | Distillation or RO with UF from Purified Water | Distillation | Distillation |
| Microbial (cfu/100 ml) | 10 | 10 | 10 | 10 | 10 |
| Conductivity (µS/cm at 25°C) | 1,3 (3 stage) | 1,3 (3 stage) | 1,3 on-line or 2,1 off-line | 1,3 (3 stage) | 1,3 (3 stage) |
| TOC (mg/l) | 0,5 | 0,5 | 0,5 (0,3 for control) | 0,5 | 0,5 |
| Endotoxins (EU/ml) | 0,25 | 0,25 | 0,25 | 0,25 | 0,25 |
| Nitrates (ppm) | - | 0,2 | - | 0,2 | Required |
| Acidity/Alkalinity | - | - | - | Required | - |
| Ammonium (ppm) | - | - | - | Required | - |
| Oxidizable substances | - | Required | - | 0,2 | - |

**Purified Water Monographs**

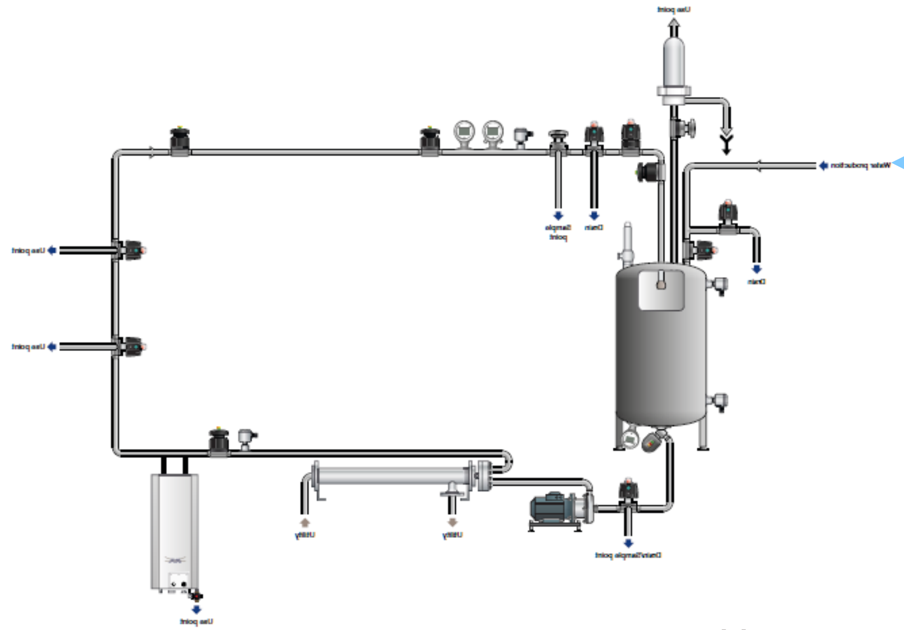
| Attribute | USP | EP | JP | ChP | IP |
|---|---|---|---|---|---|
| Source water | US, EU, Japan, WHO drinking water | Human consumption | JP water specification | Potable water or Purified water | Potable water or Purified water |
| Production Method | Suitable processes | Suitable processes | Distillation, ion-exchange, UF, or combination | Distillation, ion-exchange, or suitable processes | Distillation, ion-exchange, or suitable processes |
| Microbial (cfu/ml) | 100 | 100 | 100 | 100 | 100 |
| Conductivity (µS/cm at 25°C) | 1,3 (3 stage) | 5,1 (1 stage) | 1,3 on-line or 2,1 off-line | 5,1 (1 stage) | 1,3 (3 stage) |
| TOC (mg/l) | 0,5 | 0,5 (optional) | 0,5 (0,3 for control) | 0,5 | 0,5 |
| Nitrates (ppm) | - | 0,2 | - | 0,2 | Required |
| Acidity/Alkalinity | - | - | - | - | Required |
| Ammonium (ppm) | - | - | - | 0,2 | Required |
| Oxidizable substances | - | Required | - | - | - |

# Storage & distribution loop

## Water Generation

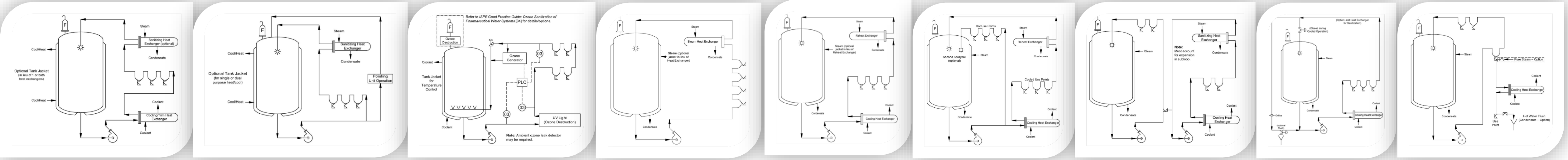
Feed water → Pre treatment → Final treatment

## Storage & Distribution



Ambient or cold water systems

Hot water systems



*Examples from ISPE Baseline Guide Vol 4: Water & Steam Systems 3rd Edition, 2019*

# Challenges & Guidance's for Heat exchangers

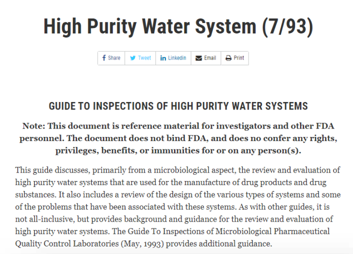
– Pharmaceutical water systems

## Challenges:

1. Cross contamination
2. Sanitization
3. Velocity
4. Surface finish
5. Welding
6. Passivation
7. Rouging
8. Installation & operation
9. Service & maintenance

## Guidance's:

- US FDA, Inspection guides
  https://www.fda.gov/inspections-compliance-enforcement-and-criminal-investigations/inspection-references/inspection-guides
- ASME BPE – 2019
- ISPE Baseline Guide Volume 4,
  Water and Steam Systems, Third edition, 2019



**High Purity Water System (7/93)**

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**GUIDE TO INSPECTIONS OF HIGH PURITY WATER SYSTEMS**

**Note: This document is reference material for investigators and other FDA personnel. The document does not bind FDA, and does no confer any rights, privileges, benefits, or immunities for or on any person(s).**

This guide discusses, primarily from a microbiological aspect, the review and evaluation of high purity water systems that are used for the manufacture of drug products and drug substances. It also includes a review of the design of the various types of systems and some of the problems that have been associated with these systems. As with other guides, it is not all-inclusive, but provides background and guidance for the review and evaluation of high purity water systems. The Guide To Inspections of Microbiological Pharmaceutical Quality Control Laboratories (May, 1993) provides additional guidance.

**Heat Exchangers to Avoid Contamination**

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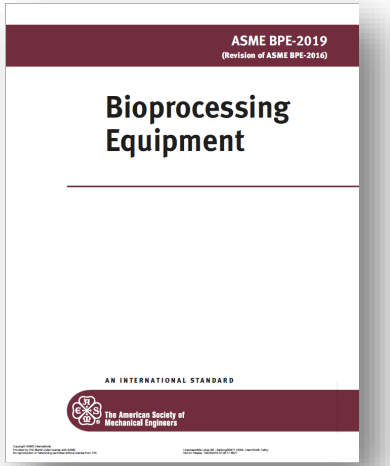
[Previous Chapter] [Table of Contents] [Next Chapter]

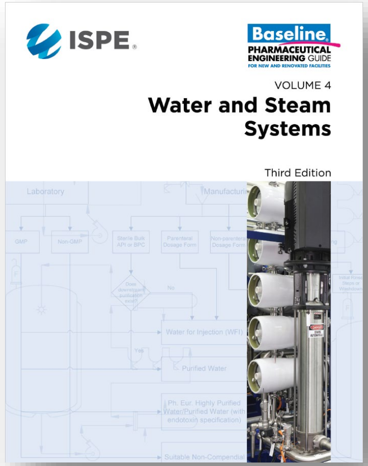
DEPT. OF HEALTH, EDUCATION, AND WELFARE PUBLIC HEALTH SERVICE FOOD AND DRUG ADMINISTRATION *ORA/ORO/DEIO/IB*

Date: 7/31/79 Number: 34
Related Program Areas:
Drugs, Diagnostic Products,Biologics

**ITG SUBJECT: HEAT EXCHANGERS TO AVOID CONTAMINATION**

Subpart D, section 212.76 of the current proposed Good Manufacturing Practices (GMP) for manufacturing, processing, packing or holding of a Large Volume Parenteral (LVP) includes requirements for the use of heat exchangers. It states in part "Heat exchangers, other than the welded double-concentric-tube type or double-tubesheet type, must employ a pressure differential and a means for monitoring the differential."



# 1. Cross contamination

– ISPE & FDA

<u>Two ways to control:</u>

- Over pressure (Plate or single tube sheet heat exchangers)
- Double tube sheet S&T or Tube-in-tube heat exchangers

<u>Recommendations:</u>

- Hygienic applications:
  - Double tube sheet S&T or Tube-in-tube
- Pretreatment or non-hygienic:
  - Plate or single tube sheet S&T

ISPE Vol 4

- 8.3.4.2 Heat Exchangers – Design Considerations

US FDA Inspection Guides

- GUIDE TO INSPECTIONS OF HIGH PURITY WATER SYSTEMS
- HEAT EXCHANGERS TO AVOID CONTAMINATION

# 2. Sanitization & Bacteria control

– ISPE & FDA

It is recognized that hot (65 - $80^{o}$C) systems are self sanitizing

Sanitization:

- S&T, no need for special arrangement
- Gasketed plate, heat sanitization ok, chemical sanitization requires additional rinse

