RUHRPUMPEN

Specialist for Pumping Technology

Sessions 13 & 14 – Performance Testing and Inspection of API 610 Pumps

Simon Smith March 2022







Presenter Profile – Simon Smith

Simon graduated with an honours degree in Chemical Engineering from the University of Surrey in 1978 and began a long career in the engineered pump industry spanning 40 years (so far!) with Peerless Pump, BW/IP International / Flowserve, SPP Pumps, Ruhrpumpen and Ebara Cryodynamics.

Over his long career he has filled various roles as Applications Engineer / Manager, Project Manager, Key Account Specialist, Vertical Pump Product Specialist, International Sales Engineer / Manager / Director and he has considerable experience in Training & Mentoring young engineers.

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Ruh*RP*umpen Short Courses

Here is a listing of all the previous courses.

- No 1 – API610 12th v 11th editions
- No 2 - Curve Shape
- No 3 – The Importance of System Curves
- No 4 - Selecting the Right Pump for the Application
- No 5 - NPSH & Nss
- No 6 - Mechanical Seals & Systems
- No 7 - Firepumps
- No 8 - BB5 Barrel Pumps
- No 9 - Pump Instrumentation
- No 10 – Non-Destructive Examination
- No 11 - Vertical Pumps (Part 1) Type VS1, VS2, VS3
- No 12 – Vertical Pumps (Part 2) Type VS4, VS5, VS6 & VS7
- No 13 – Performance Testing of Centrifugal Pumps; the What, the Why & the How

Any you have missed you can get from our website using this link https://short-courses.ruhrpumpen.com/

Or from www.ruhrpumpen.com and follow the link to RP Short Courses

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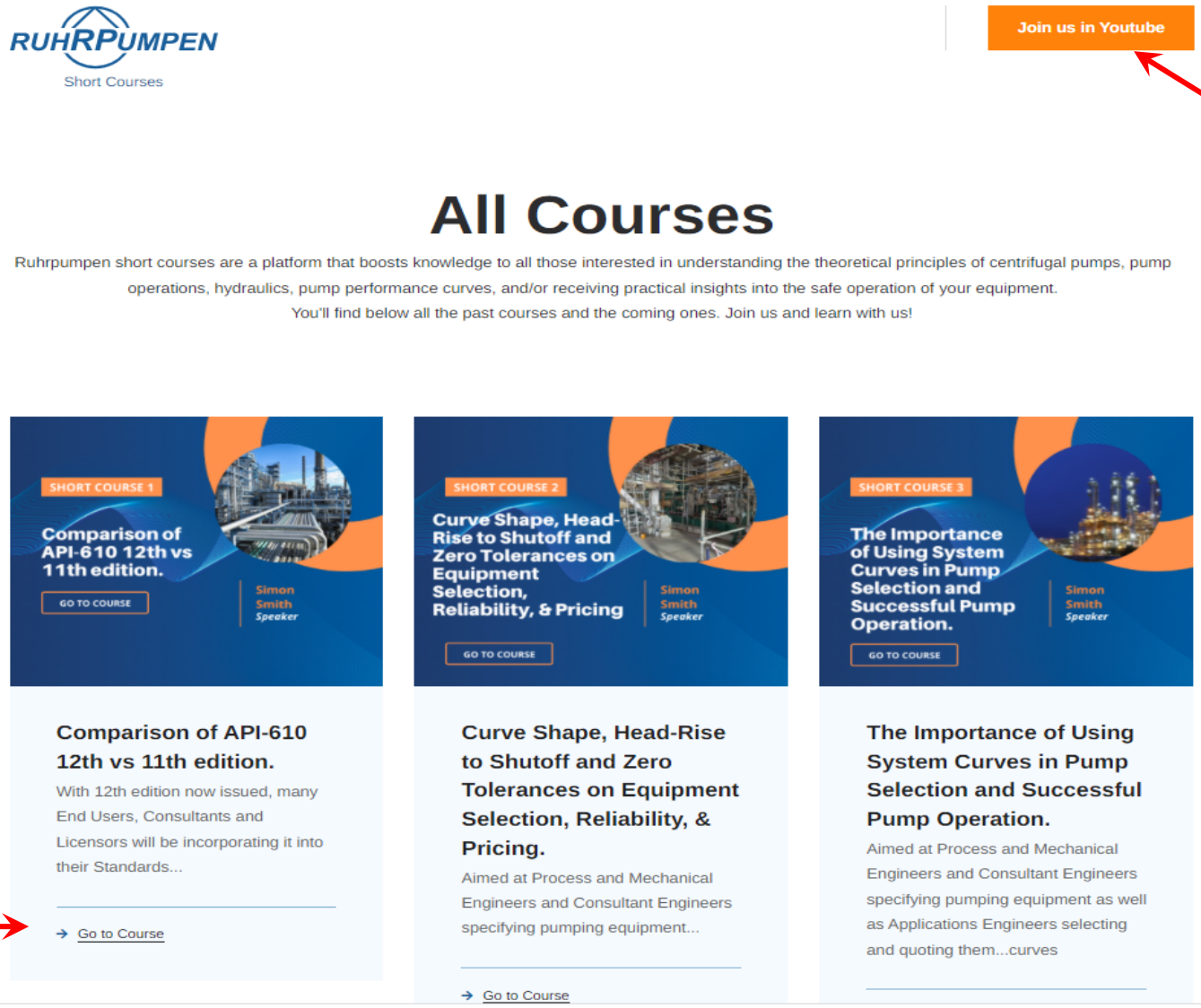


Session 14 – “Performance Testing & Inspection of API 610 Pumps”

Aimed at Process and Mechanical Engineers, and Consultant Engineers who specify pumping equipment as well as Applications & Sales Engineers selecting and quoting them.
Session 13 looked at the What, the Why and the How of Pump Performance Testing and now in Session 14 we look at the various Inspections & Tests that are frequently specified on the Data Sheets (Session 14).

Source Material – Jennifer Knox Global Product Line Manager BB4/BB5

Purpose of this presentation

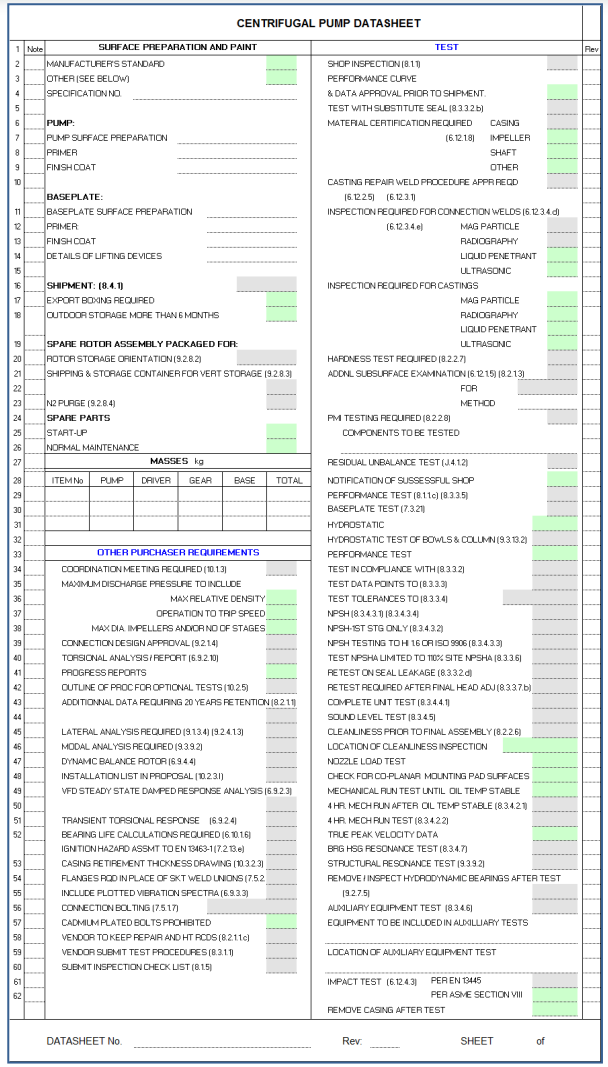
- To give an overview of the types of testing discussed in API 610 11th Edition
- Brief description of methodology and intention of tests and inspections
- Important points from perspective of sales and quotations

Additional descriptions and details of each test are provided in other presentations.

API 610 Datasheet

- Page 5 of the API 610 datasheet reflects the testing and inspection requirements for the pump
- Most lines in the datasheet include an API 610 paragraph reference
- Cells are colour coded
- Drop-down options are mostly Yes/No or Non-Wit/Wit/Obs
- This is a change from previous editions on API where datasheets had check-boxes to indicate if a test was required and different columns for witnesses/non witnessed

	contain drop-down options
	contain calculated values based on input data that do not change.
	identifies a cross-referenced paragraph in the document; note may also contain a drop-down list



CENTRIFUGAL PUMP DATASHEET

Note	SURFACE PREPARATION AND PAINT		TEST		Rev
	MANUFACTURER'S STANDARD		SHOP INSPECTION (8.1.1)		
	OTHER (SEE BELOW)		PERFORMANCE CURVE		
	SPECIFICATION NO.		& DATA APPROVAL PRIOR TO SHIPMENT		
			TEST WITH SUBSTITUTE SEAL (8.3.3.2.b)		
	PUMP:		MATERIAL CERTIFICATION REQUIRED (6.12.1.8)	CASING	
	PUMP SURFACE PREPARATION			IMPELLER	
	PRIMER			SHAFT	
	FINISH COAT			OTHER	
			CASTING REPAIR WELD PROCEDURE APPR REQD (6.12.2.5) (6.12.3.1)		
	BASEPLATE:		INSPECTION REQUIRED FOR CONNECTION WELDS (6.12.3.4.d)		
	BASEPLATE SURFACE PREPARATION		(6.12.3.4.e)	MAG PARTICLE	
	PRIMER			RADIOGRAPHY	
	FINISH COAT			LIQUID PENETRANT	
	DETAILS OF LIFTING DEVICES			ULTRASONIC	
			INSPECTION REQUIRED FOR CASTINGS		
	SHIPMENT: (8.4.1)			MAG PARTICLE	
	EXPORT BOXING REQUIRED			RADIOGRAPHY	
	OUTDOOR STORAGE MORE THAN 6 MONTHS			LIQUID PENETRANT	
				ULTRASONIC	
	SPARE ROTOR ASSEMBLY PACKAGED FOR:		HARDNESS TEST REQUIRED (8.2.2.7)		
	ROTOR STORAGE ORIENTATION (9.2.8.2)		ADDNL SUBSURFACE EXAMINATION (6.12.1.5) (8.2.1.3)		
	SHIPPING & STORAGE CONTAINER FOR VERT STORAGE (9.2.8.3)			FOR	
				METHOD	
	N2 PURGE (9.2.8.4)		PMI TESTING REQUIRED (8.2.2.8)		
	SPARE PARTS		COMPONENTS TO BE TESTED		
	START-UP				
	NORMAL MAINTENANCE		RESIDUAL UNBALANCE TEST (J.4.1.2)		
	MASSES kg		NOTIFICATION OF SUSSESSFUL SHOP		
	ITEM No. / PUMP / DRIVER / GEAR / BASE / TOTAL		PERFORMANCE TEST (8.1.1.c) (8.3.3.5)		
			BASEPLATE TEST (7.3.2.1)		
			HYDROSTATIC		
	OTHER PURCHASER REQUIREMENTS		HYDROSTATIC TEST OF BOWLS & COLUMN (9.3.13.2)		
	COORDINATION MEETING REQUIRED (10.1.3)		PERFORMANCE TEST		
	MAXIMUM DISCHARGE PRESSURE TO INCLUDE		TEST IN COMPLIANCE WITH (8.3.3.2)		
	MAX RELATIVE DENSITY		TEST DATA POINTS TO (8.3.3.3)		
	OPERATION TO TRIP SPEED		TEST TOLERANCES TO (8.3.3.4)		
	MAX DIA. IMPELLERS AND/OR NO OF STAGES		NPSH (8.3.4.3.1) (8.3.4.3.4)		
	CONNECTION DESIGN APPROVAL (9.2.1.4)		NPSH-IST STG ONLY (8.3.4.3.2)		
	TORSIONAL ANALYSIS / REPORT (6.9.2.10)		NPSH TESTING TO HI 1.6 OR ISO 9906 (8.3.4.3.3)		
	PROGRESS REPORTS		TEST NPSHA LIMITED TO 110% SITE NPSHA (8.3.3.6)		
	OUTLINE OF PROC FOR OPTIONAL TESTS (10.2.5)		RETEST ON SEAL LEAKAGE (8.3.3.2.d)		
	ADDITIONNAL DATA REQUIRING 20 YEARS RETENTION (8.2.1.1)		RETEST REQUIRED AFTER FINAL HEAD ADJ (8.3.3.7.b)		
			COMPLETE UNIT TEST (8.3.4.4.1)		
	LATERAL ANALYSIS REQUIRED (9.1.3.4) (9.2.4.1.3)		SOUND LEVEL TEST (8.3.4.5)		
	MODAL ANALYSIS REQUIRED (9.3.9.2)		CLEANLINESS PRIOR TO FINAL ASSEMBLY (8.2.2.6)		
	DYNAMIC BALANCE ROTOR (6.9.4.4)		LOCATION OF CLEANLINESS INSPECTION		
	INSTALLATION LIST IN PROPOSAL (10.2.3.1)		NOZZLE LOAD TEST		
	VFD STEADY STATE DAMPED RESPONSE ANALYSIS (6.9.2.3)		CHECK FOR CO-PLANAR MOUNTING PAD SURFACES		
			MECHANICAL RUN TEST UNTIL OIL TEMP STABLE		
	TRANSIENT TORSIONAL RESPONSE (6.9.2.4)		4 HR. MECH RUN AFTER OIL TEMP STABLE (8.3.4.2.1)		
	BEARING LIFE CALCULATIONS REQUIRED (6.10.1.6)		4 HR. MECH RUN TEST (8.3.4.2.2)		
	IGNITION HAZARD ASSMT TO EN 13463-1 (7.2.13.e)		TRUE PEAK VELOCITY DATA		
	CASING RETIREMENT THICKNESS DRAWING (10.3.2.3)		BRG HSG RESONANCE TEST (8.3.4.7)		
	FLANGES RQD IN PLACE OF SKT WELD UNIONS (7.5.2)		STRUCTURAL RESONANCE TEST (9.3.9.2)		
	INCLUDE PLOTTED VIBRATION SPECTRA (6.9.3.3)		REMOVE / INSPECT HYDRODYNAMIC BEARINGS AFTER TEST (9.2.7.5)		
	CONNECTION BOLTING (7.5.1.7)		AUXILIARY EQUIPMENT TEST (8.3.4.6)		
	CADMIUM PLATED BOLTS PROHIBITED		EQUIPMENT TO BE INCLUDED IN AUXILLIARY TESTS		
	VENDOR TO KEEP REPAIR AND HT RODS (8.2.1.1.c)				
	VENDOR SUBMIT TEST PROCEDURES (8.3.1.1)		LOCATION OF AUXILIARY EQUIPMENT TEST		
	SUBMIT INSPECTION CHECK LIST (8.1.5)				
			IMPACT TEST (6.12.4.3)	PER EN 13445	
				PER ASME SECTION VIII	
			REMOVE CASING AFTER TEST		

DATASHEET No. _____ Rev: _____ SHEET of

SHOP INSPECTION (PURCHASER PARTICIPATION IN TESTING)

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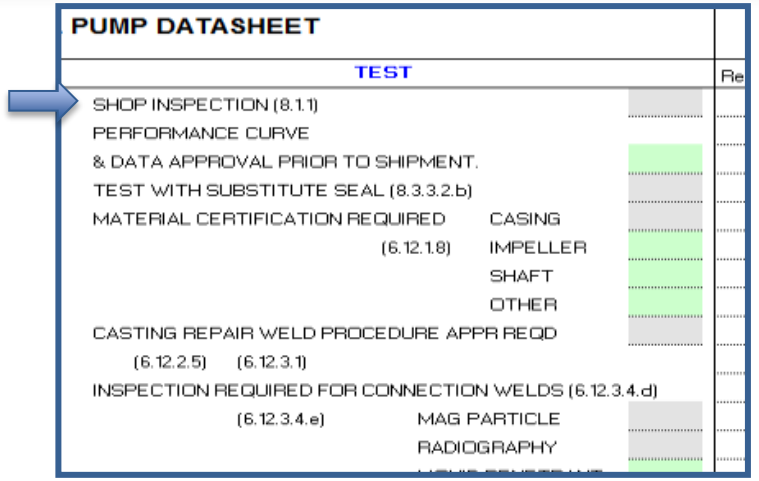
8.1.1 The purchaser shall specify the extent of his participation in the inspection and testing.

a) *If shop inspection and testing have been specified, the purchaser and the vendor shall coordinate manufacturing hold points and inspector's visits.*

b) *….. Unless otherwise agreed, the vendor shall give at least five working days advanced notification of a witnessed or observed inspection or test. …... All witnessed inspections and tests are hold points. For observed tests, the purchaser should expect to be in the factory longer than for a witnessed test.*


PUMP DATASHEET

TEST

SHOP INSPECTION (8.1.1)
PERFORMANCE CURVE
& DATA APPROVAL PRIOR TO SHIPMENT.
TEST WITH SUBSTITUTE SEAL (8.3.3.2.b)
MATERIAL CERTIFICATION REQUIRED (6.12.1.8) CASING IMPELLER SHAFT OTHER
CASTING REPAIR WELD PROCEDURE APPR REQD (6.12.2.5) (6.12.3.1)
INSPECTION REQUIRED FOR CONNECTION WELDS (6.12.3.4.d) (6.12.3.4.e) MAG PARTICLE RADIOGRAPHY

observed test
inspection or test where the purchaser is notified of the timing of the inspection or test and the inspection or test is performed as scheduled, regardless of whether the purchaser or his representative is present

witnessed inspection
inspection or test for which the purchaser is notified of the timing of the inspection or test and a hold is placed on the inspection or test until the purchaser or his representative is in attendance

- In the case of an observed test: if the purchasers representative chooses not to attend the test on the notified day the vendor can proceed with the test regardless.
- But a witness test is a hold point, so if the purchaser's representative does not arrive for the test the vendor CANNOT proceed.
- RuhRPumpen considers that observed and witnessed tests are equivalent for the purposes of time and price adder because in both cases the pump must pass a check test before a second test for witness/observation and the witnessed / observed test will necessarily be during normal working hours rather than 2nd shift or week-ends at a moment's notice.