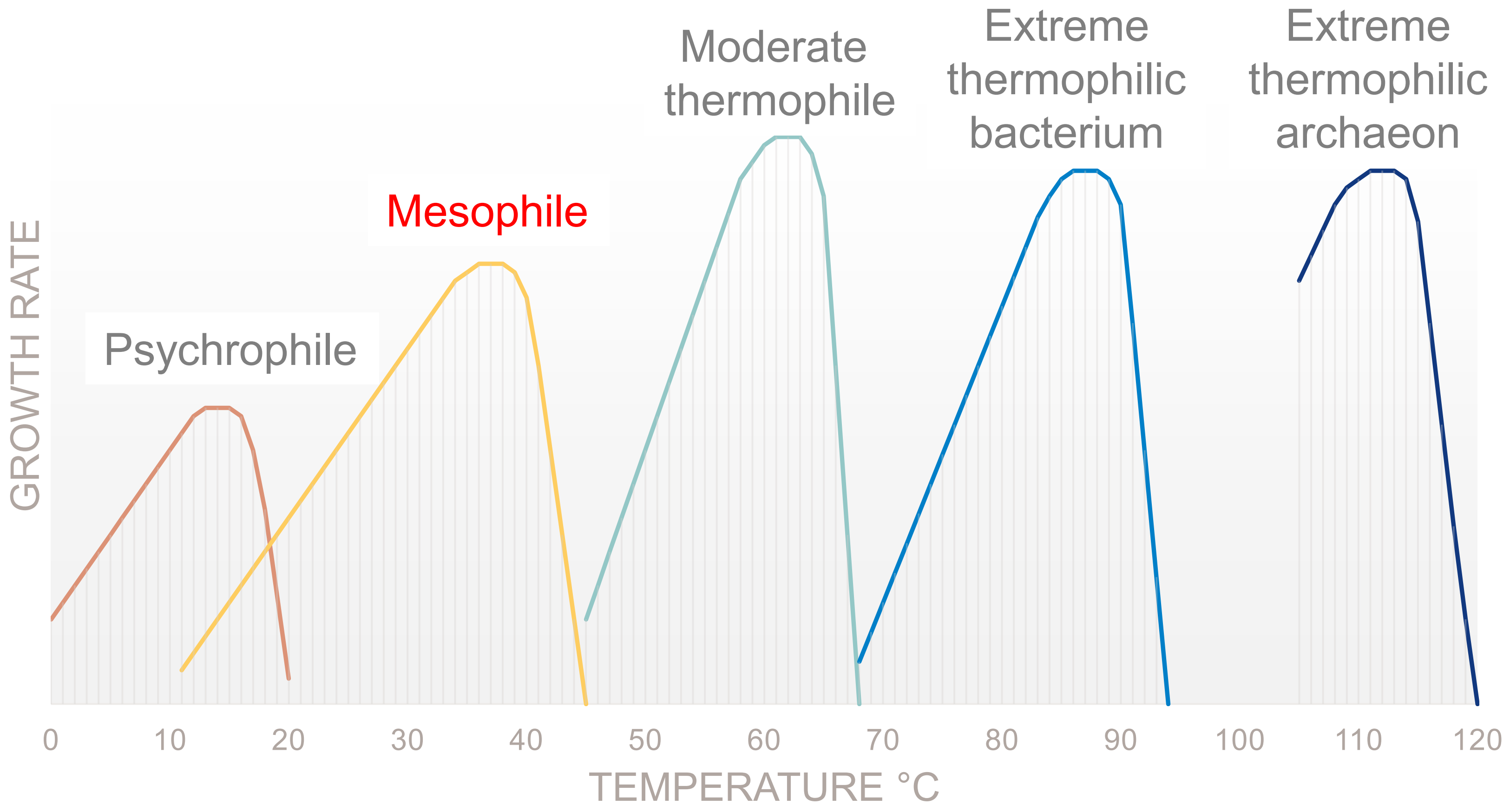
Drainability:

- S&T heat exchangers, Drainability with slope or for U-tubes with weep holes at the low point
- Plate heat exchangers, not drainable (Gasketed can be disassembled for drainability)

*non-recirculating water systems be drained daily and water not be allowed to sit in the system.*

# 2. Sanitization & Bacteria control

– Bacteria found in pharmaceutical water systems




Growth rate vs temperature for five environmental classes of prokaryotes

| Bacterium | Optimum (°C) /Upper (°C) |
|---|---|
| Escherichia coli | 37/45 |
| Staphylococcus aureus | 30-37/45 |
| Pseudomonas maltophilia | 35/41 |
| Pseudomonas aeruginosa | 37/42 |
| Pseudomonas fluorescens | 25-30/39 |
| Listeria monocytogenes | 30-37/45 |
| Campylobacter jejuni | 37-42/45 |
| Clostridium perfringens | 37/50 |
| Shigella spp. | 35-37/47 |

Belong to Mesophile class

# 1 & 2. ASME BPE - SD-3.6 Heat Exchanger Equipment

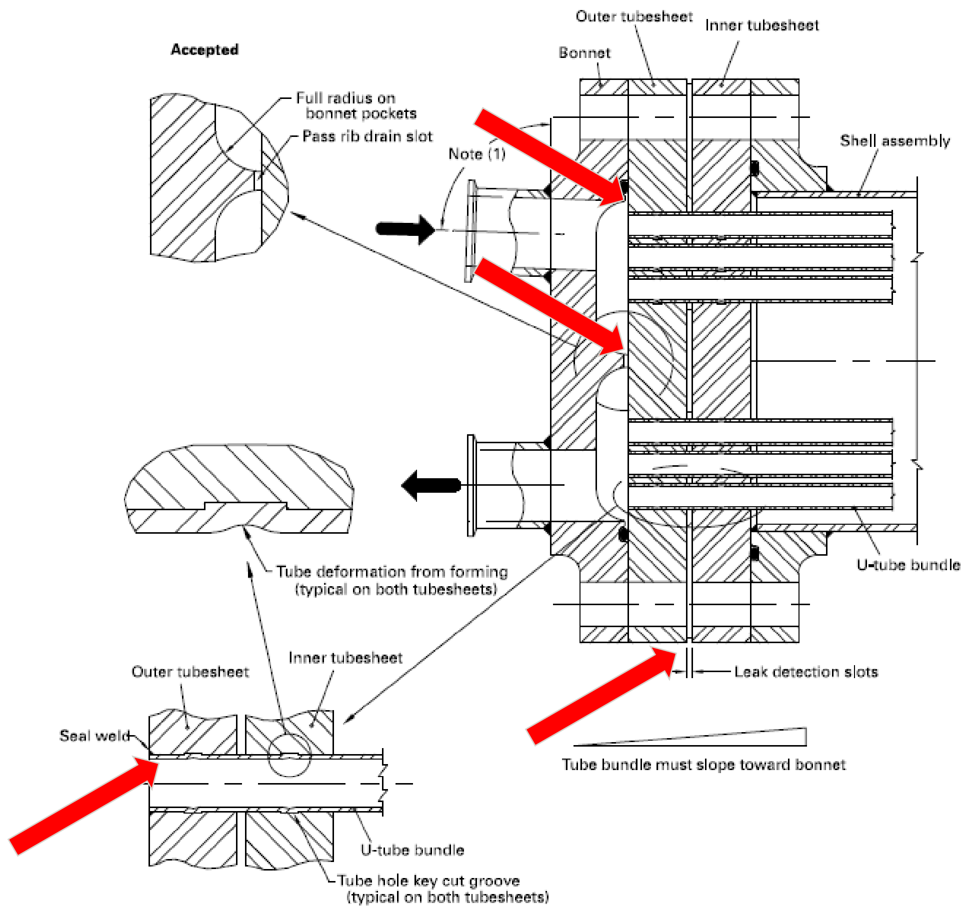
– Design for Cross contamination and Sanitization

- Easy to clean
- Inspectable
- Bending process
- Sample
- Free of liquid penetrant indications
- Double tube sheet (Figure SD- 3.6.1-1)
- Orientation/Drainability
- Thermal and Mechanical calculations (Operation & SIP)
- Design pressure: Process side ≥ Utility side
- Cleaning & Steaming
- Gaskets and Seals

*(f)* Minimum recommended bend radii for heat exchangers should be as follows:

| Nominal Tube O.D. | | Minimum Bend Radius | |
|---|---|---|---|
| in. | mm | in. | mm |
| 0.375 | 9.5 | 0.625 | 15.2 |
| 0.500 | 12.7 | 0.750 | 19.1 |
| 0.625 | 15.8 | 0.938 | 23.8 |
| 0.750 | 19.1 | 1.125 | 28.6 |
| 1.000 | 25.4 | 1.500 | 38.1 |

(19) Figure SD-3.6.1-1 Double Tubesheet Heat Exchanger Bonnet Design

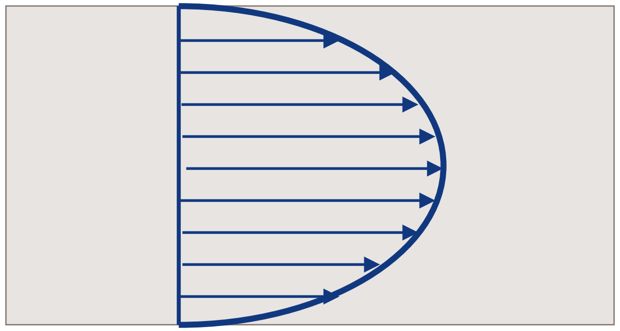


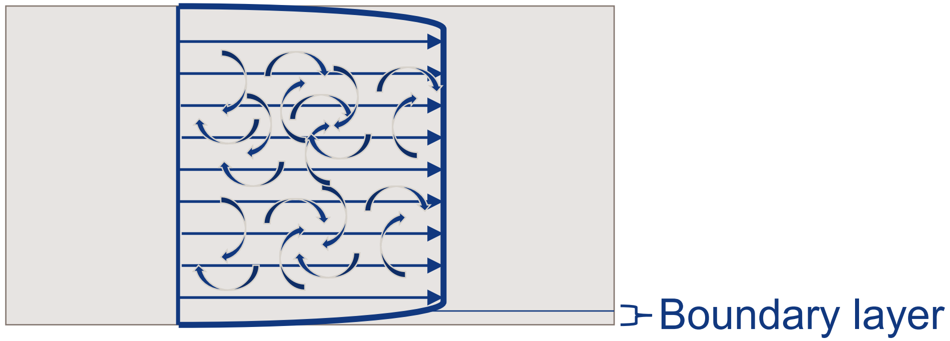

NOTE: (1) Owner/user to specify inlet tubing slope. Heat exchanger manufacturer to slope inlet on bonnet to match inlet tubing slope.

# 3. Velocity

– ISPE

- Turbulent flow, Reynolds > 4000 (Biofilm)






Re <4 000 – Laminar flow
Low shear forces

Re >4 000 – Turbulent flow
Higher shear forces

| Velocity | Boundary layer |
|---|---|
| 0,9 m/s (3 ft/s) | 120 µm |
| 2,4 m/s (8 ft/s) | 50 µm |
| Very high velocity | 10-20 µm |

# 4. Surface finish

## – ISPE & ASME BPE

- Ra 0,3-0,8 µm (10-30 µinch)
- Mechanically or Electro polished
- Polishing rests
- Passivation

**Table SF-2.4.1-1 $R_a$ Readings for Metallic Process Contact Surfaces**

| Surface Designation | Mechanically Polished [Note (1)] $R_a$ Max. µin. | Mechanically Polished [Note (1)] $R_a$ Max. µm |
|---|---|---|
| SF0 | No finish requirement | No finish requirement |
| SF1 | 20 | 0.51 |
| SF2 | 25 | 0.64 |
| SF3 | 30 | 0.76 |
| | **Electropolished $R_a$ Max. µin.** | **Electropolished $R_a$ Max. µm** |
| SF4 | 15 | 0.38 |
| SF5 | 20 | 0.51 |
| SF6 | 25 | 0.64 |

GENERAL NOTES:
(a) All $R_a$ readings are to be in accordance with ASME B46.1.
(b) All $R_a$ readings are taken across the lay, wherever possible.
(c) No single $R_a$ reading shall exceed the $R_a$ max. value in this table.
(d) Other $R_a$ readings are available if agreed on between the owner/user and supplier, not to exceed values in this table.

NOTE:
(1) Or any other finishing method that meets the $R_a$ max.

**Table SF-2.2-1 Acceptance Criteria for Metallic Process Contact Surface Finishes**

| Anomaly or Indication | Acceptance Criteria |
|---|---|
| Pits/porosity | If diameter <0.020 in. (0.51 mm) and bottom is shiny [Notes (1) and (2)]. Pits <0.003 in. (0.08 mm) diameter are irrelevant and acceptable. |
| Cluster of pits/porosity | No more than 4 pits per 0.5 in. (13 mm) × 0.5 in. (13 mm) inspection window. The cumulative total diameter of all relevant pits shall not exceed 0.040 in. (1.02 mm). |
| Dents | None accepted [Note (3)] |
| Finishing marks | If $R_a$ max. is met |
| Welds | Welds used in the as-welded condition shall meet the requirements of MJ-8.<br>Welds finished after welding shall be flush with the base metal, and concavity and convexity shall meet the requirements of MJ-8. Such finishing shall meet the $R_a$ requirements of Table SF-2.4.1-1. |
| Nicks | None accepted |
| Scratches | For tubing, if cumulative length is <12.0 in. (305 mm) per 20 ft (6.1 m) tube length or prorated and if depth is <0.003 in. (0.08 mm)<br>For fittings, valves, and other process components, if cumulative length is <0.25 in. (6.4 mm), depth <0.003 in. (0.08 mm), and $R_a$ max. is met<br>For vessels, if length <0.50 in. (13 mm) at 0.003 in. (0.08 mm) depth and if <3 per inspection window [Note (4)] |
| Surface cracks | None accepted |
| Surface inclusions | If $R_a$ max. is met |
| Surface residuals | None accepted, visual inspection |
| Surface roughness ($R_a$) | See Table SF-2.4.1-1 |
| Weld slag | For tubing, up to 3 per 20 ft (6.1 m) length or prorated, if <75% of the width of the weld bead<br>For fittings, valves, vessels, and other process components, none accepted (as welded shall meet the requirements of MJ-8 and Table MJ-8.4-1) |
| Blistering | None accepted |

GENERAL NOTE: This table covers surface finishes that are mechanically polished or any other finishing method that meets the $R_a$ max.

NOTES:
(1) Black bottom pit of any depth is not acceptable.
(2) Pits in superaustenitic and nickel alloys may exceed this value. Acceptance criteria for pit size shall be established by agreement between owner/user and supplier. All other pit criteria remain the same.
(3) For vessels, dents in the area covered by and resulting from welding dimple heat transfer jackets are acceptable.
(4) An inspection window is defined as an area 4 in. × 4 in. (100 mm × 100 mm).

**Table SF-2.2-2 Additional Acceptance Criteria for Electropolished Metallic Process Contact Surface Finishes**

| Anomaly or Indication | Acceptance Criteria |
|---|---|
| Cloudiness | Acceptable if $R_a$ max. is met |
| End grain effect | Acceptable if $R_a$ max. is met |
| Fixture marks | Acceptable if electropolished |
| Haze | Acceptable if $R_a$ max. is met |
| Interrupted electropolish | Acceptable if $R_a$ max. is met |
| Orange peel | Acceptable if $R_a$ max. is met |
| Stringer indication | Acceptable if $R_a$ max. is met |
| Weld whitening | Acceptable if $R_a$ max. is met |
| Variance in luster | Acceptable if $R_a$ max. is met |

# 5. Welding

– ASME BPE, Chapter 5, Part MJ Materials joining

MJ-1 Purpose & Scope

MJ-2 Materials

MJ-2 Joint design and preparation

MJ-4 Procedure qualifications

MJ-6 Performance qualifications

MJ-7 Examination, inspection, and testing

**MJ-8 Acceptance criteria**

MJ-9 Joining of polymeric materials

**MJ-10 Documentation requirements**

MJ-11 Passivation

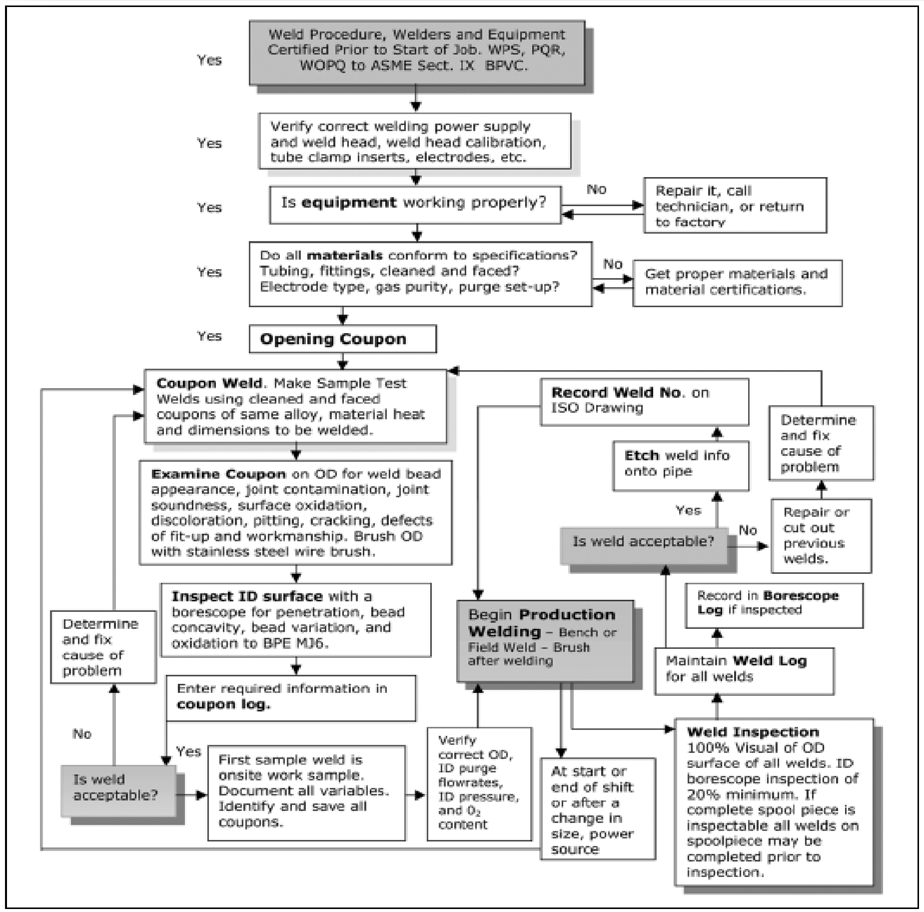


Figure 6. Flow chart for orbital welding/inspection/documentation of stainless steel welds.

# 5. Welding

– ASME BPE MJ-8 Acceptance critera

- Cracks
- Lack of fusion
- Incomplete penetration
- Porosity
- Inclusions
- Undercut
- Groove weld concavity
- Fillet weld concavity
- Discoloration (HAZ)
- Discoloration (weld bead)
- Oxide island
- Reinforcement
- Tack welds
- Arc strikes
- Overlap
- Weld bead width
- Minimum fillet weld size
- Misalignment

**Table MJ-8.2-1 Visual Examination Acceptance Criteria for Welds on Metallic Pressure Vessels and Tanks**

| Discontinuities | Welds on Process Contact Surfaces | | | Welds on Non-Process Contact Surfaces | |
|---|---|---|---|---|---|
| | Welds Left in the As-Welded Condition | Prior to Postweld Finishing | After Postweld Finishing | Welds Left in the As-Welded Condition | After Postweld Finishing |
| Cracks | None | None | None | None | None |
| Lack of fusion | None | None | None | None | None |
| Incomplete penetration | None on process contact side; otherwise, see Note (1) | None on process contact side; otherwise, see Note (1) | None on process contact side; otherwise, see Note (1) | See Notes (1) and (2) | See Notes (1) and (2) |
| Porosity | None open to the surface; otherwise, see Note (1) | See Note (1) | See Table SF-2.2-1 for acceptance criteria for pits/porosity | None open to the surface; otherwise, see Note (1) | None open to the surface; otherwise, see Note (1) |
| Inclusions [metallic (e.g., tungsten) or nonmetallic] | None open to the surface; otherwise, see Note (1) | See Note (1) | None open to the surface; otherwise, see Note (1) | None open to the surface; otherwise, see Note (1) | None open to the surface; otherwise, see Note (1) |
| Undercut | None | See Note (1) | None | See Note (1) | See Note (1) |
| Groove weld concavity | See Note (1) | See Note (1) | Maximum of 10% of the nominal wall thickness of thinner member | See Note (1) | See Note (1) |
| Fillet weld convexity | $^1/_{16}$ in. (1.5 mm) max. | Per applicable design and fabrication code | $^1/_{32}$ in. (0.8 mm) max. | See Note (1) | See Note (1) |