TEST WITH SUBSTITUTE SEAL

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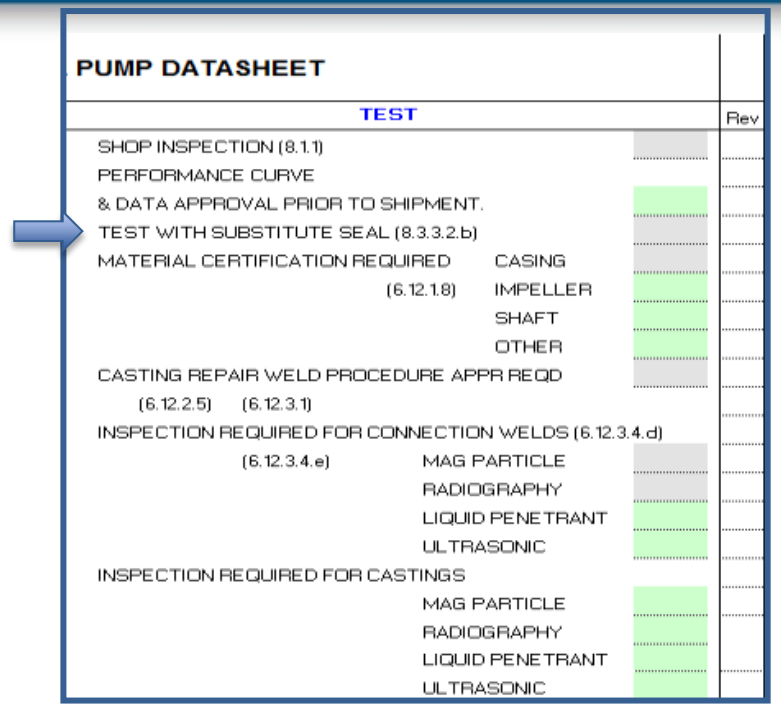
8.3.3.2 b) If approved by the purchaser, substitute seals may be used during the performance test if needed to prevent damage to the contract seals or if the contract seals are not compatible with the test liquid….



PUMP DATASHEET			
TEST			Rev
SHOP INSPECTION (8.1.1)			
PERFORMANCE CURVE			
& DATA APPROVAL PRIOR TO SHIPMENT.			
TEST WITH SUBSTITUTE SEAL (8.3.3.2.b)			
MATERIAL CERTIFICATION REQUIRED		CASING	
	(6.12.1.8)	IMPELLER	
		SHAFT	
		OTHER	
CASTING REPAIR WELD PROCEDURE APPR REQD			
(6.12.2.5) (6.12.3.1)			
INSPECTION REQUIRED FOR CONNECTION WELDS (6.12.3.4.d)			
	(6.12.3.4.e)	MAG PARTICLE	
		RADIOGRAPHY	
		LIQUID PENETRANT	
		ULTRASONIC	
INSPECTION REQUIRED FOR CASTINGS			
		MAG PARTICLE	
		RADIOGRAPHY	
		LIQUID PENETRANT	
		ULTRASONIC	

- In almost all cases manufacturers will prefer to use contract seals for testing.
- We may wish to use a substitute mechanical seal if the contract seal could be damaged by running in water or if the mechanical seal is late/on critical path of the order and causing a delay to the schedule.
- For most product lines there is not a complete range of test seals available.

MATERIAL CERTIFICATION

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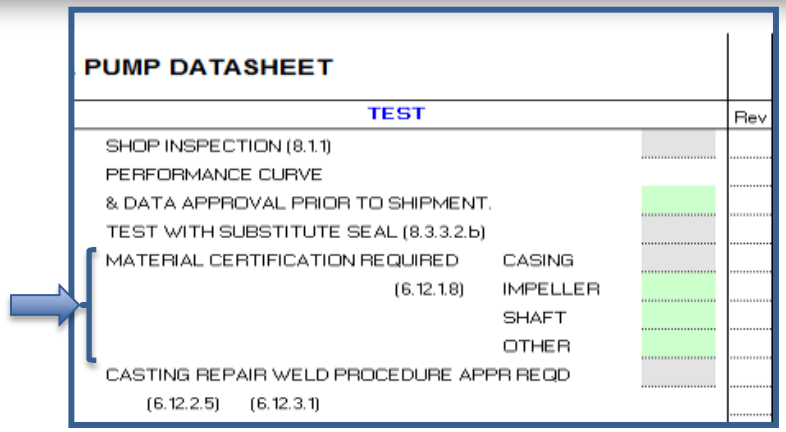
6.12.1.8 If specified, the vendor shall furnish material certificates that include chemical analysis and mechanical properties for the heats from which the material is supplied for pressure-containing castings and forgings, impellers and shafts. Unless otherwise specified, piping nipples, auxiliary piping components, and bolting are excluded from this requirement.



- 6.12.1.8 requires 3.1 Inspection Certificate (defined in EN 10204)
- These are also referred to as ‘Actual MTRs’
- 3.1 Inspection Certificates and Parts are tied together by the heat number which is unique combination of letters and numbers stamped on the part and listed on the certificate
- 2.2 and 3.2 certificates are sometimes required by customer in place of 3.1
- It is possible to provide 3.1 certificates on piping components, wear rings, bolting and other small components, but that is not included in this clause. They should not be offered unless clearly specified since they stock parts do not have MTRs and so they have to be order specially for the project.

MTR Type	Description
2.2	‘Typical MTR’. Material Test Report from similar parts and same material but not necessarily for the parts used in subject pump.
3.1	**“Actual MTR”. Material Test Report that is traceable to the actual parts used in subject pump. MTR is certified and signed by the manufacturer’s representative.**
3.2	Same as 3.1 MTR PLUS the MTR must be certified and signed by purchaser’s representative. In practice this means 3rd party inspector must witness the chemical and physical testing and validate MTR. Practically speaking this means duplicating the foundry / forge tests at an independent test laboratory.

MATERIAL CERTIFICATION

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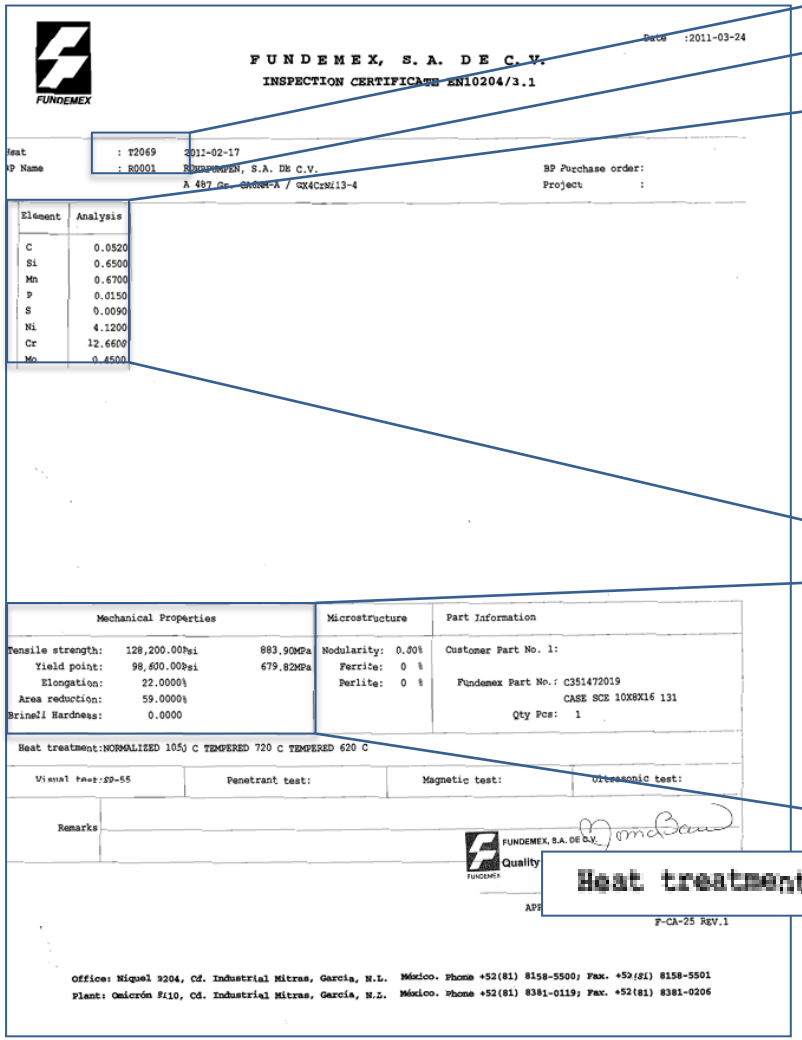

FUNDEMEX, S. A. DE C. V.
INSPECTION CERTIFICATE EN10204/3.1

Date :2011-03-24

Heat : T2069 2011-02-17
RP Name : R0001 RUHRPUMPEN, S.A. DE C.V.
A 487 Gr. CA6NM-A / GX4CrNi13-4
BP Purchase order:
Project :

Element	Analysis
C	0.0520
Si	0.6500
Mn	0.6700
P	0.0150
S	0.0090
Ni	4.1200
Cr	12.6600
Mo	0.4500

Mechanical Properties		
Tensile strength:	128,200.00Psi	883.90MPa
Yield point:	98,600.00Psi	679.82MPa
Elongation:	22.0000%	
Area reduction:	59.0000%	
Brinell Hardness:	0.0000	

Microstructure
Nodularity: 0.00%
Ferrite: 0 %
Perlite: 0 %

Part Information
Customer Part No. 1:
Fundemex Part No.: C351472019
CASE SCE 10X8X16 131
Qty Pcs: 1

Heat treatment:NORMALIZED 105) C TEMPERED 720 C TEMPERED 620 C

Visual test:20-55 | Penetrant test: | Magnetic test: | Ultrasonic test:

Remarks

FUNDEMEX, S.A. DE C.V. Quality

F-CA-25 Rev.1

Office: Miquel 3204, Cd. Industrial Mitras, García, N.L. México. Phone +52(81) 8158-5500; Fax. +52(81) 8158-5501
Plant: Omicrón 5110, Cd. Industrial Mitras, García, N.L. México. Phone +52(81) 8381-0119; Fax. +52(81) 8381-0206

: T2069

Heat Number

Element	Analysis
C	0.0520
Si	0.6500
Mn	0.6700
P	0.0150
S	0.0090
Ni	4.1200
Cr	12.6600
Mo	0.4500

Element analysis.
Criteria for % composition for materials is defined by applicable ASTM specification.

Mechanical Properties		
Tensile strength:	128,200.00Psi	883.90MPa
Yield point:	98,600.00Psi	679.82MPa
Elongation:	22.0000%	
Area reduction:	59.0000%	
Brinell Hardness:	0.0000	

Mechanical Properties.
Limits and requirements are defined for each material by appropriate ASTM specification.

Heat treatment:NORMALIZED 105) C TEMPERED 720 C TEMPERED 620 C

Heat treatment details, NACE compliance, hardness tests and other special requirements will also be recorded

CASTING WELD REPAIR PROCEDURE

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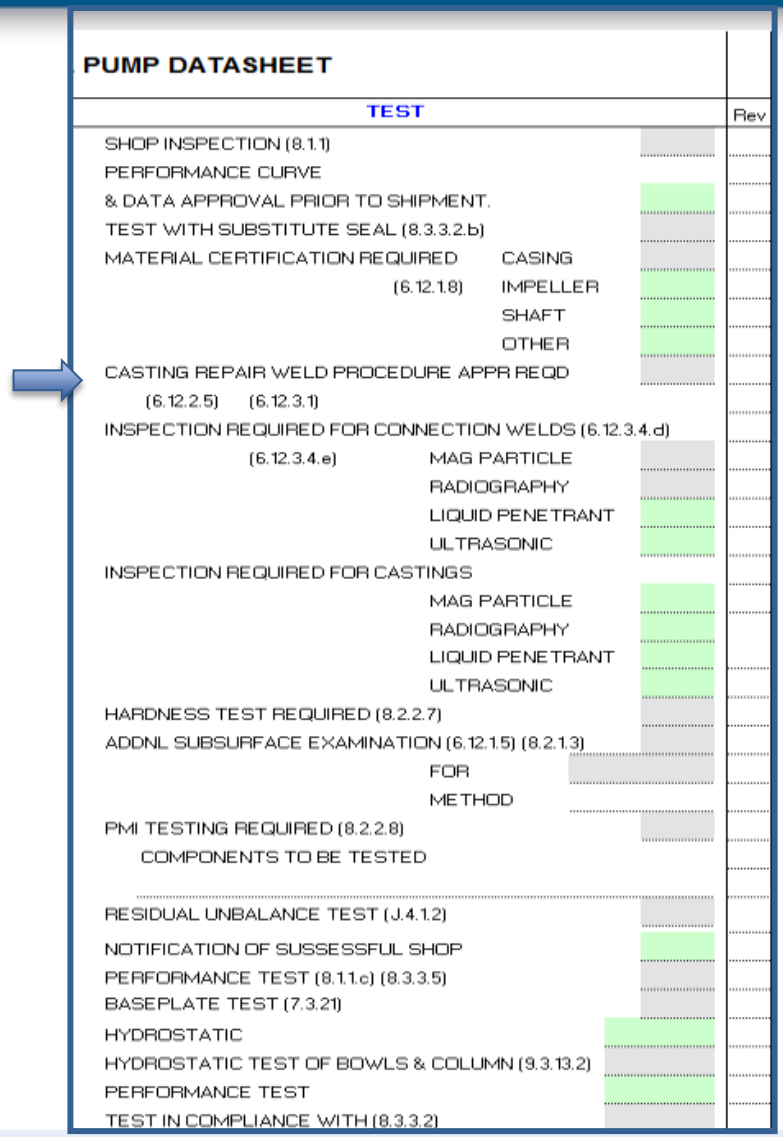
6.12.2.5 If specified, for casting repairs made in the vendor's shop, repair procedures including weld maps shall be submitted for purchaser's approval. The purchaser shall specify if approval is required before proceeding with repair …….

6.12.2.5 will be handled by Project Engineering/Production during order process if the requirement is defined in the datasheet or the specification. If approval is required before proceeding with repair the impact is potentially a delay to the schedule while repair procedures are created and then approved by the customer.

6.12.3.1 Welding and weld repairs shall be performed by operators and in accordance with procedures qualified to the requirements of Table 11…...



PUMP DATASHEET

TEST		Rev
SHOP INSPECTION (8.1.1)		
PERFORMANCE CURVE & DATA APPROVAL PRIOR TO SHIPMENT.		
TEST WITH SUBSTITUTE SEAL (8.3.3.2.b)		
MATERIAL CERTIFICATION REQUIRED (6.12.1.8)	CASING	
	IMPELLER	
	SHAFT	
	OTHER	
CASTING REPAIR WELD PROCEDURE APPR REQD (6.12.2.5) (6.12.3.1)		
INSPECTION REQUIRED FOR CONNECTION WELDS (6.12.3.4.d) (6.12.3.4.e)	MAG PARTICLE	
	RADIOGRAPHY	
	LIQUID PENETRANT	
	ULTRASONIC	
INSPECTION REQUIRED FOR CASTINGS	MAG PARTICLE	
	RADIOGRAPHY	
	LIQUID PENETRANT	
	ULTRASONIC	
HARDNESS TEST REQUIRED (8.2.2.7)		
ADDNL SUBSURFACE EXAMINATION (6.12.1.5) (8.2.1.3)		
	FOR	
	METHOD	
PMI TESTING REQUIRED (8.2.2.8)		
COMPONENTS TO BE TESTED		
RESIDUAL UNBALANCE TEST (J.4.1.2)		
NOTIFICATION OF SUSSESSFUL SHOP PERFORMANCE TEST (8.1.1.c) (8.3.3.5)		
BASEPLATE TEST (7.3.21)		
HYDROSTATIC		
HYDROSTATIC TEST OF BOWLS & COLUMN (9.3.13.2)		
PERFORMANCE TEST TEST IN COMPLIANCE WITH (8.3.3.2)		

INSPECTION REQUIRED FOR CASE CONNECTION WELDS

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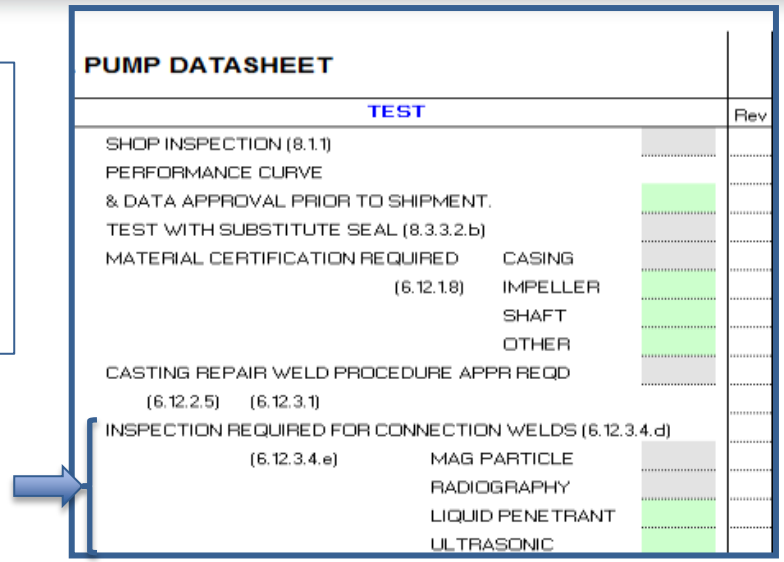
6.12.3.4 e) …. The purchaser shall specify if the following additional examinations shall be performed:

1) magnetic-particle or liquid-penetrant examination of auxiliary connection welds;

2) ultrasonic or radiographic examination of any casing welds.