# 5. Welding

– ASME BPE MJ-10 Documentation requirements

## Welding, Inspection, and Examination Qualification Documentation

(1) Welding Procedure Specifications/Parameters (WPS/P)

(2) Procedure Qualification Records (PQRs)

(3) Welder Performance Qualifications (WPQs) – manual weld

(4) Welding Operator Performance Qualifications (WOPQs) – automatic weld

(5) Examiner qualifications

(6) documentation of approval of the above by the owner/user's representative prior to welding

(7) Inspector qualifications

(8) documentation of the approval of (7) by the owner/user prior to welding

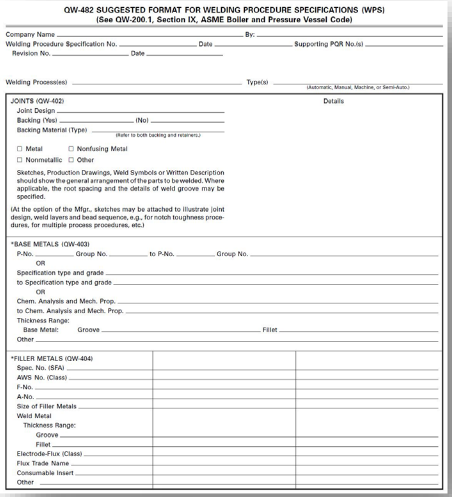
## Weld Documentation

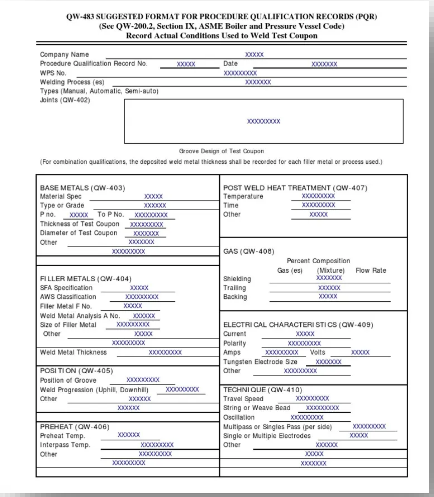
(1) weld maps

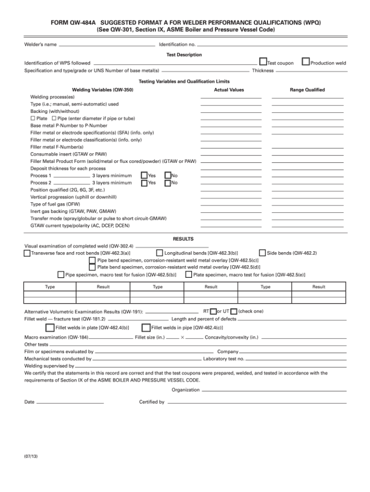
(2) weld logs

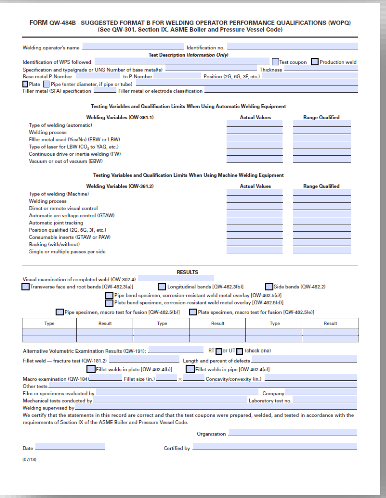
(3) weld examination and inspection logs

(4) coupon logs



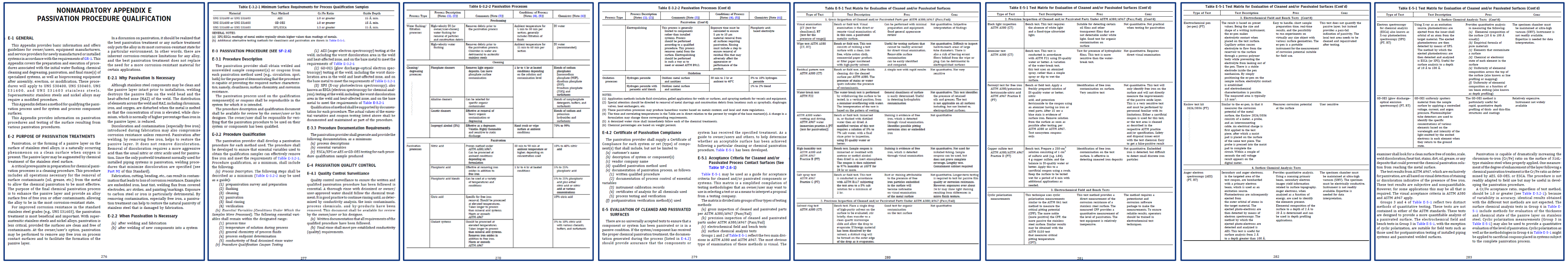



# 6. Passivation

– ISPE & ASME BPE

- Re-passivation (ISPE)
- Passivated before being placed in service (ASME BPE)
- Passivation of electropolished surfaces is not required unless the surface has been altered (ASME BPE)
- ASME BPE Nonmandatory Appendix E, Passivation procedure qualification


NONMANDATORY APPENDIX E
PASSIVATION PROCEDURE QUALIFICATION

# 7. Rouging

– ISPE, ASME BPE, FDA, & USP

ISPE - whether or not the presence of rouge may be detrimental to the drug products. Refers to FDA, USP and ASME BPE

FDA - surfaces shall not be reactive, additive, or absorptive so as to alter the safety, identity, strength, quality, or purity of the drug product beyond the official or other established requirements.

USP - does not address design or material criteria directly, but rather indirectly by defining limits for the components that ultimately will enter the human body.

USP 788 & 789 Particulate matter in injections and ophthalmic solutions

| | ≥ 10 µm | ≥ 25 µm |
|---|---|---|
| 788 Injections | 25 per mL | 3 per mL |
| 789 Opthalmic | 50 per mL | 5 per mL |

# 7 Rouging

– ASME BPE Nonmandatory appendix D, Rouge and stainless steel

- D-1 General
- D-2 Considerations for reducing rouge formation
  - Alloy selection/composition
  - Polishing
  - Passivation
  - Welding
  - Product form and fabrication
- D-3 Evaluation methods to measure rouge
- D-4 Methods to remediate the presence of rouge in a system

**Table D-2-1 Considerations That Affect the Amount of Rouge Formation During the Fabrication of a System**

| Variables | Considerations |
|---|---|
| Category 3 — Strong Influence on the Formation of Rouge [Note (1)] | |
| Alloy selection | Selection of the proper alloy (e.g., 316L-type or 6 moly-type stainless steel) should address the corrosive effects of the process conditions. For example, low-carbon stainless steel (316L-type) has better corrosion resistance than higher-carbon stainless steels (316-type). Beneficial alloys can mitigate premature or accelerated corrosion. Higher nickel content will enhance corrosion resistance. |
| Mechanical polishing/buffing | Striations from cold working techniques may include residual grinding/polishing debris in lapping inclusions. Cumulative increase of interior area due to surface finish inconsistency proportionally exposes more alloy to the mechanisms of corrosion and burden of passivation. |
| Electropolishing | Minimizes the exposure area of the alloy to oxidizing fluids or halides and minimizes the origins for micropitting by corrosion mechanisms. |
| Passivation | Impedes or retards corrosive development of stainless steel surfaces. The effectiveness of passivation methods in terms of depth and enhancement of surface alloy ratios (i.e., chrome to iron) determines the eventual propensity of an alloy to corrode and the rate of corrosion. |
| Alloy composition | (% molybdenum, chromium, nickel, etc.) The microstructure quality affects precipitation of impurities at grain boundaries. Migration of impurities to the alloy surface can either support corrosion cells or seed downstream corrosion. Weld joints on tubing and/or components with dissimilar sulfur concentrations may result in lack of penetration due to weld pool shift. The resulting crevice may become a corrosion initiation site. |
| Welding, welding conditions, purging, etc. | Improper welds can result in chromium-depleted heat-affected zones (HAZs) and other conditions that reduce corrosion resistance. Weld discontinuities create opportunities to trap fluid-borne impurities. Cracks resulting from poor welds will create breaches in the passive layer and form active corrosion cells. Proper purging prevents weld contamination by heat tint oxides and the concurrent loss of corrosion resistance. Passivation cannot reverse the effects of improper purging. |
| Product form and fabrication methods | The ferrite content can be greatly affected by the forming process (e.g., a forging will typically have much lower ferrite percentages than a casting). Barstock endgrain voids at the surface can enhance the potential of the alloy to pit and corrode. Minimization of differences in sulfur content will enhance the potential for successful welding. |
| Category 2 — Moderate Influence on the Formation of Rouge [Note (1)] | |
| Installation/storage environment | Unidentified corrosion due to the storage or installation environment, including carbon steel contamination, scratching, exposure to chemical contaminants, stagnated condensation or liquids, etc., may warrant a derouging step prior to passivation. Failure to detect instances of corrosion will marginalize the effect of a normal passivation. |
| Expansion and modifications to an established system | Oxide formations in newly commissioned systems can form at different rates than in older systems and initially generate migratory Class I rouge. Where oxide films exist in established systems, they are likely to be more stable, producing less migratory iron or chrome oxides. Because the newer system can generate and distribute lightly held Class I migratory hematite forms throughout the system, the corrosion origin and cause can be difficult to identify. |

NOTE: (1) There is well-established industry data supporting this, and it needs to be considered.

# 8. Installation & operation

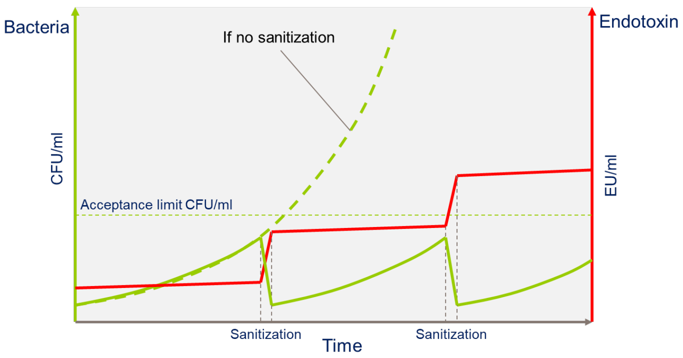
## – ISPE, FDA & ASME BPE

- Slope
- Space for inspection and service
- Pressure relief devices
- Over pressure
- Thermal shocks
- No drain of utility side

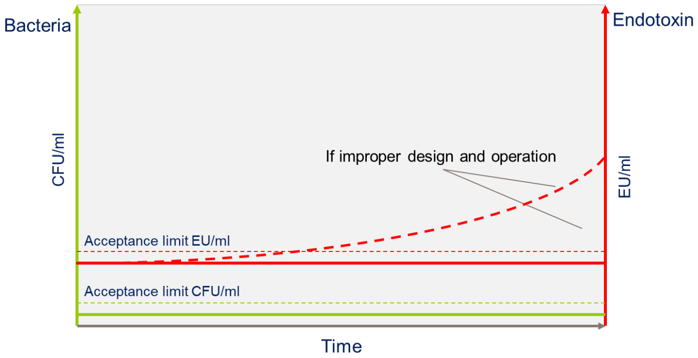
**Table SD-2.4.3.1-1 Slope Designations for Gravity-Drained Lines**

| Slope Designation | Minimum Slope, in./ft | Minimum Slope, mm/m | Minimum Slope, % | Minimum Slope, deg |
|---|---|---|---|---|
| GSD1 | 1/16 | 5 | 0.5 | 0.29 |
| GSD2 | 1/8 | 10 | 1.0 | 0.57 |
| GSD3 | 1/4 | 20 | 2.0 | 1.15 |
| GSD0 | Line slope not required | | | |

Ambient or cold system




Hot system



# 9. Service & maintenance

– ISPE & FDA

- Periodic disassembly and inspection
- Pressure testing
- Documentation
- Original spare parts

**§ 211.67 Equipment cleaning and maintenance.**

(a) Equipment and utensils shall be cleaned, maintained, and, as appropriate for the nature of the drug, sanitized and/or sterilized at appropriate intervals to prevent malfunctions or contamination that would alter the safety, identity, strength, quality, or purity of the drug product beyond the official or other established requirements.

(b) Written procedures shall be established and followed for cleaning and maintenance of equipment, including utensils, used in the manufacture, processing, packing, or holding of a drug product. These procedures shall include, but are not necessarily limited to, the following:

(1) Assignment of responsibility for cleaning and maintaining equipment;

(2) Maintenance and cleaning schedules, including, where appropriate, sanitizing schedules;

(3) A description in sufficient detail of the methods, equipment, and materials used in cleaning and maintenance operations, and the methods of disassembling and reassembling equipment as necessary to assure proper cleaning and maintenance;

(4) Removal or obliteration of previous batch identification;

(5) Protection of clean equipment from contamination prior to use;

(6) Inspection of equipment for cleanliness immediately before use.

(c) Records shall be kept of maintenance, cleaning, sanitizing, and inspection as specified in §§ 211.180 and 211.182.

*[43 FR 45077, Sept. 29, 1978, as amended at 73 FR 51931, Sept. 8, 2008]*

# Part 2: Guidance fulfilment and challenge solving

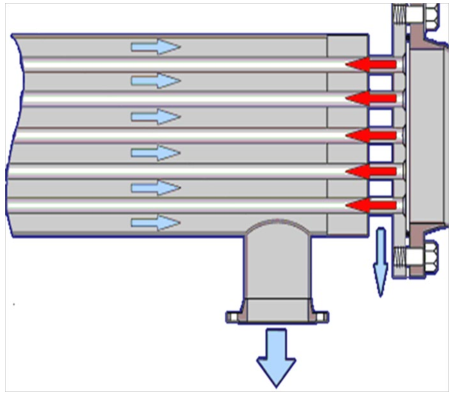
– With Alfa Laval Pharma-line S&T and Pharma-line Point of Use

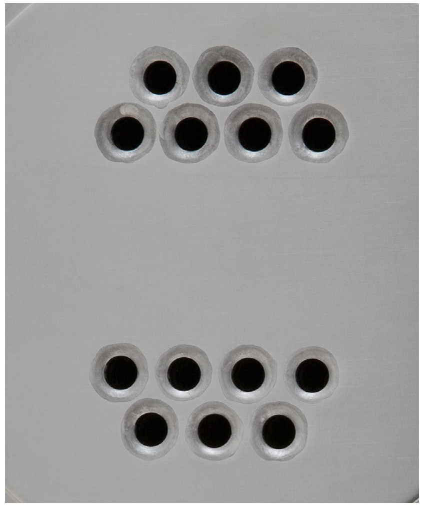
# Part 2: Guidance fulfilment and challenge solving

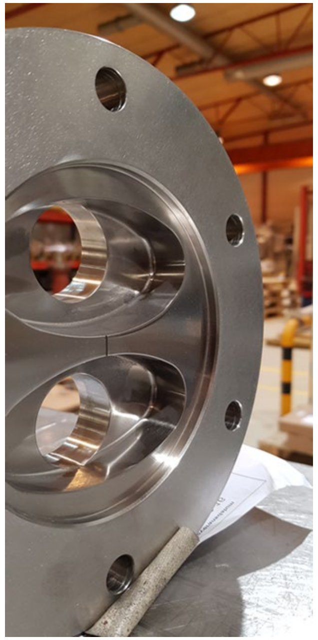
– With Alfa Laval Pharma-line S&T

# Cross contamination and sanitization

- Double tubesheet design
- Tube expansion
- U-bend design
- Weld
- Weep hole / Drain slot
- Slope







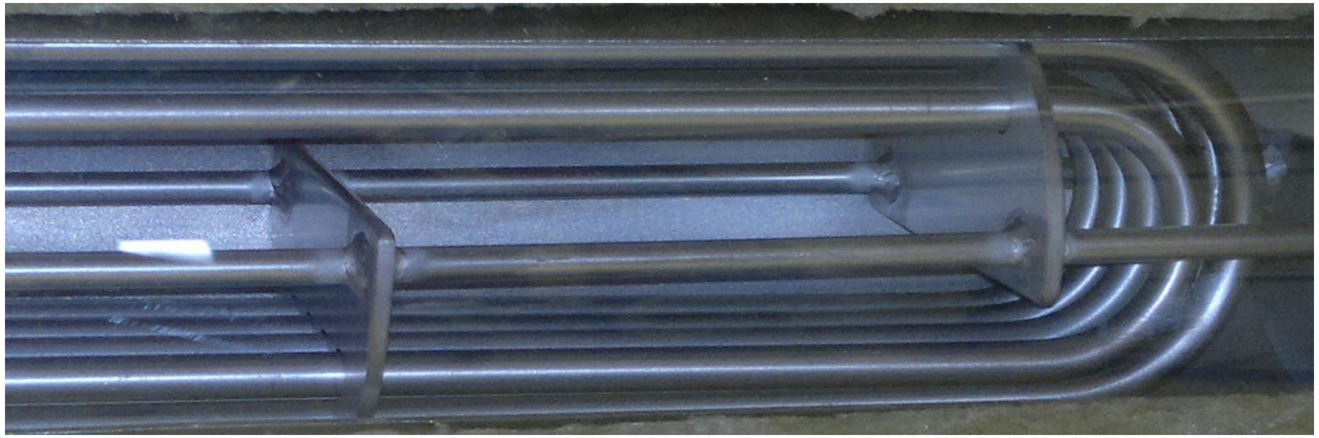
# U-bend

*(f)* Minimum recommended bend radii for heat exchangers should be as follows:

| Nominal Tube O.D. | | Minimum Bend Radius | |
|---|---|---|---|
| in. | mm | in. | mm |
| 0.375 | 9.5 | 0.625 | 15.2 |
| 0.500 | 12.7 | 0.750 | 19.1 |
| 0.625 | 15.8 | 0.938 | 23.8 |
| 0.750 | 19.1 | 1.125 | 28.6 |
| 1.000 | 25.4 | 1.500 | 38.1 |

| Nominal tube O.D. | Minimum Bend Radius |
|---|---|
| 8 | 22 |
| 10 | 23 |
| 14 | 36 |

In Alfa Laval Pharma-line we are going beyond ASME BPE recommendation for bending radius



# U-bend

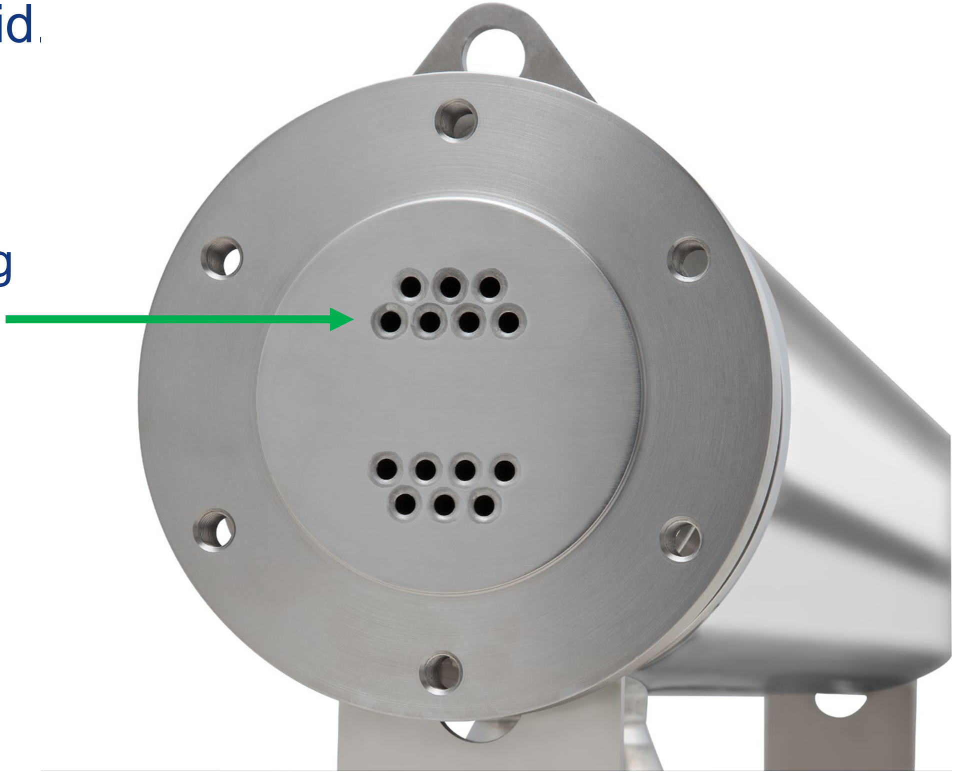
Bad bending makes SCC
(Stress Corrosion Cracking)

In Alfa Laval Pharma-line we are going beyond the ASME BPE recommendation for bending radius

# Weld

MJ-8.1 The weld shall not have any discontinuities such as cracks, voids, porosity, or joint misalignment that will promote contamination of the process fluid.