PUMP DATASHEET

TEST		Rev
SHOP INSPECTION (8.1.1)		
PERFORMANCE CURVE & DATA APPROVAL PRIOR TO SHIPMENT.		
TEST WITH SUBSTITUTE SEAL (8.3.3.2.b)		
MATERIAL CERTIFICATION REQUIRED (6.12.1.8)	CASING	
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CASTING REPAIR WELD PROCEDURE APPR REQD (6.12.2.5) (6.12.3.1)		
INSPECTION REQUIRED FOR CONNECTION WELDS (6.12.3.4.d) (6.12.3.4.e)	MAG PARTICLE	
	RADIOGRAPHY	
	LIQUID PENETRANT	
	ULTRASONIC	

- Intent of LPE/MPE is to find discontinuities on the weld surface that may indicate defect with the weld.
- The main intention of radiographic examination of weld is to confirm weld penetration.
- If RXE is specified where RP is offering socket welds it is recommended to offer it as an option with a comment such as: “RXE offered as optional price because by definition socket welds are not full penetration so the radiograph will not provide useful information”.
- If RXE is specified where RP is offering butt welds it is recommended to offer it as an option with a comment such as: “RXE is offered as an optional price because per API 610 11th edition Table 14 note d) states: ‘Due to complex geometry and thickness variations, it is not practical to RT butt-welded auxiliary casing connections’”
- If NDE is specified and the case connections are integrally flanged (no welds to the case casting) it is recommended to make a comment such as: *“Case connections are integrally flanged (no welds to case casting) so NDE is not applicable at that location but an optional price has been offered to carry out NDE of welded drain assembly (defined as auxiliary process piping per 7.5.2.1) ”*

INSPECTION REQUIRED FOR CASE CONNECTION WELDS

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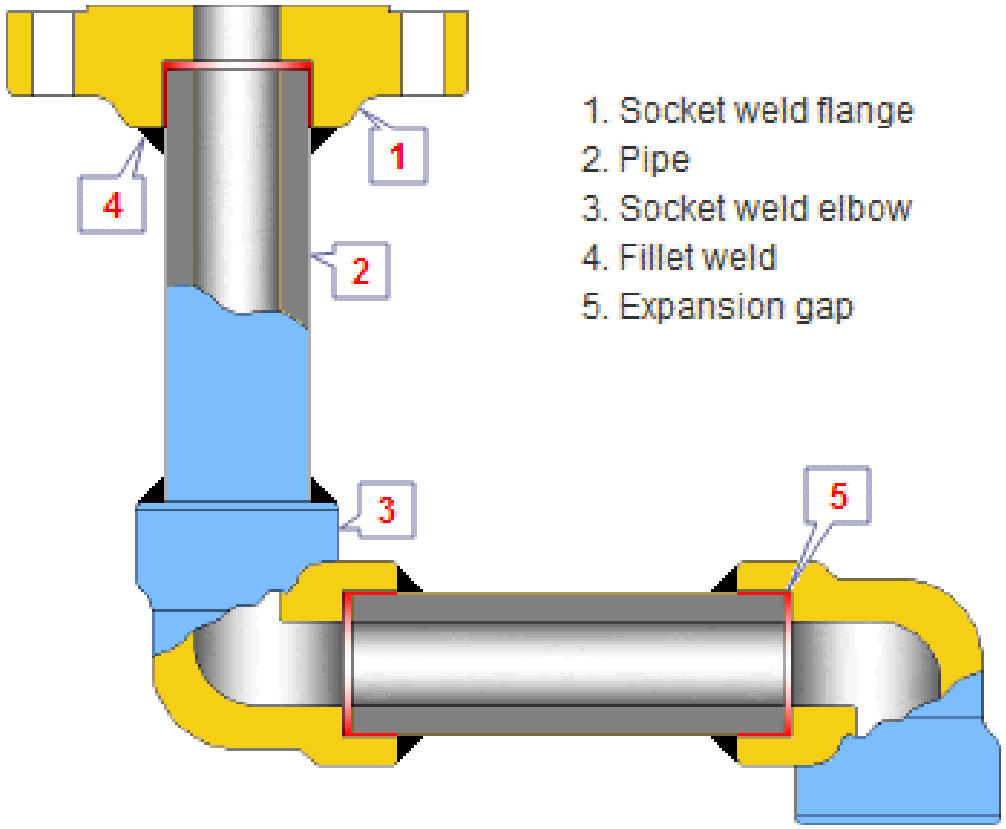
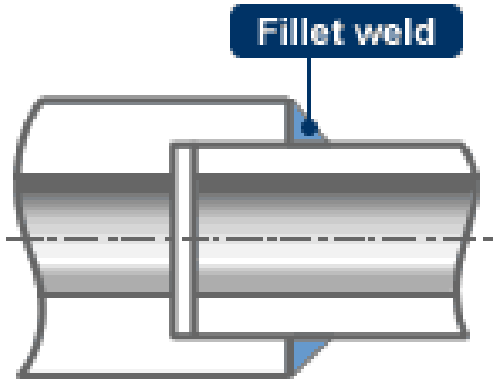
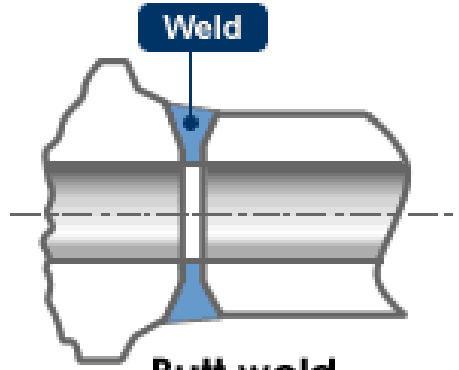


1. Socket weld flange
2. Pipe
3. Socket weld elbow
4. Fillet weld
5. Expansion gap



Socket weld



Butt weld

INSPECTION REQUIRED FOR CASE CONNECTION WELDS

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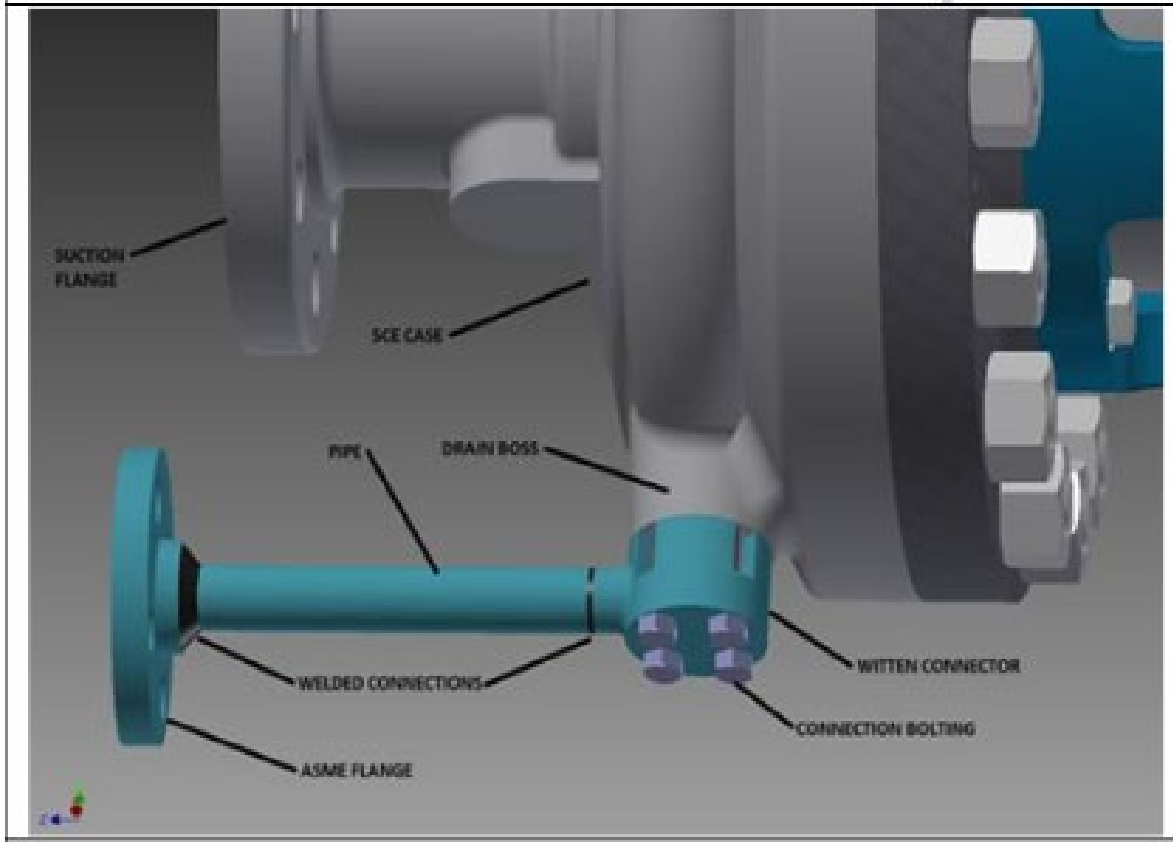
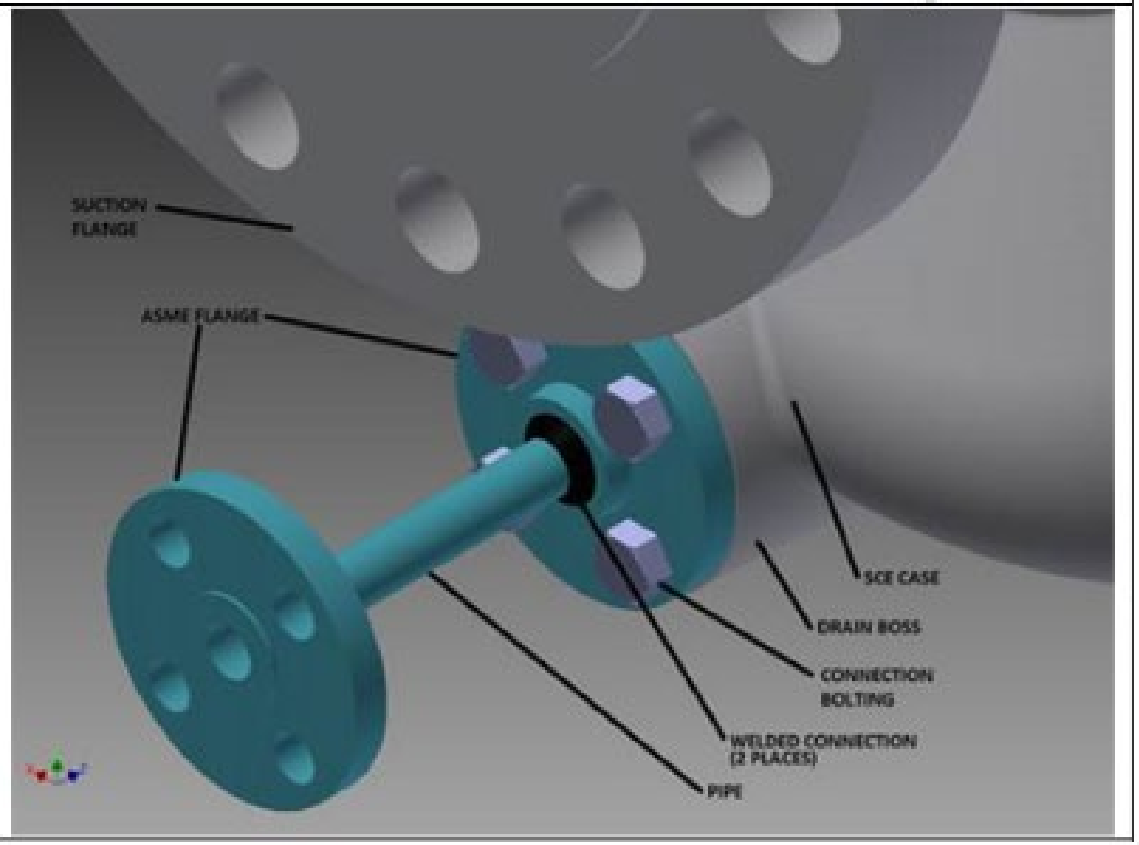
Example of Flange Connector (Bottom) See section 6.1 of SCE Tech Book for "Front" configuration	Example of ASME Flange (Front) See section 6.1 of SCE Tech Book for "Bottom" configuration
	

INSPECTION REQUIRED FOR CASTINGS

See Session 10 – Non Destructive Examination

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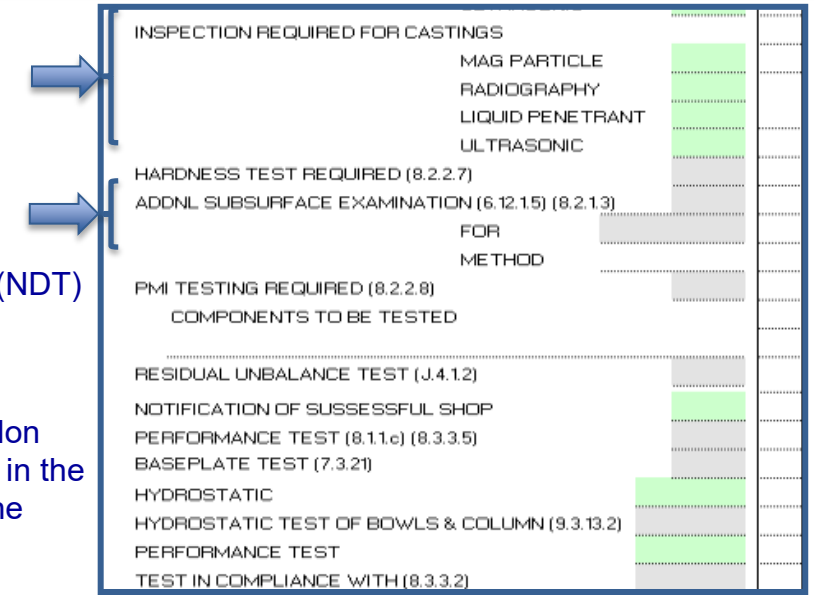
6.12.1.5 ……The purchaser shall specify if any additional tests and inspections are required, especially for materials used for components or in services considered critical by the purchaser. …



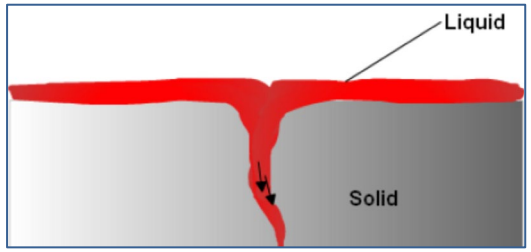
- Radiography (RXE, RT) and Ultrasound (UT) are Non Destructive Tests (NDT) for detecting cracks or flaws **below the surface** of any material.
- Liquid Penetrant (LPE, LP, DPE) and Magnetic Particle (MPE, MP) are Non Destructive Tests (NDT) for detecting **surface** cracks or other anomalies in the material (MPE can also detect some sub-surface flaws). LPE/MPE are the most commonly done tests. MPE is most often used for castings (where materials allow) and LPE for fabrication welds.
- The intention of these inspections is to detect discontinuities/flaws in the material that could indicate possibility of reduced life of the part (eg failure in the field as a result of cyclical stresses from operation).
- Once detected, flaws are compared with the acceptance criteria and repaired/eliminated as necessary
- Radiography is the most stringent test (will identify the most/smallest flaws) and is the highest cost because it requires very specialist equipment, methods and interpretation. Also because most foundries will pour a special casting when they see RXE required.

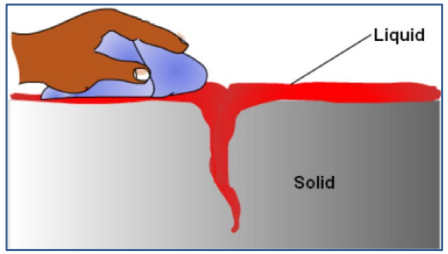
LIQUID PENETRANT EXAMINATION (LPE, LPI, DPE, DPI)

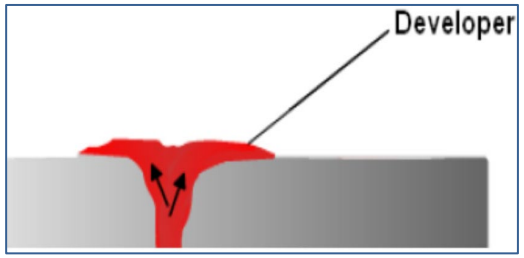
See Session 10 – Non Destructive Examination

- **What is it?**
  - ✓ (LPE= Liquid Penetrant Examination/Inspection, D= Dye .. same test)
  - ✓ This is a Non-Destructive Test (NDT or NDE) for detecting surface cracks or other anomalies

- **How does it work?**
  - ✓ Low surface tension liquid is spayed over the part and capillary action will draw the liquid into the crack.
  - ✓ Excess liquid removed from the surface and the liquid remaining within the crack is made more visible by the use of a “developer” or by the use of “black light” (ultra-violet light)
  - ✓ Ruhrpumpen primarily uses the “developer” method (spray on white developer draws out the dye)







- **What interpretation is required**
  - ✓ Length and shape of the crack is clearly visible, and it can be compared with whatever acceptance criteria is applicable
  - ✓ Since LPE is only used for surface detection, it does not show how deep the crack is, or its extent below the surface.

MAGNETIC PARTICLE EXAMINATION (MPE/MPI)

See Session 10 – Non Destructive Examination

- **What is it:**
  - ✓ This is a Non-Destructive Test for detecting cracks or flaws both at the surface, or near the surface for shallow depth flaws.
  - ✓ MPE= Magnetic Penetrant Examination/Inspection)
  - ✓ Only possible for ferromagnetic materials

- **How does it work:**
  - ✓ It works by magnetizing the part.
  - ✓ The magnetic field will change at or near a crack or flaw.
  - ✓ This effect is then made visible by the use of iron filings spread over the component.
  - ✓ The process can be “wet” or “dry”. Ruhrpumpen use the “dry” method in-house.

- **What interpretation is required:**
  - ✓ Length and shape of the crack is clearly visible, and it can be compared with whatever acceptance criteria is applicable
  - ✓ MPE will detect near-surface cracks that do not actually break the surface. Some indication of the size and depth of the flaw can be interpreted.

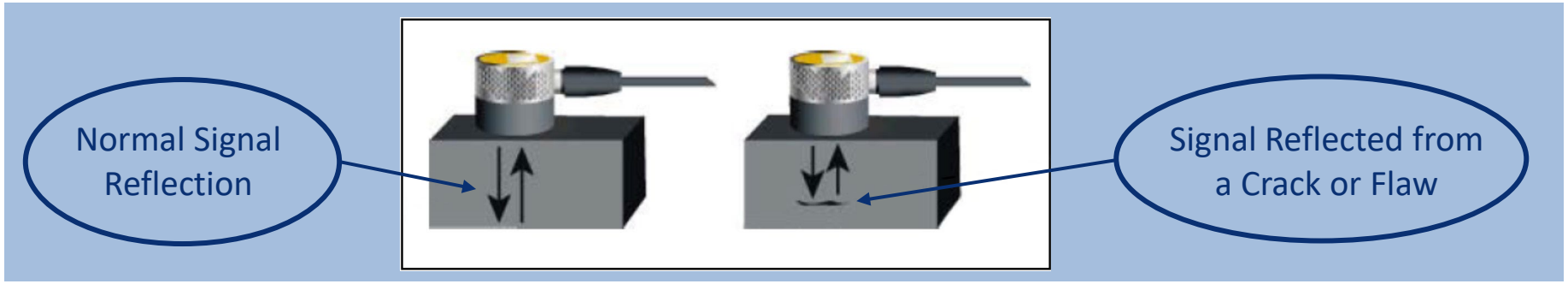
ULTRASONIC EXAMINATION

See Session 10 – Non Destructive Examination

- **What is it:**
  - ✓ This is a Non-Destructive Test for detecting cracks or flaws below the surface of any material, and can also determine material thicknesses.

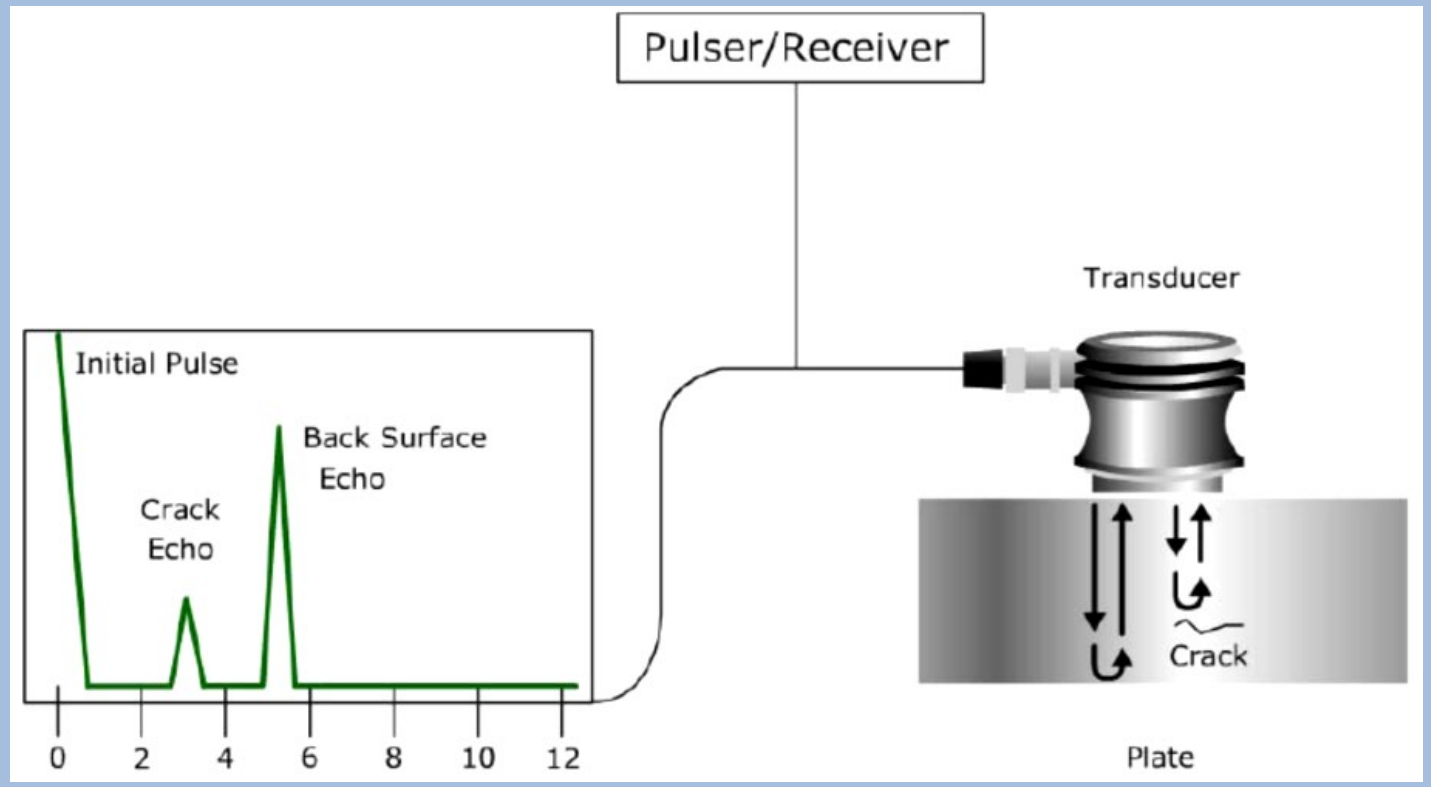
- **How does it work (think of Sonar used in submarines… same principle here):**
  - ✓ An ultrasonic signal is passed into the part.
  - ✓ Any crack or flaw within the part will cause a change in the reflection of this ultrasonic signal.
  - ✓ This change is seen on a display or diagnostic machine.
  - ✓ This can then be used to determine the depth, size and shape of the crack or flaw.

- **What interpretation is required:**
  - ✓ Interpretation of the displayed signal requires skill, and the strength of the signal gives an indication as to the size of the crack, and the time taken for the various signal returns through the part give an indication of the depth and location of the crack.



ULTRASONIC EXAMINATION

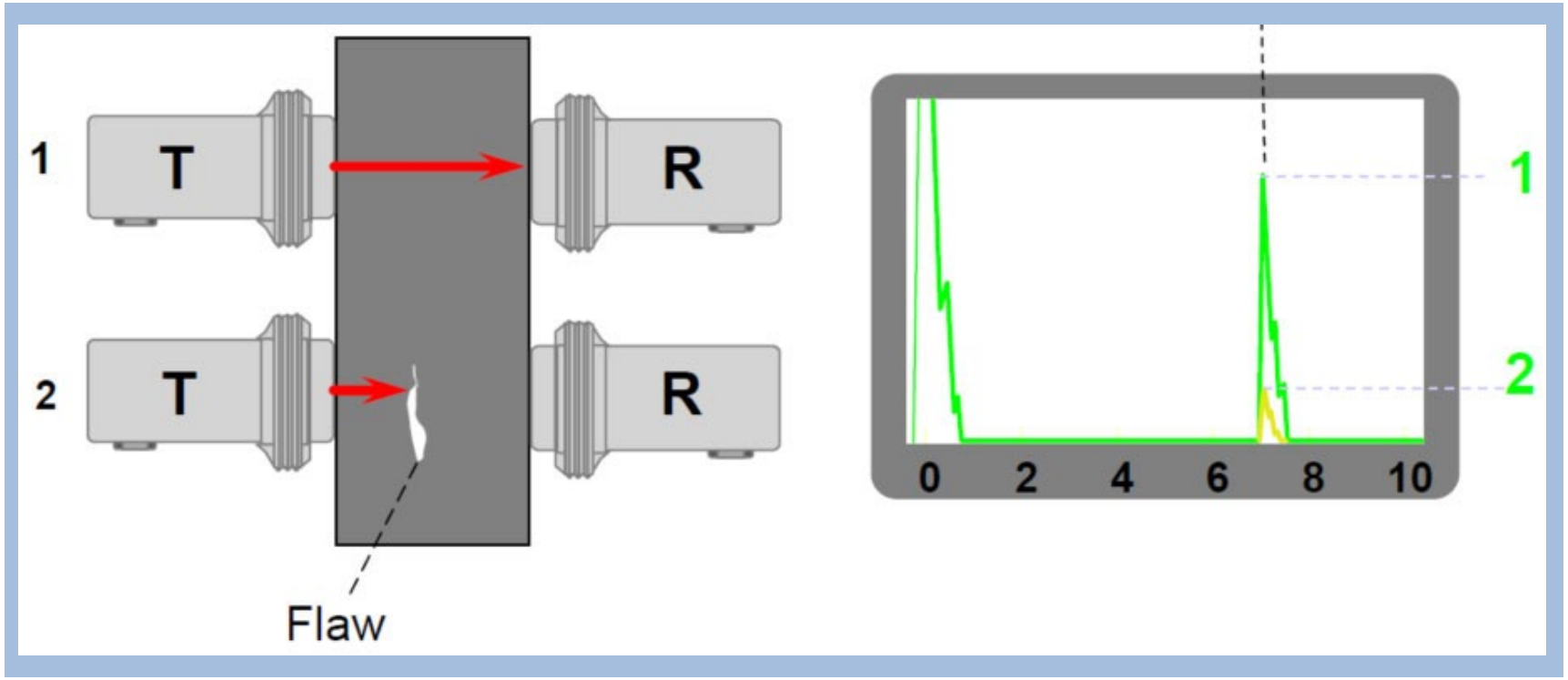
See Session 10 – Non Destructive Examination



The above plot, shows another illustration of the Reflection technique.

ULTRASONIC EXAMINATION

See Session 10 – Non Destructive Examination



The above plot, shows another illustration of the Attenuation (2 Probe) technique.

RADIOGRAPHIC EXAMINATION (RXE)

See Session 10 – Non Destructive Examination

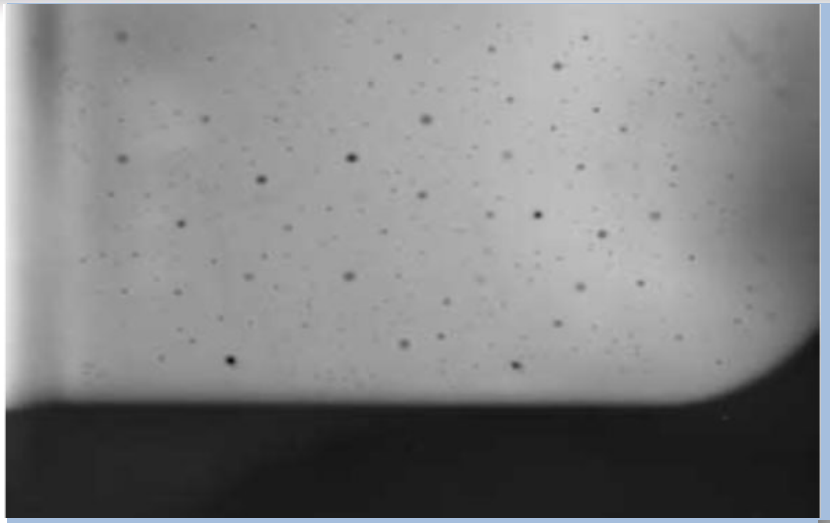
- **What is it:**
  - ✓ This is a Non-Destructive Test for detecting cracks or flaws below the surface of any material, and is suitable for thin and very thick parts. This method is the most specialized of all NDT we carry out, and requires much more safeguards than any other NDT method due to the use of ionizing radiation.

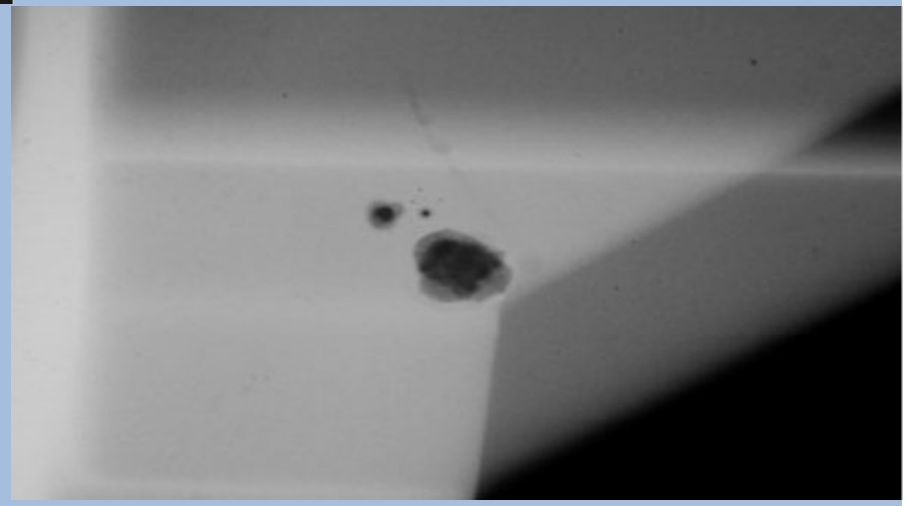
- **How does it work:**
  - ✓ Industrial radiography uses one of the following two sources of radiation:
  - ✓ X-radiation (Xrays), these are produced by an electronic X-ray generator.
  - ✓ Gamma radiation (strongest of the two), is the product of a radioactive isotope.
  - ✓ X-rays and Gamma rays differ only in their source of origin & strength.
  - ✓ The X-rays or Gamma rays are targeted to pass through the part to be inspected.
  - ✓ A photographic film is then placed at the other side of the part, ready to be affected by the ionizing
  - ✓ rays after they have passed through the part being inspected.
  - ✓ Flaws & cracks are seen as shadows on the film, after it is exposed & developed.
  - ✓ By convention, the film is left as a negative.

- **What interpretation is required:**
  - ✓ Interpretation of the developed film is carried out using a “Viewer” and requires skill and training to evaluate the shadows shown on the developed film.

RADIOGRAPHIC EXAMINATION

See Session 10 – Non Destructive Examination

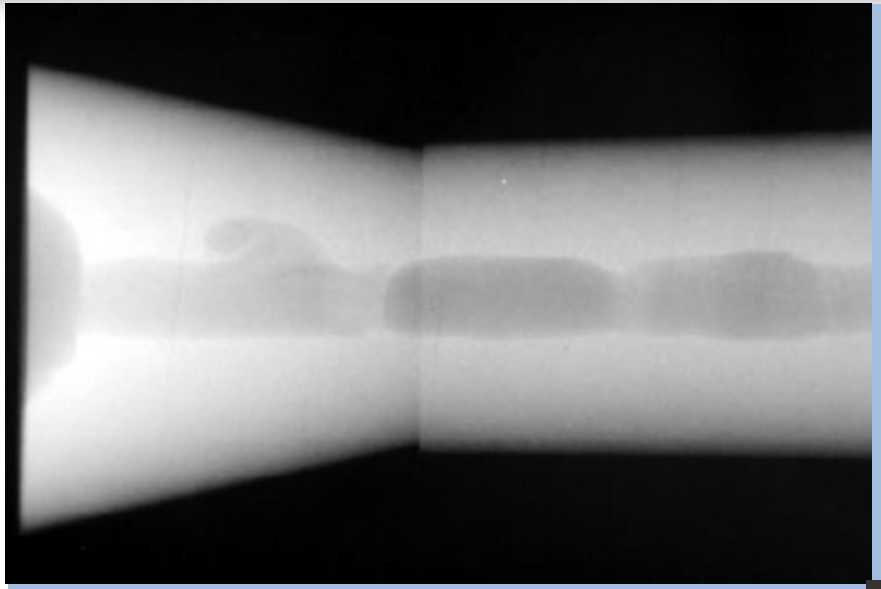




Examples of casting porosity being detected

RADIOGRAPHIC EXAMINATION

See Session 10 – Non Destructive Examination



Examples of casting defects such as shrinkage & tears

Non Destructive Examination (NDE)

What Does API 610 Require?

Table 14 — Pressure casing material inspection requirements

Type of component	Requirements by inspection class[a]		
	I	II	III
—	Minimum	> 80 % MAWP and > 200 °C (392 °F)	< 0,5 SG or > 200 °C (392 °F) and < 0,7 SG, or > 260 °C (500 °F) Extremely hazardous services[e]
Casing[b]: cast	VI	VI, plus MT or PT of critical areas	VI, plus MT or PT of critical areas, plus RT or UT of critical areas
Casing[b]: wrought[c]	VI	VI, plus MT or PT of critical areas	VI, plus MT or PT (critical areas), plus UT (critical areas)
Nozzle weld: casing	VI, plus 100 % MT or PT	VI, plus 100 % MT or PT	VI, plus 100 % MT or PT plus RT (100 %)
Auxiliary connection welds[d]	VI	VI, plus MT or PT	VI, plus MT or PT (100 %)
Internals	VI	VI	VI
Auxiliary process piping: socket-welded	VI	VI, plus 100 % MT or PT	VI, plus 100 % MT or PT
Auxiliary process piping: butt-welded	VI, plus 5 % RT	VI, plus 100 % MT or PT and 5 % RT	VI, plus 100 % MT or PT and 10 % RT

= 32 Bar (465 psi)for 300# flange rating process pumps

Non Destructive Examination (NDE)

What Does API 610 Require?

a Definition of abbreviations:

VI:	Visual inspection	RT:	Radiographic inspection
MT:	Magnetic particle inspection	UT:	Ultrasonic examination
PT:	Liquid penetrant inspection		

b "Casing" includes all items of the pressure boundary of the finished pump casing (e.g. the casing itself and other parts, such as nozzles, flanges, etc. attached to the casing). "Critical areas" are inlet nozzle locations, outlet nozzle locations and casing wall thickness changes. The manufacturer shall submit details of the critical areas proposed to receive MT/PT/RT/UT inspection for purchaser's approval.

c "Wrought" materials include forgings, plate and tubular products.

d Due to complex geometry and thickness variations, it is not practical to RT butt-welded auxiliary casing connections.

e Extremely hazardous services, as specified by the purchaser.