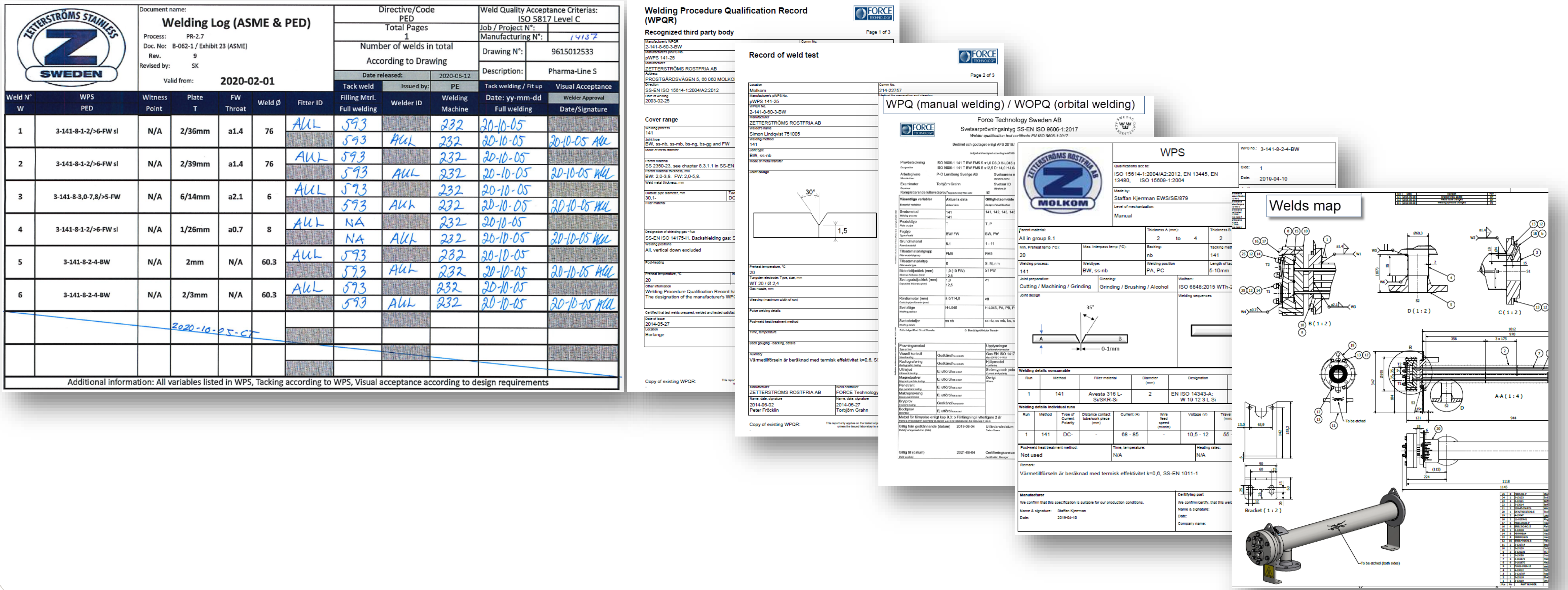
- Careful welding
- No grinding



- Grinding to correct bad welds causes weak construction and porosity
- Bad welding causes roughing

# Weld Documentation

## Weld log, WPQR, WPQ, WOPQ, WPS, Weld map



ZETTERSTRÖMS STAINLESS — SWEDEN

Document name: **Welding Log (ASME & PED)**
Process: PR-2.7
Doc. No: B-062-1 / Exhibit 23 (ASME)
Rev. 9
Revised by: SK
Valid from: 2020-02-01

Directive/Code: PED
Total Pages: 1
Number of welds in total According to Drawing
Date released: 2020-06-12 — Issued by: PE

Weld Quality Acceptance Criterias: ISO 5817 Level C
Job / Project N°:
Manufacturing N°: 14137
Drawing N°: 9615012533
Description: Pharma-Line S

| Weld N° W | WPS PED | Witness Point | Plate T | FW Throat | Weld Ø | Fitter ID | Tack weld / Filling Mtrl. / Full welding | Welder ID | Welding Machine | Tack welding / Fit up Date: yy-mm-dd / Full welding | Visual Acceptance, Welder Approval, Date/Signature |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3-141-8-1-2/>6-FW sl | N/A | 2/36mm | a1.4 | 76 | AUL | 593 / 593 | AUL | 232 / 232 | 20-10-05 / 20-10-05 | 20-10-05 AUL |
| 2 | 3-141-8-1-2/>6-FW sl | N/A | 2/39mm | a1.4 | 76 | AUL | 593 / 593 | AUL | 232 / 232 | 20-10-05 / 20-10-05 | 20-10-05 AUL |
| 3 | 3-141-8-3,0-7,8/>5-FW | N/A | 6/14mm | a2.1 | 6 | AUL | 593 / 593 | AUL | 232 / 232 | 20-10-05 / 20-10-05 | 20-10-05 AUL |
| 4 | 3-141-8-1-2/>6-FW sl | N/A | 1/26mm | a0.7 | 8 | AUL | NA / NA | AUL | 232 / 232 | 20-10-05 / 20-10-05 | 20-10-05 AUL |
| 5 | 3-141-8-2-4-BW | N/A | 2mm | N/A | 60.3 | AUL | 593 / 593 | AUL | 232 / 232 | 20-10-05 / 20-10-05 | 20-10-05 AUL |
| 6 | 3-141-8-2-4-BW | N/A | 2/3mm | N/A | 60.3 | AUL | 593 / 593 | AUL | 232 / 232 | 20-10-05 / 20-10-05 | 20-10-05 AUL |
| | 2020-10-05-CT | | | | | | | | | | |

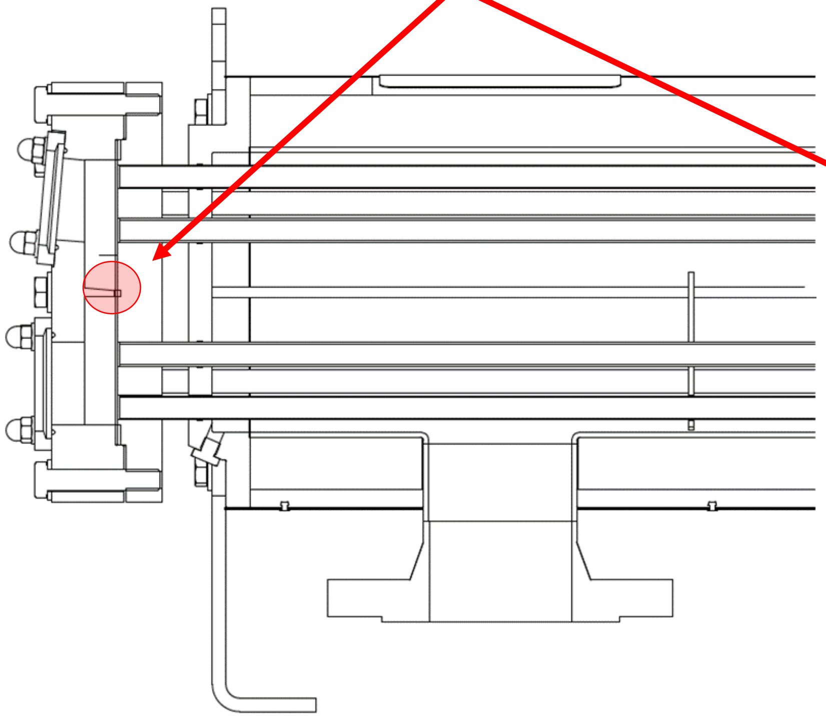
Additional information: All variables listed in WPS, Tacking according to WPS, Visual acceptance according to design requirements