Non Destructive Examination (NDE)

Table 15 — Materials inspection standards

Type of inspection	Methods	Acceptance criteria	
		For fabrications	For castings
Radiography	ASME BPVC, Section V, Articles 2 and 22	ASME BPVC, Section VIII, Division 1, UW-51 (for 100 % radiography) and UW-52 (for spot radiography)	ASME BPVC, Section VIII, Division 1, Appendix 7
Ultrasonic inspection	ASME BPVC, Section V, Articles 5 and 23	ASME BPVC, Section VIII, Division 1, Appendix 12	ASME BPVC, Section VIII, Division 1, Appendix 7
Liquid-penetrant inspection	ASME BPVC, Section V, Articles 6 and 24	ASME BPVC, Section VIII, Division 1, Appendix 8	ASME BPVC, Section VIII, Division 1, Appendix 7
Magnetic-particle inspection	ASME BPVC, Section V, Articles 7 and 25	ASME BPVC, Section VIII, Division 1, Appendix 6	ASME BPVC, Section VIII, Division 1, Appendix 7
Visual Inspection (all surfaces)	ASME BPVC, Section V, Article 9	In accordance with the material specification and the manufacturer's documented procedures	MSS SP-55

HARDNESS TEST REQUIRED

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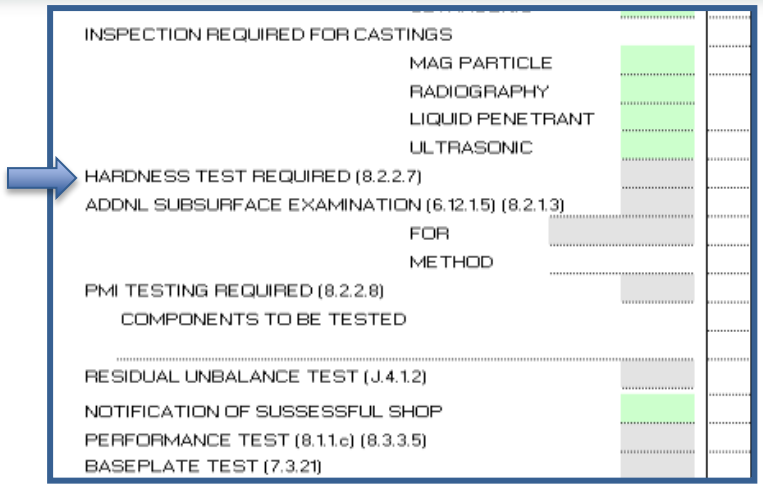
8.2.2.7 If specified, the hardness of parts, welds and heat-affected zones shall be verified as being within the allowable values by testing…



- Customer may ask for hardness test of wear rings to ensure they comply with API requirements.
  - 2 rotating parts with similar or low hardness can ‘pick up’ or gall during operation
  - Per API 610 wear rings need to have a difference of at least 50 BHN (typically case wear ring is hardest) or both need to have hardness of at least 400 BHN.
- Welds and surrounding areas (heat affected zone) of cast materials can undergo microstructural changes due to heating and re-cooling. This can adversely impact the mechanical properties of the material. Since hardness is correlated with other critical mechanical properties – customers sometimes ask for hardness testing of welded areas to confirm that welding has been done correctly.
- Hardness test would also be done as part of the foundry work for pump in H2S service where NACE applies.

PMI TESTING REQUIRED

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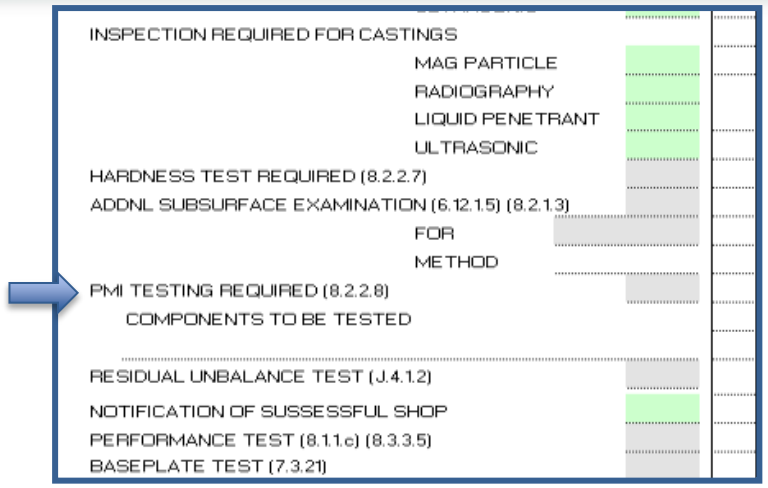
8.2.2.8 If specified, pressure boundary parts of alloy materials shall be subject to positive material identification (PMI) using recognized testing methods, instrumentation and standards. …



- Positive Material Identification is a non-destructive process for analyzing an alloy metal to find the percentage of each of its alloying elements.
- Often used to differentiate between stainless steels to check that different, but visually similar, grades have not been mixed up during assembly or in warehouse (e.g. 304 and 316 piping, fittings etc). Also as a second verification of the MTR.
- In RuhRPumpen we mostly use handheld devices (eg x-ray fluorescence type in Tulsa and Monterrey) which give an instant digital readout of the % quantity of each of the elements.
- If PMI is specified for carbon steel or cast iron it is recommended to offer it as an option with a comment such as “The intention of PMI is to identify % of alloying components present so this test has little or no value for Carbon Steel or Cast Iron where the main component is iron”
- PMI does not read % carbon.

Example of testing with hand-held XRF analyzer
www.iimtiruchy.org

BALANCE / RESIDUAL UNBALANCE TEST

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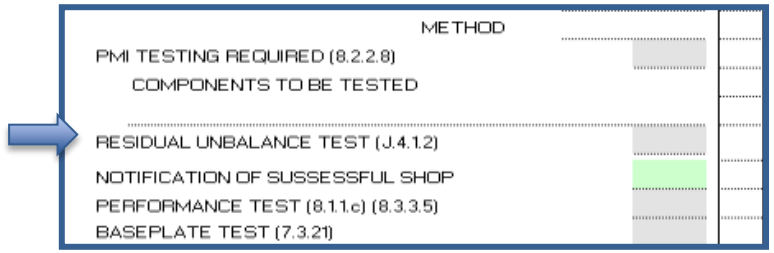
6.9.4.1 Impellers, balancing drums and similar major rotating components shall be dynamically balanced to ISO 1940-1, grade G2.5 … For single-stage BB1 and BB2 pump rotors with interference fit components, the vendor may choose to balance the assembled rotor (in accordance with 9.2.4.2) instead of balancing major rotating components individually.

6.9.4.4 If specified, impellers, balancing drums and similar rotating components shall be dynamically balanced to ISO 1940-1, grade G1

- Impeller balancing to Grade G2.5 is standard. Balancing to G1 is available as an option. But since this level of balance is not considered repeatable - witness of G1 of balance is not recommended.
- Impellers are balanced on test arbor (shaft).
- Per 9.2.4.2 pumps with 3 or more stages or 1 or 2 stage pumps running greater than 3800rpm should have the complete rotor balanced.
- Some customers require OH2 rotating elements to be balanced and this can be done if required but during balance the shaft must be supported either side of impeller and in operation only from one end (overhung pump). So we consider that there is little additional benefit to this test compared with impeller balancing. Offer as option if specified.

J.2.1 residual unbalance
amount of unbalance remaining in a rotor after balancing



- J.2.1 includes a format for the calculation.
- No impeller or rotor can be perfectly balanced. There will always be some remaining unbalance.
- RuhRPumpen balance report includes remaining unbalance after balancing - measured directly from balance machine.
- Purpose of residual unbalance test is to double check the remaining unbalance by using a known mass attached in different locations.

BALANCE GRADES PER ISO 21940

BALANCE QUALITY GRADE G	MAGNITUDE e per Ω mm/s	MACHINERY TYPES – GENERAL EXAMPLES
G 6,3	6,3	• Aircraft gas turbines • Centrifuges (separators, decanters) • Electric motors and generators (of at least 80 mm shaft height), of maximum rated speeds up to 950 r/min • Electric motors of shaft heights smaller than 80 mm • Fans • Gears • Machinery, general • Machine tools • Paper machines • Process plant machines • Pumps • Turbo chargers • Water turbines
G 2,5	2,5	• Compressors • Computer drives • Electric motors and generators (of at least 80 mm shaft height), of maximum rated speeds up 950 r/min • Gas turbines and steam turbines • Machine-tool drives • Textile machines
G 1	1	• Audio and video drives • Grinding machine drives

BALANCING VS6 ROTOR – WHY IMPOSSIBLE

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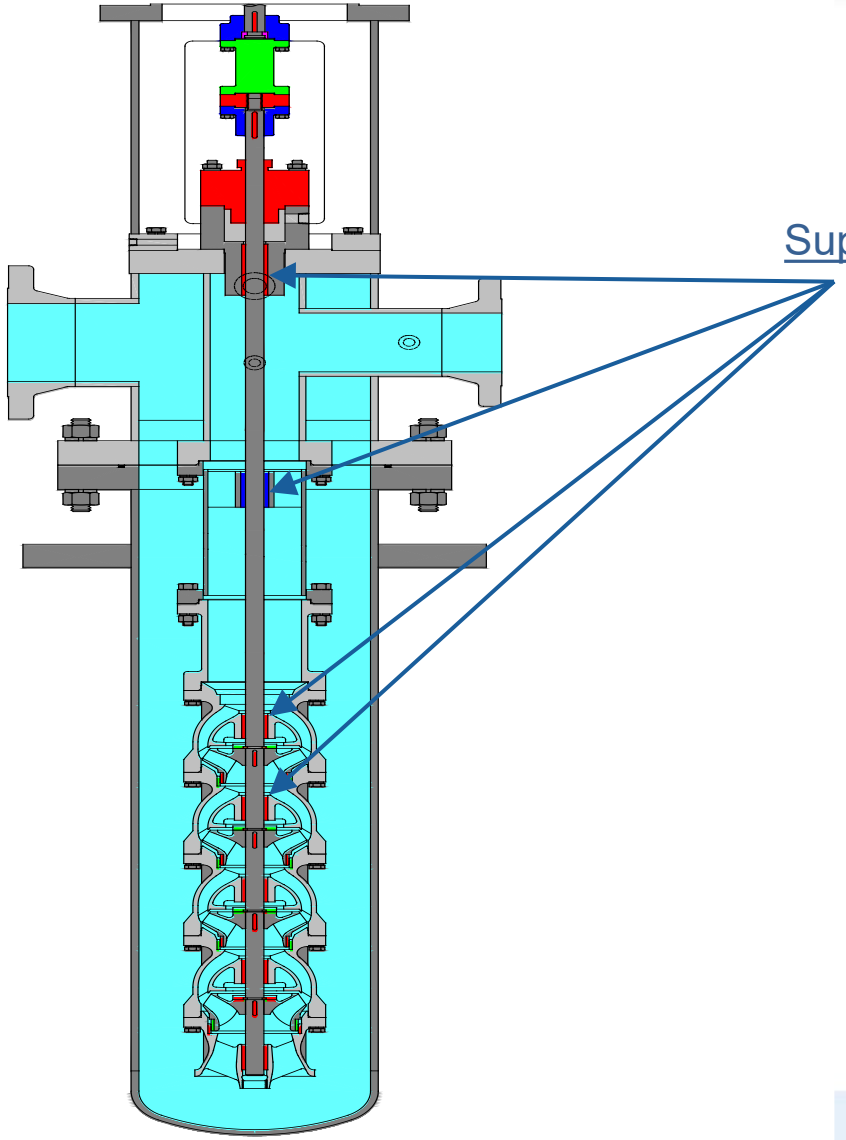

NOTIFICATION OF SUCCESSFUL SHOP TEST

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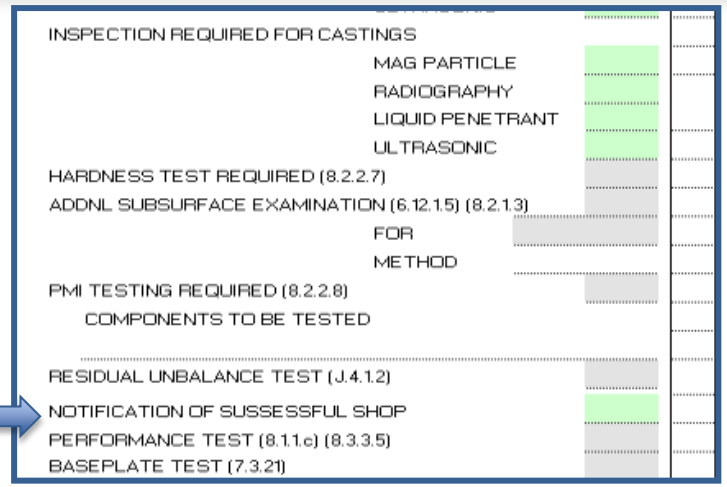
8.1.1 ……..
c) If specified, witnessed mechanical and performance tests shall require a written notification of a successful preliminary test. ….

8.1.1 Will be handled by Project Engineering/Production during order process if the requirement is defined in the datasheet or the spec.



8.3.3.5 During the performance test, the requirements of a) through d) as follows shall be met.

a) Vibration values shall be recorded at each test point except shutoff during the test in accordance with 6.9.3.2. Vibration values shall not exceed those given in 6.9.3.6.

b) For ring and splash-oil systems, oil temperatures shall be recorded at the beginning and the end of the test. For pressurized systems, bearing metal temperatures shall be recorded at the beginning and the end of the test. The duration of the test shall be indicated on the test report.

c) Pumps shall operate within bearing temperature limits as defined in 6.10.2.4 and shall not display signs of unusual operation, such as noise caused by cavitation

d) When operated at rated speed, pumps shall perform within the tolerances given in Table 16 [see 8.3.3.3 b)].

BASEPLATE TEST / NOZZLE LOAD TEST

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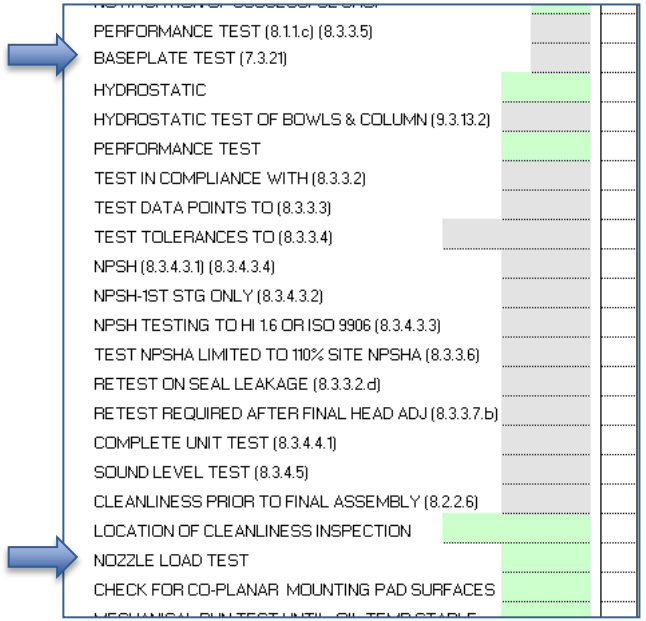
7.3.20 To minimize misalignment of the pump and driver shafts due to piping load effects, the pump and its baseplate shall be constructed with sufficient structural stiffness to limit displacement of the pump shaft … to values inTable 13

7.3.21 If specified, the vendor shall test to demonstrate that the pump and its baseplate assembly, anchored at foundation bolt hole locations, are in compliance with 7.3.20. …..

Table 13 — Stiffness test acceptance criteria

Baseplate intended for grouting		Baseplate not intended for grouting	
Loading condition	Pump shaft displacement µm (in)	Pump shaft displacement µm (in)	Direction
M_{Yc}	175 (0,007)	125 (0,005)	+Z
M_{Zc}	75 (0,003)	50 (0,002)	–Y
M_{Yc} and M_{Zc} equal the sum of the allowable suction and discharge nozzle moments from Table 5. $M_{Yc} = (M_Y)_{suction} + (M_Y)_{discharge}$ $M_{Zc} = (M_Z)_{suction} + (M_Z)_{discharge}$			



- The purpose is to confirm the pump + baseplate is structurally capable of handling the agreed forces and moments without undue displacement of the shaft (too much shaft displacement can lead to problems short bearing life, short seal life etc..)
- Pump is mounted on the baseplate, forces are applied to the nozzles as per the procedure and the resulting shaft deflection is measured and compared with acceptance criteria in Table 13.
- Tulsa procedure uses fixtures bolted to flanges and calibrated pneumatic cylinders to apply pressure (which is then converted to force). A dial indicator on the shaft measures resulting displacement.
- These 2 tests are listed separately on API datasheet (although Nozzle Load Test does not reference specific API paragraph here - 7.3.2.1 is the applicable paragraph). RuhRPumpen considers our method covers both tests.

HYDROSTATIC TEST

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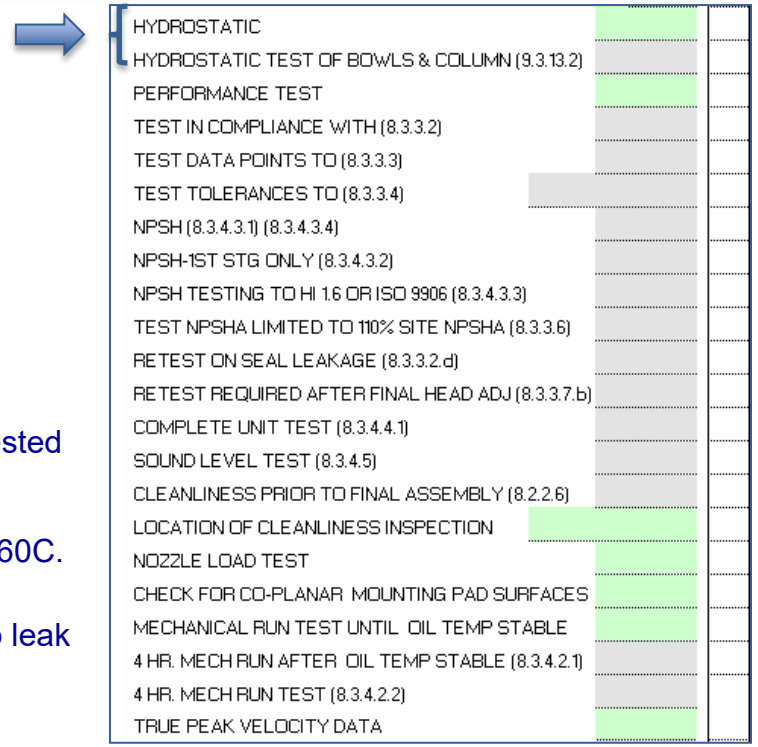
Specialist for Pumping Technology

8.3.2.1 The intent of a hydrostatic test of a centrifugal pump casing is to ensure that the design and construction of the pump pressure containing components and joints are leak-free from ambient conditions to the maximum operation conditions defined on the data sheet.



- 1.5 x MAWP of the pump
- 30 minutes unless otherwise specified.
- Socket welded drains and seal piping will be welded to the casing before hydrotest. With integral flange design - drain assemblies are usually hydrotested separately.
- Wetting agent should be added if site SG < 0.7 or operating temperature >260C.
  - Wetting agent is an additive to the hydrotest water that breaks up the surface tension. It makes the fluid more ‘searching’ and more likely to leak through any flaw in the casing. Testing with wetting agent is a more stringent test than testing with plain water.

9.3.13.2 If specified, bowls and column pipe shall be hydrostatically tested with liquid at a minimum of 1,5 times the maximum differential pressure developed by the bowl assembly. Hydrostatic testing shall be conducted in accordance with the requirements of 8.3.2.

- In a VS6 pump pressure boundary is can and nozzle head. Bowls and column are only hydrotested if clearly required in customer specification.

PERFORMANCE TEST 11th Edition

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Specialist for Pumping Technology

8.3.3.1 Unless otherwise specified, each pump shall be given a performance test.

- Pump must pass internal check test before witness test.

- 8.3.3.2

a) Job seals shall be used
b) Test with substitute seals is allowed if agreed with purchaser (see slide 9)
d) Retest after seal leakage if specified

- 8.3.3.3 Minimum 5 flow points to be tested including:
  1) Shutoff
  2) Minimum flow
  3) between 95 % and 99 % of rated flow,
  4) between rated flow and 105 % of rated flow,
  5) approximately the best efficiency flow
  6) end of allowable operating region.

11th Edition

Speed must be within 3% of site speed unless otherwise agreed.

- 8.3.3.4 If specified for pumps >1MW pumps we can apply tolerances different from Table 16.

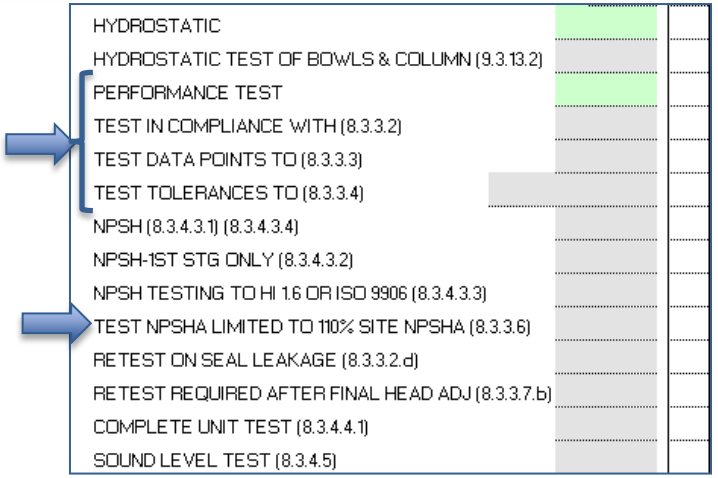


Table 16 — Performance tolerances

Condition	Rated point %	Shutoff %
Rated differential head:		
0 m to 75 m (0 ft to 250 ft)	± 3	± 10[a]
> 75 m to 300 m (> 250 ft to 1 000 ft)	± 3	± 8[a]
> 300 m (1 000 ft)	± 3	± 5[a]
Rated power	4[b]	—
Efficiency	[c]	
Rated NPSH	0	—

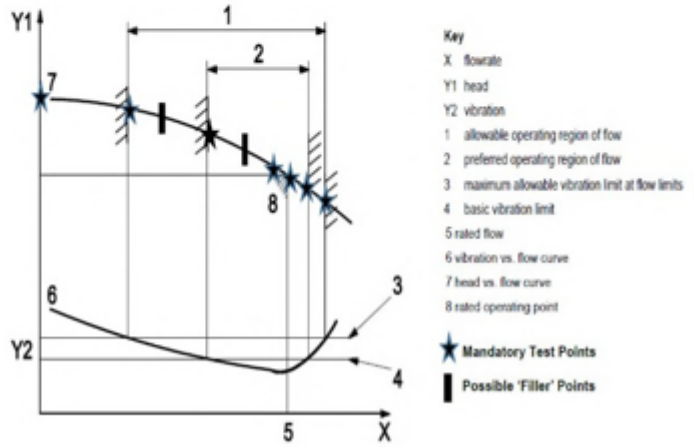
[a] If a rising head flow curve is specified (see 6.1.11), the negative tolerance specified here shall be allowed only if the test curve still shows a rising characteristic.

[b] With test results corrected to rated conditions [see 8.3.3.3 b)] for flow, speed, density (specific gravity) and viscosity, it is necessary that the power not exceed 104 % of the rated value, from all causes (cumulative tolerances are not acceptable).

[c] The uncertainty of test efficiency by the test code specified is ± 2,5 %; therefore, efficiency is not included in the pump's rated performance. In those applications where efficiency is of prime importance to the purchaser, a specific value and related tolerance should be negotiated at the time of the order (see 8.3.3.4).

- 8.3.3.5 Bearing temperature limits shall be recorded and within limits as defined in 6.10.2.4
  Tolerances of test data compared with quote data is per Table 16.

- 8.3.3.6 If specified the NPSHA during test shall be no more than 110% of the site NPSHA shown on the customer datasheet.
  Review with test lab of business unit before quoting this test – depending on site NPSHA this may not be straightforward.

Section	API 610, 11th edition	API 610, 12th edition, difference or additions
Performance test points	1. Shutoff (No vibration data) 2. Minimum continuous stable flow 3. Between 95% and 99% of rated flow 4. Between rated flow and 105% of rated flow 5. Approximately best efficiency flow (if rated flow is not within 5% of BEP flow) 6. End ofallowable operating region	1. Shutoff (no vibration data required) 2. Minimum continuous stable flow 3. Approx halfway between continuous stable flow and minimum preferred operating flow 4. Minimum preferred operating flow 5. Approx. halfway b/w minimum preferred operating flow and rated flow 6. B/w 95 % and 99 % of rated flow 7. B/w rated flow and 105 % of rated flow 8. End of preferred operating region 9. End of allowable operating region if different from the end of the preferred operating region.  For units with BEP less than 11 m3/h, Point 3) and Point 5) are not required.

PERFORMANCE TEST RESULTS

RUHRPUMPEN

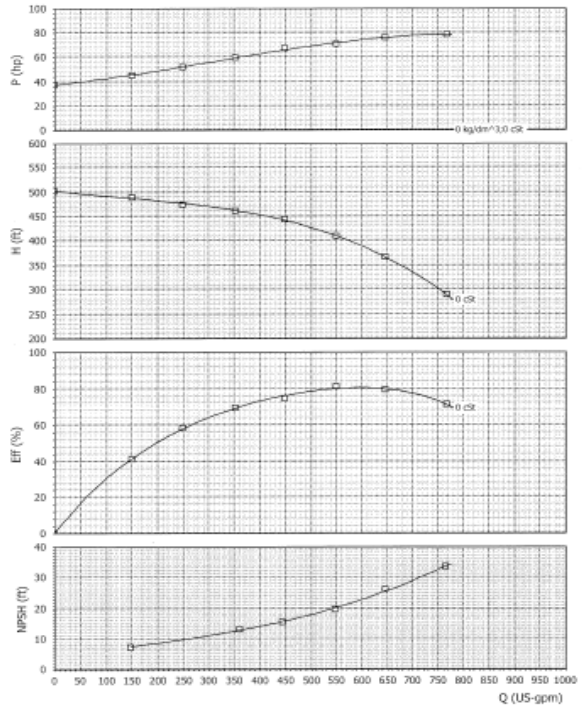
Ruhrpumpen, Inc.
4501 S. 86th E. Ave.
Tulsa , OK , 74145
U.S.A.

Date : May/02/2011
Page : 4/4

PUMP TEST SHEET

Test Nr : 1150VLT-99

Speed: 3550 rpm



Project Nr 191803
Item Nr na
Pump Type 1150VLT-H

Inspected By :
Company :

Test Leader : Steve Johnson

RUHRPUMPEN

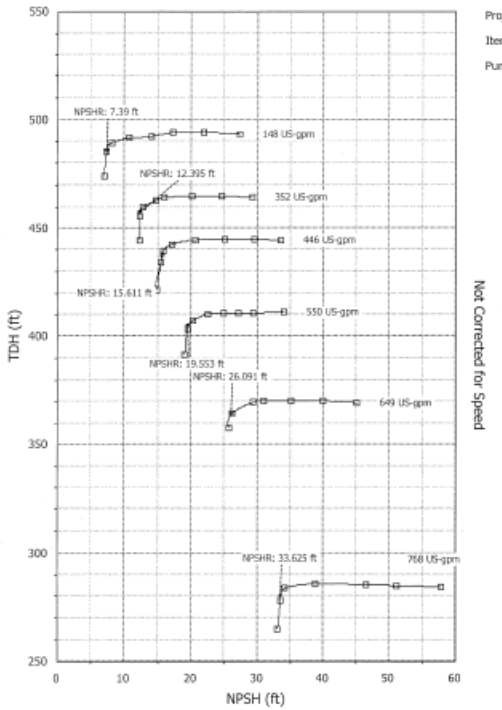
Ruhrpumpen, Inc.
4501 S. 86th E. Ave.
Tulsa , OK , 74145
U.S.A.

Date : May/02/2011
Page : 4/4

NPSH TEST SHEET

Test Nr : 1150VLT-99

TDH vs NPSH



Project Nr : 191803
Item Nr : na
Pump Type : 1150VLT-H

Inspected By :
Company :

Test Leader : Chris Hanlon

PERFORMANCE TEST - VIBRATION

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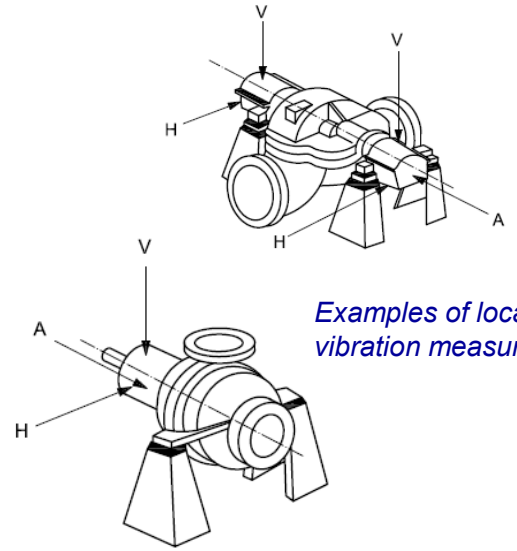
6.9.3.2 During the performance test, overall vibration measurements over a range of 5 Hz to 1 000 Hz and a Fast Fourier Transform (FFT) spectrum shall be made at each test point except shutoff

6.9.3.3 The FFT spectra shall include the range of frequencies from 5 Hz to 2Z times running speed (where Z is the number of impeller vanes; in multistage pumps with different impellers, Z is the highest number of impeller vanes in any stage). If specified the plotted spectra shall be included with the pump test results

8.3.3.5 a) Vibration values shall be recorded at each test point except shutoff during the test in accordance with 6.9.3.2. Vibration values shall not exceed those given in 6.9.3.6.

HYDROSTATIC		
HYDROSTATIC TEST OF BOWLS & COLUMN (9.3.13.2)		
PERFORMANCE TEST		
TEST IN COMPLIANCE WITH (8.3.3.2)		
TEST DATA POINTS TO (8.3.3.3)		
TEST TOLERANCES TO (8.3.3.4)		
NPSH (8.3.4.3.1) (8.3.4.3.4)		
NPSH-1ST STG ONLY (8.3.4.3.2)		
NPSH TESTING TO HI 1.6 OR ISO 9906 (8.3.4.3.3)		
TEST NPSHA LIMITED TO 110% SITE NPSHA (8.3.3.6)		
RETEST ON SEAL LEAKAGE (8.3.3.2.d)		
RETEST REQUIRED AFTER FINAL HEAD ADJ (8.3.3.7.b)		
COMPLETE UNIT TEST (8.3.4.4.1)		
SOUND LEVEL TEST (8.3.4.5)		



Examples of location of vibration measurements

NPSH TEST

8.3.4.3.1 If specified, NPSH3 shall be determined at each test point identified in 8.3.3.3 a) except shut-off.

8.3.4.3.4 NPSH3 at the rated point shall not exceed the quoted value (see Table 16). Dismantling to correct NPSH3 performance requires a retest (see 8.3.3.5 and 8.4.3.1).

HYDROSTATIC		
HYDROSTATIC TEST OF BOWLS & COLUMN (9.3.13.2)		
PERFORMANCE TEST		
TEST IN COMPLIANCE WITH (8.3.3.2)		
TEST DATA POINTS TO (8.3.3.3)		
TEST TOLERANCES TO (8.3.3.4)		
NPSH (8.3.4.3.1) (8.3.4.3.4)		
NPSH-1ST STG ONLY (8.3.4.3.2)		
NPSH TESTING TO HI 1.6 OR ISO 9906 (8.3.4.3.3)		
TEST NPSHA LIMITED TO 110% SITE NPSHA (8.3.3.6)		
RETEST ON SEAL LEAKAGE (8.3.3.2.d)		
RETEST REQUIRED AFTER FINAL HEAD ADJ (8.3.3.7.b)		
COMPLETE UNIT TEST (8.3.4.4.1)		
SOUND LEVEL TEST (8.3.4.5)		

- Note API 11th edition now used nomenclature ‘NPSH3’ instead of ‘NPSHR’
- Test normally specified when the NPSH margin is low.
- 2 common methods are suction tank and suction valve throttling (RuhRPumpen business units use different methods. Check with business unit if customer specifies a certain method).
- Flow is set. NPSHA is gradually reduced (by suction tank or closing suction valve). When the head has dropped by 3% - that point is defined as NPSH3 for that flow rate (8.3.4.3.2). This is repeated for same points as performance test. Graph of NPSH3 against flow can then be plotted.
- Standard criteria is 3% head drop but some customers require 1% head drop. Effectively this increases NPSR by around 20-30%.

Table 16 — Performance tolerances

Condition	Rated point %	Shutoff %
Rated differential head:		
0 m to 75 m (0 ft to 250 ft)	± 3	± 10[a]
> 75 m to 300 m (> 250 ft to 1 000 ft)	± 3	± 8[a]
> 300 m (1 000 ft)	± 3	± 5[a]
Rated power	4[b]	—
Efficiency	[c]	
Rated NPSH	0	—

[a] If a rising head flow curve is specified (see 6.1.11), the negative tolerance specified here shall be allowed only if the test curve still shows a rising characteristic.

[b] With test results corrected to rated conditions [see 8.3.3.3 b)] for flow, speed, density (specific gravity) and viscosity, it is necessary that the power not exceed 104 % of the rated value, from all causes (cumulative tolerances are not acceptable).

[c] The uncertainty of test efficiency by the test code specified is ± 2,5 %; therefore, efficiency is not included in the pump's rated performance. In those applications where efficiency is of prime importance to the purchaser, a specific value and related tolerance should be negotiated at the time of the order (see 8.3.3.4).

Tolerances of test data compared with quote data is per Table 16.

NPSH-1st STAGE ONLY

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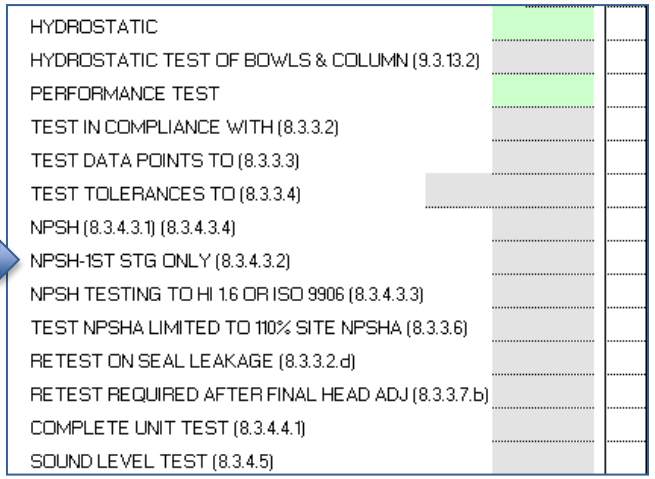
8.3.4.3.2 ….The first-stage head of pumps with two or more stages shall be measured using a separate connection to the first-stage discharge if possible. If this is not feasible, testing of the first stage only should be considered. With purchaser approval, first-stage head may be determined by dividing total developed head by the number of stages.



- Vertical pumps can be specially assembled as a single stage unit for NPSH test. But in some cases the 1st stage alone only cannot overcome system resistance so more than 1 stage is required.
- Single stage measurement may not be possible for horizontal multistage pumps and we invoke the last part of this paragraph: “With purchaser approval, first-stage head may be determined by dividing total developed head by the number of stages.” The standard API 610 comments for the product will state this exception if applicable.

Table 16 — Performance tolerances

Condition	Rated point %	Shutoff %
Rated differential head:		
0 m to 75 m (0 ft to 250 ft)	± 3	± 10[a]
> 75 m to 300 m (> 250 ft to 1 000 ft)	± 3	± 8[a]
> 300 m (1 000 ft)	± 3	± 5[a]
Rated power	4[b]	—
Efficiency	[c]	
Rated NPSH	0	—

[a] If a rising head flow curve is specified (see 6.1.11), the negative tolerance specified here shall be allowed only if the test curve still shows a rising characteristic.