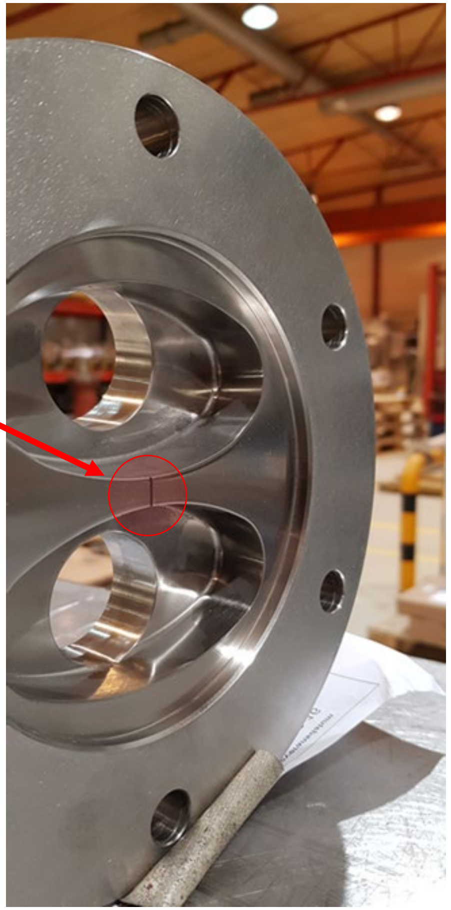
# Weep hole / Drain slot

## ASME BPE 2019 Chapter 2 : Design

- SD-3.6.1 G : Construction

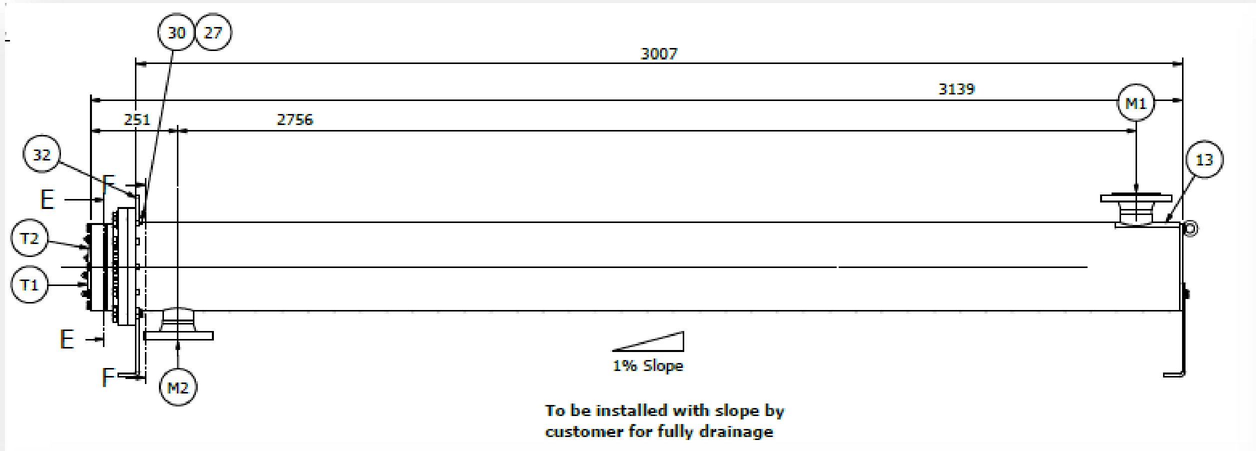
Pass rib drain slot in bonnet



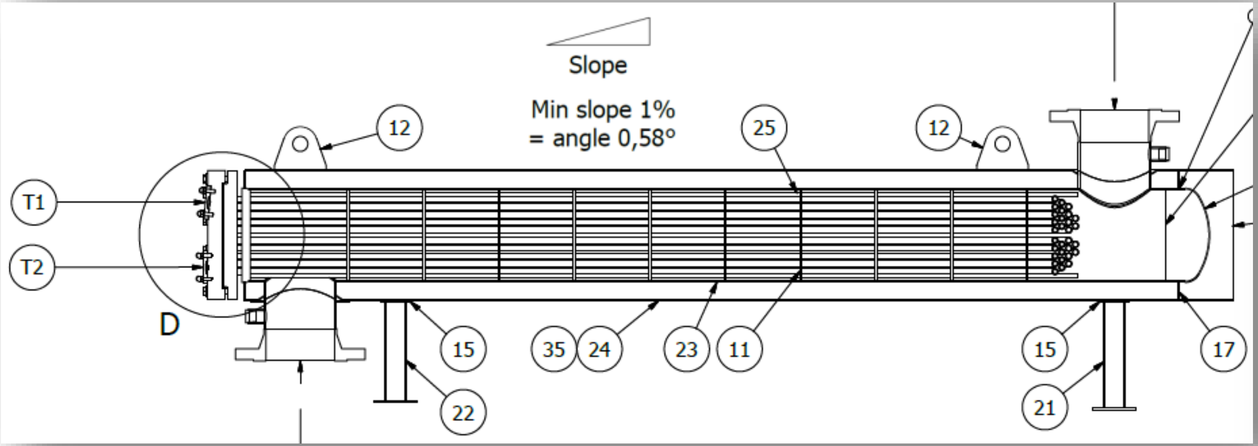


# Slope

Pharma-line S

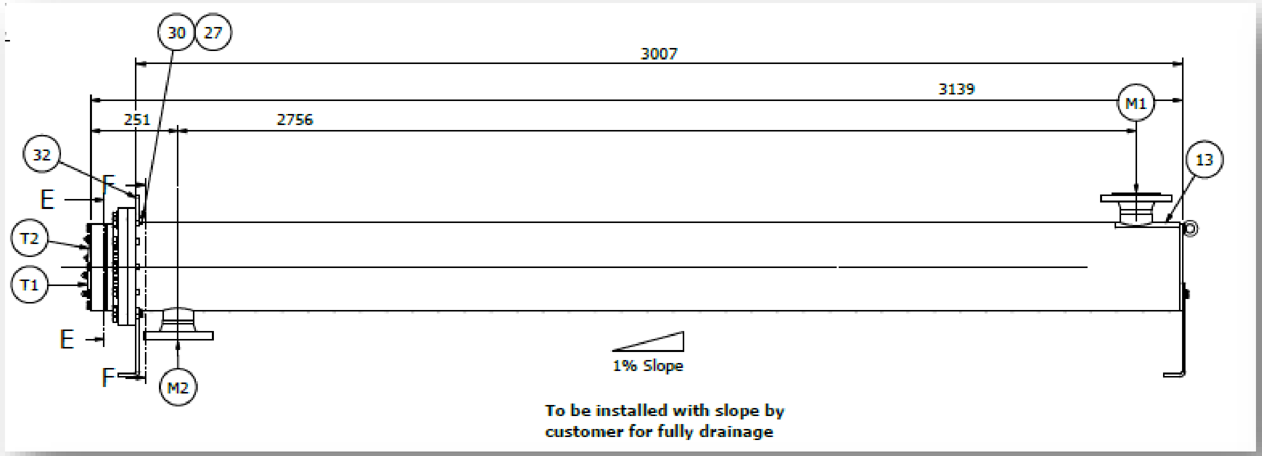



Pharma-line P

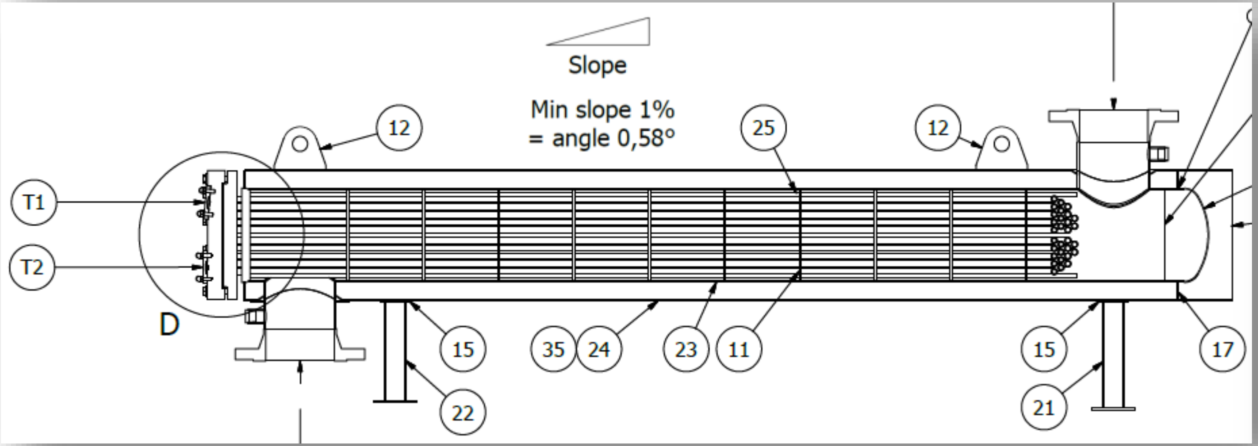



# Slope

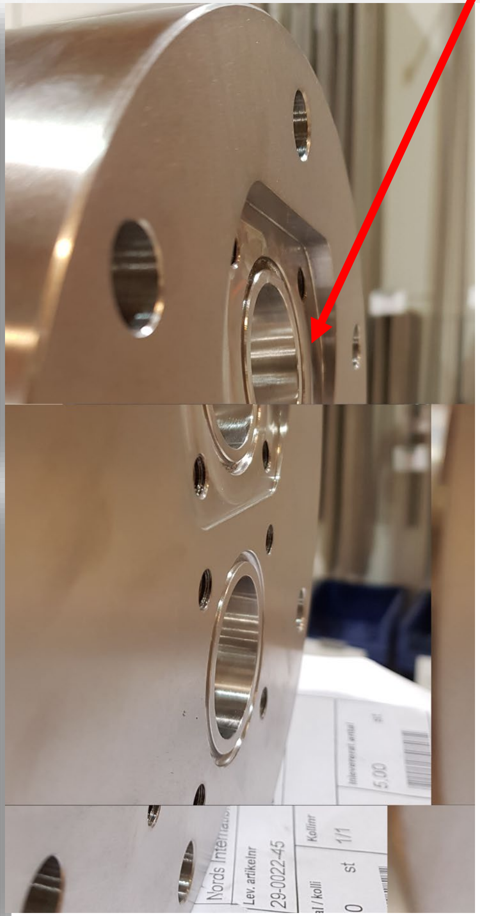
Pharma-line S




Pharma-line P




Inlet slope



# Velocity

## Pharma-line S&T are sized for turbulent flow

**Tubeside Incremental Monitor** Page 1 … Page 6

Released to the following HTRI Member Company:

*Alfa Laval*

*Alfa Laval*

Xist 8.0.1 2021-11-04 15:30 SN: 00571-500098257 **SI Units**

9615012521 BEU14-16-3

Rating - Horizontal Multipass Flow Small BEU Shell With Single-Segmental Baffles

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Point number | (--) | 1 | 2 | 3 | 4 | 5 | 6 | | 35 | 36 |
| Tube Pass | (--) | 1 | 1 | 1 | 1 | 1 | 1 | | 2 | 2 |
| Local Reynolds | (--) | 26815 | 26826 | 25608 | 24722 | 23881 | 23082 | | 11673 | 11668 |
| Vapor Reynolds | (--) | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | | 0,0000 | 0,0000 |
| Liquid Reynolds | (--) | 27614 | 26826 | 25608 | 24722 | 23881 | 23082 | ….. | 11673 | 11543 |

# Surface finish

### Surface Measurement Report of all different pipe for Pharma-line

**Surface Ra-measurement pipe before bending and after bending.**

- We have cut 2 pipe 8x1, 3 pipe 10x1 and 3 pipe 14x1 and taken RA- measurement for all pipes. From the beginning all pipes are RA<0,4µm Electropolished
- We have taken RA- measurement before and after the bending. In the protocol below can you see radius of the bending.
- After the bending all the pipes are within the specified surface finish.

Example

| Product | Before bending 1 point | After bending 3 point |
|---|---|---|
| Rör 8x1 Radie 22 (inner) | 0.119µm | 0.376µm / 0.373µm / 0.145µm |
| Rör 8x1 Radie 32 (outer) | 0.099µm | 0.199µm / 0.085µm / 0.244µm |
| Rör 10x1 Radie 22 (inner) | 0.132µm | 0.210µm / 0.165µm / 0.330µm |
| Rör 10x1 Radie 34 (middle) | 0.104µm | 0.266µm / 0.176µm / 0.311µm |
| Rör 10x1 Radie 46 (outer) | 0.074µm | 0.152µm / 0.331µm / 0.242µm |
| Rör 14x1 Radie 36 (inner) | 0.163µm | 0.222µm / 0.149µm / 0.231µm |
| Rör 14x1 Radie 52 (middle) | 0.234µm | 0.260µm / 0.235µm / 0.267µm |
| Rör 14x1 Radie 67 (ytter) | 0.081µm | 0.292µm / 0.160µm / 0.183µm |

Date: 2013-10-25

Clarification of signature

Kristina Olsson
Quality Manager
Zetterströms Rostfria AB

**Table SF-2.2-1 Acceptance Criteria for Metallic Process Contact Surface Finishes**

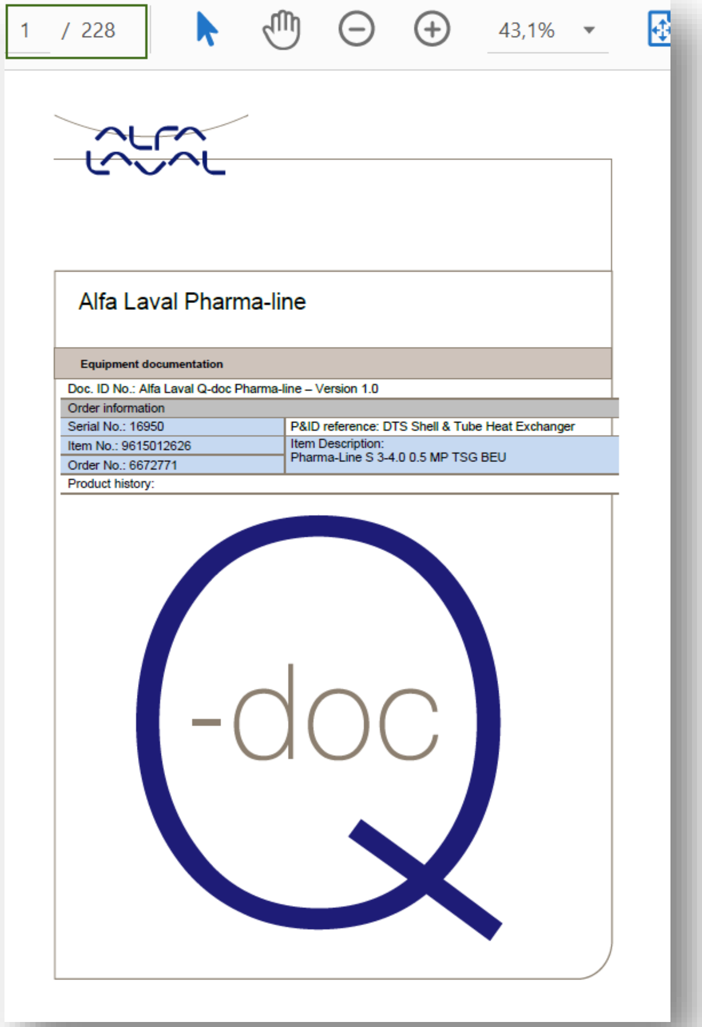
| Anomaly or Indication | Acceptance Criteria |
|---|---|
| Pits/porosity | If diameter <0.020 in. (0.51 mm) and bottom is shiny [Notes (1) and (2)]. Pits <0.003 in. (0.08 mm) diameter are irrelevant and acceptable. |
| Cluster of pits/porosity | No more than 4 pits per 0.5 in. (13 mm) × 0.5 in. (13 mm) inspection window. The cumulative total diameter of all relevant pits shall not exceed 0.040 in. (1.02 mm). |
| Dents | None accepted [Note (3)] |
| Finishing marks | If $R_a$ max. is met |
| Welds | Welds used in the as-welded condition shall meet the requirements of MJ-8.<br>Welds finished after welding shall be flush with the base metal, and concavity and convexity shall meet the requirements of MJ-8. Such finishing shall meet the $R_a$ requirements of Table SF-2.4.1-1. |
| Nicks | None accepted |
| Scratches | For tubing, if cumulative length is <12.0 in. (305 mm) per 20 ft (6.1 m) tube length or prorated and if depth is <0.003 in. (0.08 mm)<br>For fittings, valves, and other process components, if cumulative length is <0.25 in. (6.4 mm), depth <0.003 in. (0.08 mm), and $R_a$ max. is met<br>For vessels, if length <0.50 in. (13 mm) at 0.003 in. (0.08 mm) depth and if <3 per inspection window [Note (4)] |
| Surface cracks | None accepted |
| Surface inclusions | If $R_a$ max. is met |
| Surface residuals | None accepted, visual inspection |
| Surface roughness ($R_a$) | See Table SF-2.4.1-1 |
| Weld slag | For tubing, up to 3 per 20 ft (6.1 m) length or prorated, if <75% of the width of the weld bead<br>For fittings, valves, vessels, and other process components, none accepted (as welded shall meet the requirements of MJ-8 and Table MJ-8.4-1) |
| Blistering | None accepted |

GENERAL NOTE: This table covers surface finishes that are mechanically polished or any other finishing method that meets the $R_a$ max.

NOTES:
(1) Black bottom pit of any depth is not acceptable.
(2) Pits in superaustenitic and nickel alloys may exceed this value. Acceptance criteria for pit size shall be established by agreement between owner/user and supplier. All other pit criteria remain the same.
(3) For vessels, dents in the area covered by and resulting from welding dimple heat transfer jackets are acceptable.
(4) An inspection window is defined as an area 4 in. × 4 in. (100 mm × 100 mm).

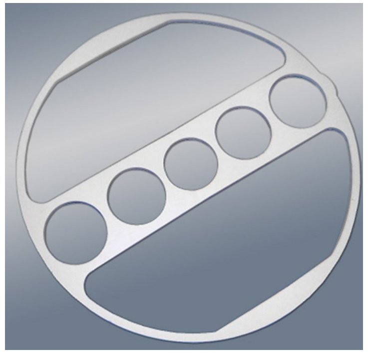
# Comprehensive documentation

- Certificate of design-examination, approved drawings and calculations
- List of welders + Weld procedure + Welder qualification
- Material certificates for pressure and product referred parts, 3.1 Certificate
- Component certificates
- Liquid Penetrant Test Report and procedure
- Surface treatment test report + Ra values (if demand)
- Dimension control report
- Pressure test certificate (signed by Notified body)
- Identification (technical sign)
- CE-Documents
- Installation, Operation and maintenance manual
- Quality System certificates (ISO9000:2000, ASME)



# Alfa Laval support

- Selection & Sizing
- Installation
- Operation
- Service & Maintenance
- Inspection
- Cleaning
- Etc.

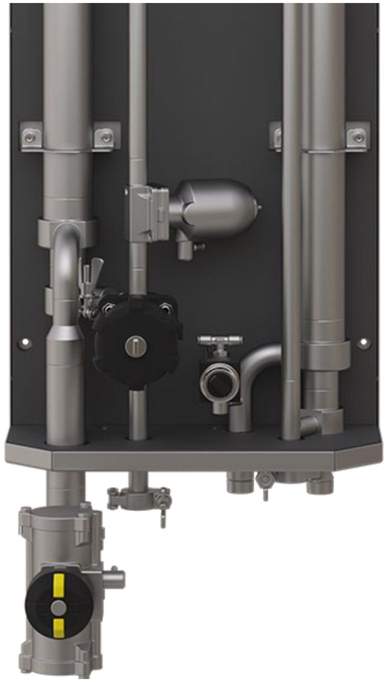


# Part 2: Guidance fulfilment and challenge solving

– Pharma-line Point of Use

# Cross contamination and sanitization

- No internal welds
- U-bend design
- Mounting vertical
- Drain in lower points
- No dead leg, L/D < 2
- High Reynold number > 4000
- Self-sanitization in standby mode



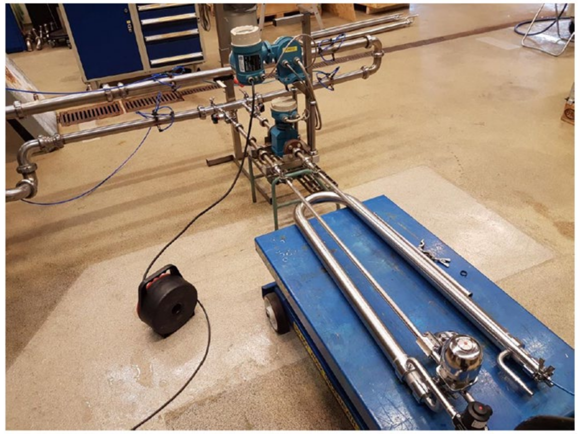
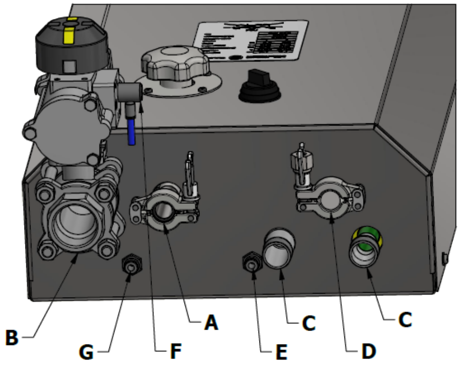


**Figure 6** *PoU200 and 2" pitot tube connected to test rig, TR1 for Stand-by-mode test.*



# Pharma-line Point of Use

Video


QUESTION
ANSWER

# Contacts

– For questions or support

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