[b] With test results corrected to rated conditions [see 8.3.3.3 b)] for flow, speed, density (specific gravity) and viscosity, it is necessary that the power not exceed 104 % of the rated value, from all causes (cumulative tolerances are not acceptable).

[c] The uncertainty of test efficiency by the test code specified is ± 2,5 %; therefore, efficiency is not included in the pump's rated performance. In those applications where efficiency is of prime importance to the purchaser, a specific value and related tolerance should be negotiated at the time of the order (see 8.3.3.4).

Tolerances of test data compared with quote data is per Table 16.

RETEST AFTER SEAL LEAKAGE

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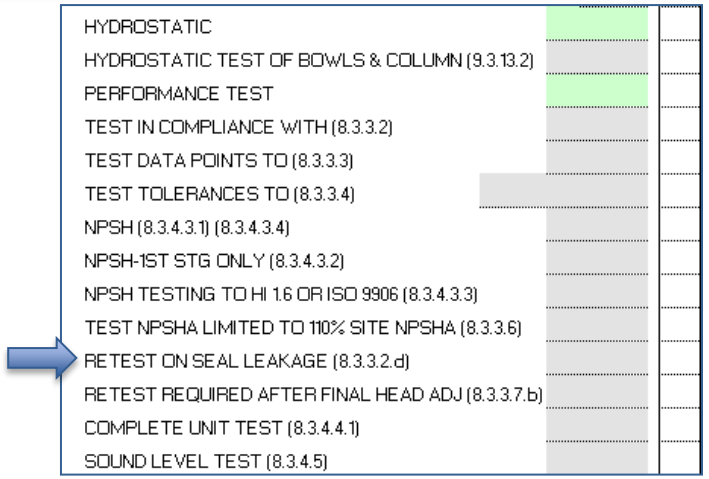
8.3.3.2 d) If specified, seal leakage during test shall require the assembled pump and seal to be rerun to demonstrate satisfactory seal performance



- During test we do visual inspection for seal leakage. That's the acceptable method per API.
- If the customer specifies retest after seal leakage per 8.3.3.2 d then we will comply.
- In many cases if seal leakage is seen during test RuhRPumpen will retest for our own assurance after doing a corrective action. (Regardless this should always be specified on the datasheet if it is a customer requirement.)

RETEST REQUIRED AFTER FINAL HEAD ADJUSTMENT

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- 8.3.3.7 The requirements of a) through d) as follows shall be met after the performance test is completed.

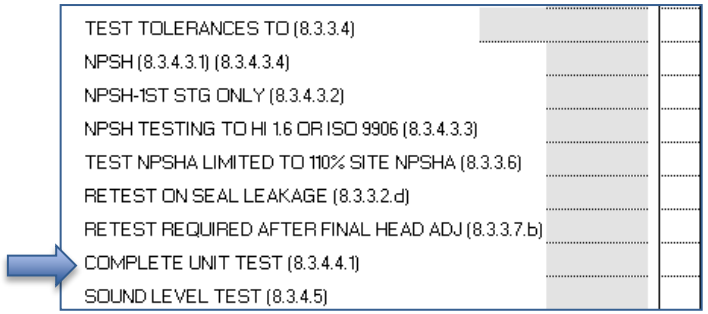
  a) If it is necessary to dismantle a pump after the performance test for the sole purpose of machining impellers to meet the tolerances for differential head, no retest is required unless the reduction in diameter exceeds 5 % of the original diameter. The diameter of the impeller at the time of shop test, as well as the final diameter of the impeller, shall be recorded on a certified shop test curve that shows the operating characteristics after the diameter of the impeller has been reduced.

  b) If specified, disassembly of multistage pumps for any head adjustment (including less than 5 % diameter change) after test, shall be cause for retest.

HYDROSTATIC		
HYDROSTATIC TEST OF BOWLS & COLUMN (9.3.13.2)		
PERFORMANCE TEST		
TEST IN COMPLIANCE WITH (8.3.3.2)		
TEST DATA POINTS TO (8.3.3.3)		
TEST TOLERANCES TO (8.3.3.4)		
NPSH (8.3.4.3.1) (8.3.4.3.4)		
NPSH-1ST STG ONLY (8.3.4.3.2)		
NPSH TESTING TO HI 1.6 OR ISO 9906 (8.3.4.3.3)		
TEST NPSHA LIMITED TO 110% SITE NPSHA (8.3.3.6)		
RETEST ON SEAL LEAKAGE (8.3.3.2.d)		
RETEST REQUIRED AFTER FINAL HEAD ADJ (8.3.3.7.b)		
COMPLETE UNIT TEST (8.3.4.4.1)		
SOUND LEVEL TEST (8.3.4.5)		

- RuhRPumpen will comply if this is specified.
- This will add an additional test and time because normally trim with no retest is allowed for less than 5% diameter change.

8.3.4.4.1 If specified, the pump and driver train, complete with all auxiliaries that make up the unit, shall be tested together. If specified, torsional vibration measurements shall be made to verify the vendor's analysis. The complete-unit test shall be performed in place of or in addition to separate tests of individual components specified by the purchaser.



When should you specify a Complete Unit Test ?

If you are spending a million dollars on a BB5 with Lube Oil System, Seal-Oil System, Gearbox, VFD, Control Panel - then absolutely you would want to have a CUT

But if you are spending $50,000 on an OH2 or a BB2 then I certainly would not go to the considerable expense.

It is wise to specify precisely WHAT you want included in the Complete Unit Test

- Job Baseplate
- Job Pump
- Job Motor
- Job Gearbox
- Job Sealing System
- Job Lube Oil System
- Job Instrumentation
- Job Control Panel
- Job Bently Nevada System
- Job VFD
- Flow and Head measurement?

A LINE 8x6x15.5

3.2 MW HV Motor / API 614 Lube oil system / Control valves
Capacity 272 m³/h / Head : 2850 m / Speed 2900 rpm
Pumped liquid : Water + abrasive solids liquid temperature 70 °C

Shown on string test test in RP factory :
Full speed / load 3.2MW motor 2980 RPM

AB 8x6x15.5 12 stage (BB5)

RUHRPUMPEN

Test Bay Capability
Power: 6.5 MW
Flow: 15000 m³/hr
Supply : up to 10kV
Crane capacity: 32 tonnes

Option to use the Siemens facility at Duisburg 50 km from Witten for up to 17 MW

“Small” Test Loop - Tulsa

RUHRPUMPEN

“Large” Test Loop - Tulsa

RUHRPUMPEN

Internal Question List for Complete Unit Test

- What will be the purpose and acceptance criteria of the test?
  - Running test at rated point?
  - Full API performance test?
  - Function test of auxiliaries?

- What equipment does the customer require us to use and what is practical within the capabilities of the test lab? If necessary check capabilities with Business unit test lab.

- Some examples of practical considerations:
  - Availability of appropriate electrical supply for contract motor
  - Is motor power sufficient for full performance test on water? (Job motor cover end of curve power with SG of water?)
  - Consider if there is sufficient space in test lab for contract baseplate.
  - If contract seal system is required consider if utilities are available (eg nitrogen for plan 53).
  - If functional test of auxiliaries is required is there appropriate control equipment available to detect instrument outputs?

- Scope of test should be considered and parameters/limitations defined clearly to estimating when requesting pricing and in the customer scope of supply.

- If torsional vibration measurement is specified contact Engineering Group in the business unit before quoting. Price adder for this test and the required analysis would be quite high since the measurement is a complex process that would need to be designed on case-to-case basis depending on factors such as pump-type and customer requirement.

SOUND LEVEL TEST

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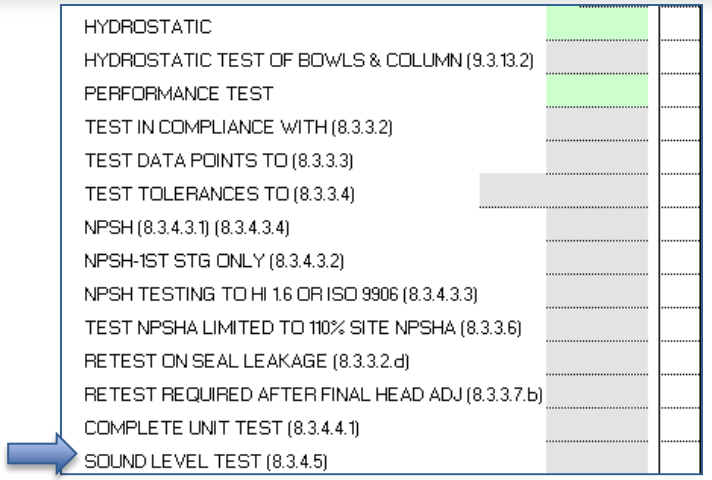
Specialist for Pumping Technology

8.3.4.5 If specified, sound level tests shall be performed as agreed between the purchaser and the vendor.



- We can use a handheld meter during factory test to get an estimate of total noise levels.
- During factory test some noise is from valves, pipework, background (machine shop etc.) and shop motor - not only the pump. So these results are not to be used as an acceptance criteria.
- While running on site some noise level is from environmental noise and is affected by quality of installation, pipework arrangement etc
- For these reasons it is EXPECTED that noise readings during factory test and noise readings during running on site will be very different! This has been confirmed by experience. Hence we cannot guarantee the noise readings made during test.
- Alternatively we can provide calculated values from a program such as Octband but they are not guaranteed to be reproduced during test or on site.

CLEANLINESS PRIOR TO FINAL ASSEMBLY

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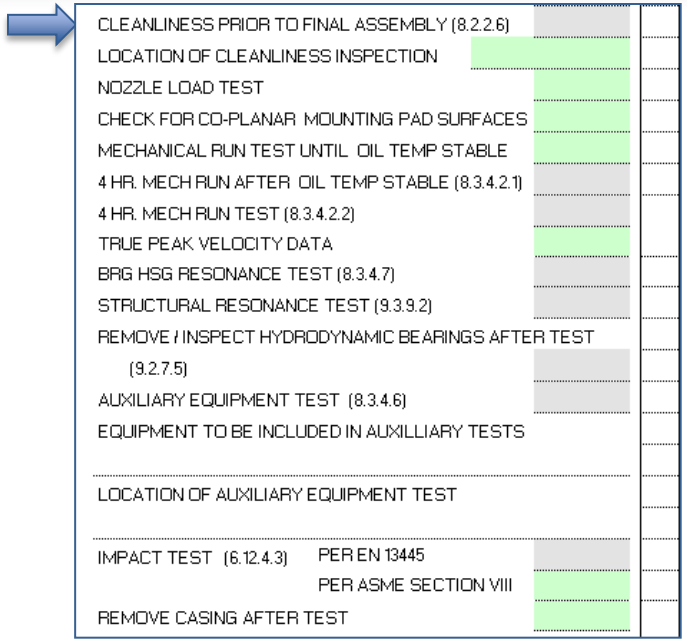
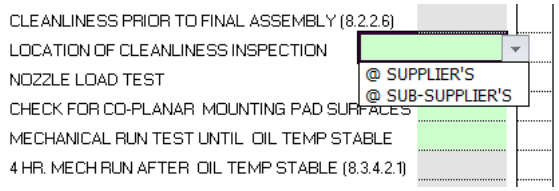
8.2.2.6 If specified, the purchaser may inspect for cleanliness of the equipment and all piping and appurtenances furnished by or through the vendor before assembly.



- RuhRPumpen will comply if this is specified.
- This can have an impact on the schedule since this is effectively a witness test that will require a notification to the inspector.
- Location of inspection is also specified in the datasheet.



CHECK FOR CO-PLANAR MOUNTING SURFACES

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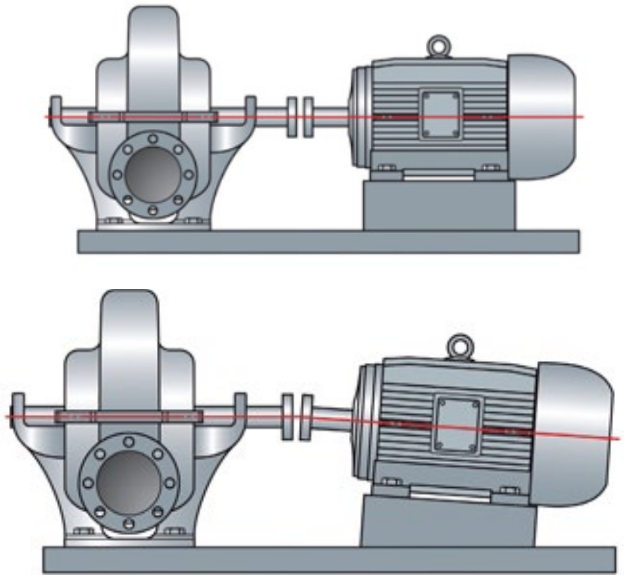
7.3.5 ….The pads shall be fully machined flat and parallel. Corresponding surfaces shall be in the same plane within 150 µm/m (0,002 in/ft) of distance between the pads.

If specified, this requirement shall be demonstrated in the pump-vendor's shop prior to mounting of the equipment …

CLEANLINESS PRIOR TO FINAL ASSEMBLY (8.2.2.6)	
LOCATION OF CLEANLINESS INSPECTION	
NOZZLE LOAD TEST	
CHECK FOR CO-PLANAR MOUNTING PAD SURFACES	
MECHANICAL RUN TEST UNTIL OIL TEMP STABLE	
4 HR. MECH RUN AFTER OIL TEMP STABLE (8.3.4.2.1)	
4 HR. MECH RUN TEST (8.3.4.2.2)	
TRUE PEAK VELOCITY DATA	
BRG HSG RESONANCE TEST (8.3.4.7)	
STRUCTURAL RESONANCE TEST (9.3.9.2)	
REMOVE / INSPECT HYDRODYNAMIC BEARINGS AFTER TEST (9.2.7.5)	
AUXILIARY EQUIPMENT TEST (8.3.4.6)	
EQUIPMENT TO BE INCLUDED IN AUXILLIARY TESTS	
LOCATION OF AUXILIARY EQUIPMENT TEST	



www.flowcontrolnetwork.com

- Check to ensure that machined surfaces of baseplate pump and motor pads are parallel within API criteria.
- Why is this important? If pump pads are out of parallel the pump and motor shafts are not parallel and it is hard to achieve good alignment.
- Good alignment is critical for low vibration, long bearing and seal life etc.
- Illustration top left shows correctly aligned shaft with pad in parallel. Illustration bottom left shows exaggerated example of pads out of parallel.

MECHANICAL RUN TEST

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- Time consuming for the test loop therefore is large additional cost.
- As most test problems are found within the first 30 minutes - most issues will become apparent during normal API performance test. Since 100% of pumps will be performance tested - customer may wish to consider purchasing one run test per tag as an alternative to a run test for every pump (lower cost than run testing all pumps, but still confirmation that the pump model will run successfully for an extended time period).

8.3.4.2.1 If specified, the pump shall be run on the test stand at the rated flow until oil temperature stabilization (6.10.2.4) has been achieved.

Mechanical Run Test Until Oil Temperature Stable
During performance test bearing temperature will rise sharply at the beginning. Rate of increase slows until temperature stabilizes. Actual time taken for oil to reach the stable temperature is anywhere from 1-4 hours depending on the pump.

4 hour Mechanical Run Test After Oil Temperature Stable
Up to 4 hours for bearing temperature to stabilize + 4 hours run, so total test could be up to 8 hours. Hence this test can be around double the price of a 4 hour run test.

8.3.4.2.2 If specified, the pump shall be mechanically run at the rated flow for 4 h.

4 hour Mechanical Run Test
4 hours run at rated flow. RuhRPumpen consider the time taken for API performance test would be part of this 4 hour run test.

CLEANLINESS PRIOR TO FINAL ASSEMBLY (8.2.2.6)	
LOCATION OF CLEANLINESS INSPECTION	
NOZZLE LOAD TEST	
CHECK FOR CO-PLANAR MOUNTING PAD SURFACES	
MECHANICAL RUN TEST UNTIL OIL TEMP STABLE	
4 HR. MECH RUN AFTER OIL TEMP STABLE (8.3.4.2.1)	
4 HR. MECH RUN TEST (8.3.4.2.2)	
TRUE PEAK VELOCITY DATA	
BRG HSG RESONANCE TEST (8.3.4.7)	
STRUCTURAL RESONANCE TEST (9.3.9.2)	
REMOVE / INSPECT HYDRODYNAMIC BEARINGS AFTER TEST (9.2.7.5)	
AUXILIARY EQUIPMENT TEST (8.3.4.6)	
EQUIPMENT TO BE INCLUDED IN AUXILLIARY TESTS	
LOCATION OF AUXILIARY EQUIPMENT TEST	
IMPACT TEST (6.12.4.3) PER EN 13445	
PER ASME SECTION VIII	
REMOVE CASING AFTER TEST	

6.10.2.4
For forced feed lubrication systems max. allowable temp. rise during test is 28 K (50 °R)

For ring-oiled or splash lubrication max allowable temp rise of the sump oil is 40 K (70 °R) above the ambient temperature

TRUE PEAK VELOCITY DATA

RUHRPUMPEN
Specialist for Pumping Technology

- Regular measurement of vibration per API is RMS (root mean square).
- True peak velocity is a different way to measure/express vibration data.
- Was a bulleted paragraph in 10th Edition – not in 11th edition.

CLEANLINESS PRIOR TO FINAL ASSEMBLY (8.2.2.6)		
LOCATION OF CLEANLINESS INSPECTION		
NOZZLE LOAD TEST		
CHECK FOR CO-PLANAR MOUNTING PAD SURFACES		
MECHANICAL RUN TEST UNTIL OIL TEMP STABLE		
4 HR. MECH RUN AFTER OIL TEMP STABLE (8.3.4.2.1)		
4 HR. MECH RUN TEST (8.3.4.2.2)		
TRUE PEAK VELOCITY DATA		
BRG HSG RESONANCE TEST (8.3.4.7)		
STRUCTURAL RESONANCE TEST (9.3.9.2)		
REMOVE / INSPECT HYDRODYNAMIC BEARINGS AFTER TEST (9.2.7.5)		
AUXILIARY EQUIPMENT TEST (8.3.4.6)		
EQUIPMENT TO BE INCLUDED IN AUXILLIARY TESTS		
LOCATION OF AUXILIARY EQUIPMENT TEST		
IMPACT TEST (6.12.4.3) PER EN 13445		
PER ASME SECTION VIII		
REMOVE CASING AFTER TEST		

BEARING RESONANCE TEST

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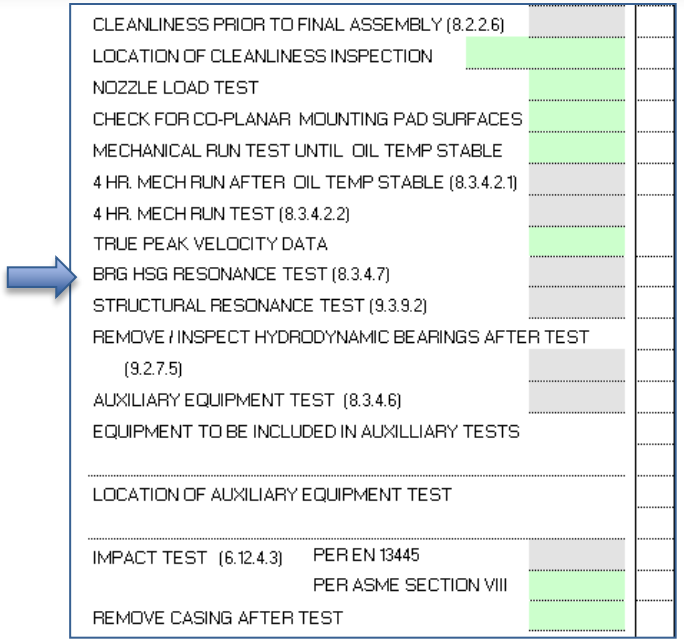
Specialist for Pumping Technology

8.3.4.7 Bearing-housing resonance test
If a resonance test is specified, the bearing housing(s) shall be excited by impact or other suitable means with the pump unpiped, and the natural frequency(ies) shall be determined from the response.…



CLEANLINESS PRIOR TO FINAL ASSEMBLY (8.2.2.6)		
LOCATION OF CLEANLINESS INSPECTION		
NOZZLE LOAD TEST		
CHECK FOR CO-PLANAR MOUNTING PAD SURFACES		
MECHANICAL RUN TEST UNTIL OIL TEMP STABLE		
4 HR. MECH RUN AFTER OIL TEMP STABLE (8.3.4.2.1)		
4 HR. MECH RUN TEST (8.3.4.2.2)		
TRUE PEAK VELOCITY DATA		
BRG HSG RESONANCE TEST (8.3.4.7)		
STRUCTURAL RESONANCE TEST (9.3.9.2)		
REMOVE / INSPECT HYDRODYNAMIC BEARINGS AFTER TEST (9.2.7.5)		
AUXILIARY EQUIPMENT TEST (8.3.4.6)		
EQUIPMENT TO BE INCLUDED IN AUXILLIARY TESTS		
LOCATION OF AUXILIARY EQUIPMENT TEST		
IMPACT TEST (6.12.4.3) PER EN 13445		
PER ASME SECTION VIII		
REMOVE CASING AFTER TEST		

- The intention is to determine the natural frequency of the pump to be sure it does not fall near the operating speed.
- The method is to attach a probe to the bearing housing and connect a vibration analyzer. The bearing housing is hit with a rubber hammer 180 degrees from the probe and the results recorded and analyzed.

STRUCTURAL RESONANCE TEST

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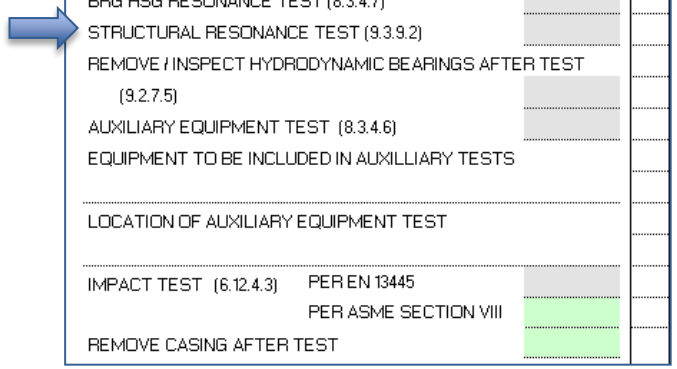
9.3.9.2 If specified, a resonance test with the pump unpiped shall be conducted on the pump structure/driver frame assembly. The test shall be performed as follows.



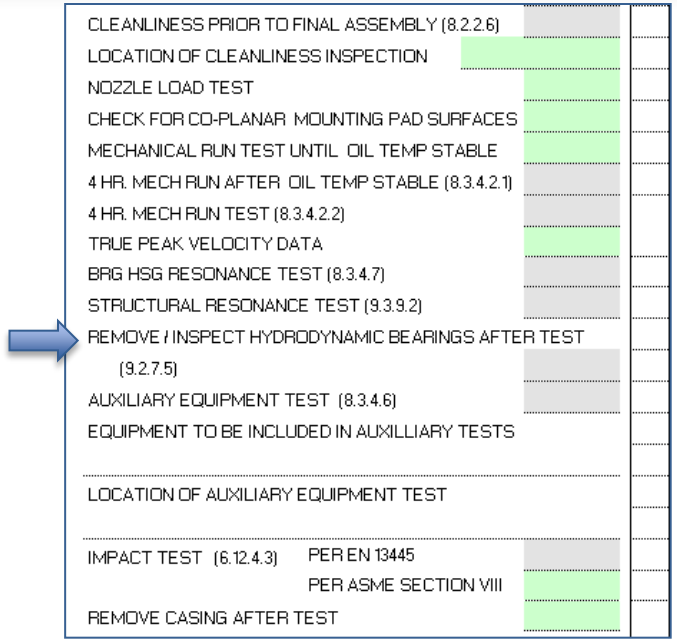
CLEANLINESS PRIOR TO FINAL ASSEMBLY (8.2.2.6)		
LOCATION OF CLEANLINESS INSPECTION		
NOZZLE LOAD TEST		
CHECK FOR CO-PLANAR MOUNTING PAD SURFACES		
MECHANICAL RUN TEST UNTIL OIL TEMP STABLE		
4 HR. MECH RUN AFTER OIL TEMP STABLE (8.3.4.2.1)		
4 HR. MECH RUN TEST (8.3.4.2.2)		
TRUE PEAK VELOCITY DATA		
BRG HSG RESONANCE TEST (8.3.4.7)		
STRUCTURAL RESONANCE TEST (9.3.9.2)		
REMOVE / INSPECT HYDRODYNAMIC BEARINGS AFTER TEST (9.2.7.5)		
AUXILIARY EQUIPMENT TEST (8.3.4.6)		
EQUIPMENT TO BE INCLUDED IN AUXILLIARY TESTS		
LOCATION OF AUXILIARY EQUIPMENT TEST		
IMPACT TEST (6.12.4.3) PER EN 13445		
PER ASME SECTION VIII		
REMOVE CASING AFTER TEST		

- The intention is to determine the natural frequency of the vertical pump to be sure it does not fall near the operating speed.
- Similar to bearing housing resonance except the probe and impact is done to the nozzle head.

REMOVE/INSPECT HYDRODYNAMIC BEARINGS AFTER TEST

RUHRPUMPEN
Specialist for Pumping Technology

9.2.7.5 If specified, hydrodynamic bearings shall be removed, inspected by the purchaser or his representative, and reassembled after the performance test is completed.



- We can comply if this is specified.

AUXILLARY EQUIPMENT TEST

RUHRPUMPEN
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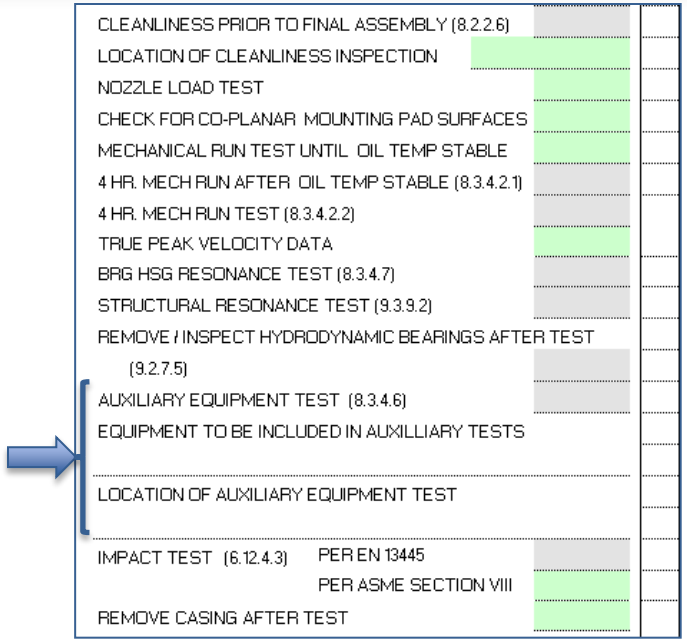
8.3.4.6 Auxiliary equipment test
If specified, auxiliary equipment, such as oil systems, gears and control systems, shall be tested in the vendor's shop. Details of the auxiliary equipment test(s) shall be developed jointly by the purchaser and the vendor.



- Generally involves functional testing of sub-vendor equipment
- Scope of this test is not clearly specified in API 610 so should be defined with customer and business unit during quotation phase and parameters/limitations defined clearly to estimating when requesting pricing and in the customer scope of supply.
- Customers may expect functional testing of sub-vendor equipment as part of complete unit test

IMPACT TEST

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6.12.4.3 The purchaser shall specify whether EN 13445 (all parts) or ASME BPVC, Section VIII, Division 1, shall apply with regard to impact-testing requirements.

REMOVE / INSPECT HYDRODYNAMIC BEARINGS AFTER TEST (9.2.7.5)		
AUXILIARY EQUIPMENT TEST (8.3.4.6)		
EQUIPMENT TO BE INCLUDED IN AUXILLIARY TESTS		
LOCATION OF AUXILIARY EQUIPMENT TEST		
IMPACT TEST (6.12.4.3)	PER EN 13445	
	PER ASME SECTION VIII	
REMOVE CASING AFTER TEST		

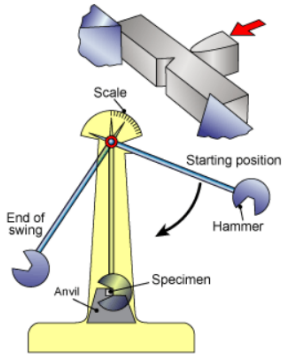

Fig.1. Charpy testing machine and specimen arrangement

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- The Charpy impact test (also called v-notch test) is the most commonly used. It measures the energy needed to fracture a notched sample of material at specific temperature or series of temperatures. Method of measurement is illustrated in Fig. 1.
- The more brittle (less ductile) the material, the lower the fracture energy value.
- Most commonly done for materials in low temperature service (e.g. from pump fluid temperature, low ambient temperature or auto-refrigeration)
- Since materials can become brittle at low temperatures there is a concern about failure of parts so impact tests are done to confirm material is sufficiently ductile at low temperatures.
- Pressure containing parts and shafts are of course the most critical so it is recommended to focus testing on those items. Even though any part can be tested – results of testing on ‘structural’ components (baseplates, bearing brackets, stands) are of less benefit that those from pressure casing. It is recommended to offer only impact testing on pressure casing and shaft unless customer specifically instructs us to do something additional.
- Testing temperature and minimum energy are defined by the ASTM specification for the material and the minimum design metal temperature from customer datasheet.
- Differences between EN 13445 and ASME Section VIII are related to testing methodology and acceptance criteria but little difference from a sales perspective. Business unit will ensure compliance to whichever standard is specified.

REMOVE CASING AFTER TEST

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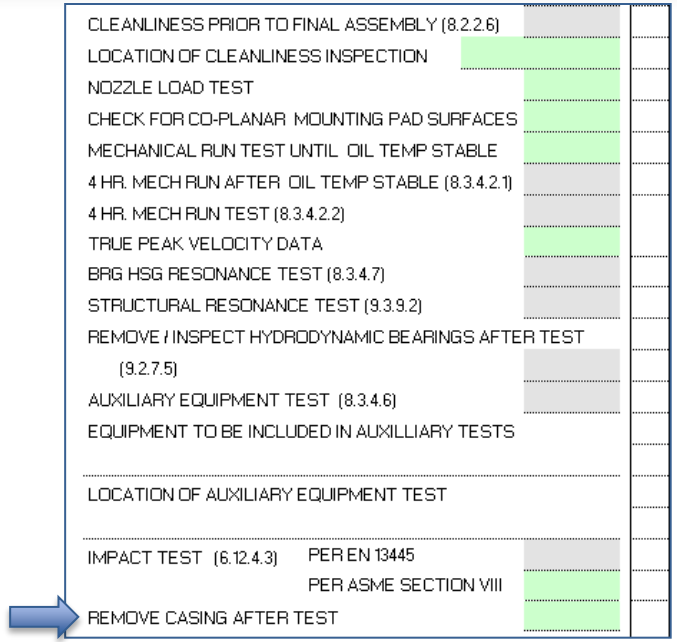
- Requirement is not well defined in API.
- Casing can easily be removed for inspection for OH2 pump, but of course more difficult for vertical pumps.
- Scope of this test is not clearly specified in API 610 so should be defined with customer and business unit during quotation phase.



Coming Attractions ☺

"Start-Up, Commissioning & Troubleshooting of Centrifugal Pumps"

Thurs 31st March – 08.00 (UK GMT) (Eastern Hemisphere) & 17.00 (UK GMT) (Western Hemisphere)

Aimed at Process and Mechanical Engineers, and Consultant Engineers who specify pumping equipment as well as Applications & Sales Engineers selecting and quoting them.

This session is not going to turn you into qualified Installation & Commissioning Engineers but it will help you to have an intelligent conversation with them!

Future sessions : TBA

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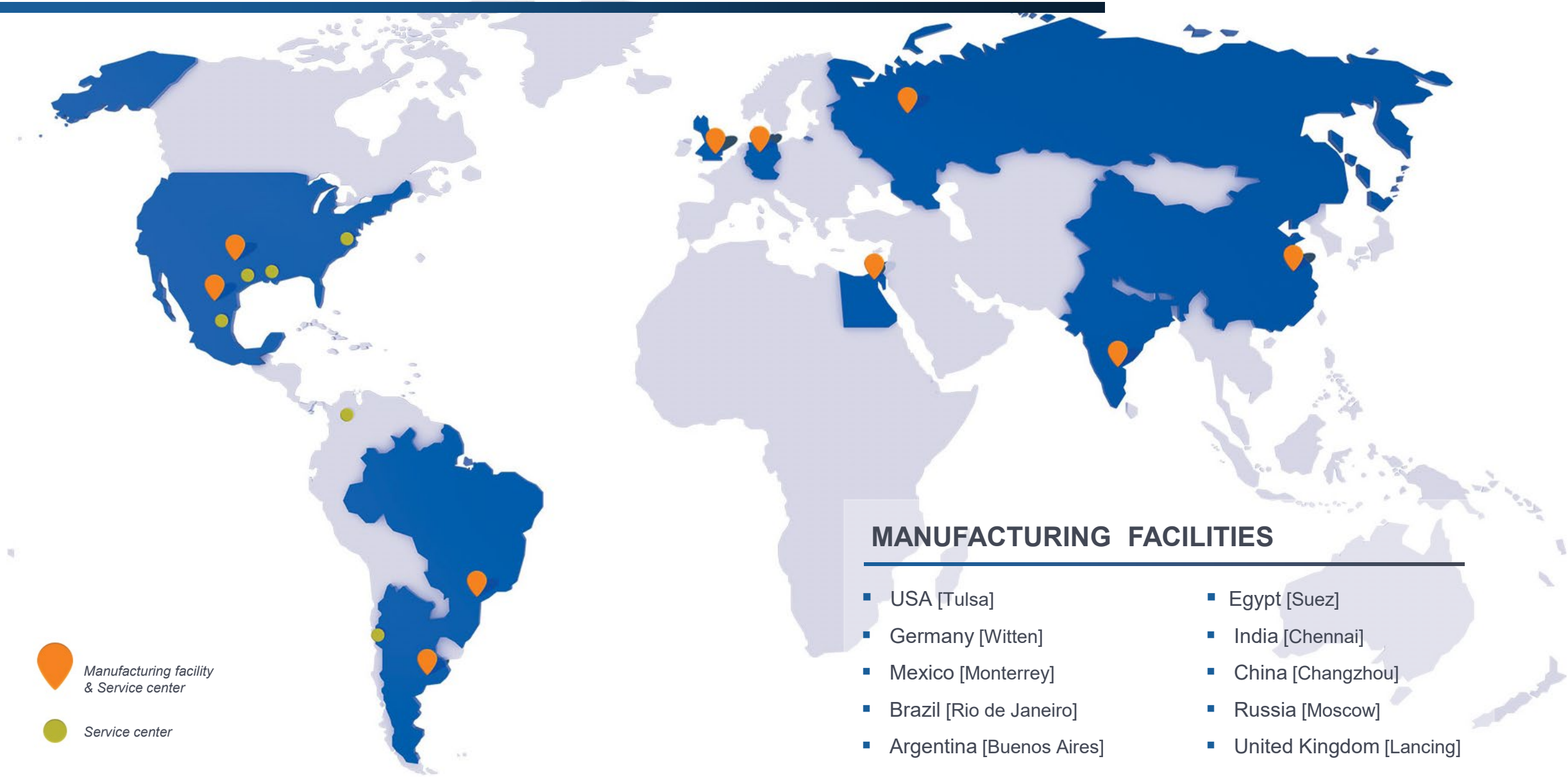

MANUFACTURING FACILITIES

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MARKETS WE SERVE

Our commitment to create innovations that offer reliable solutions to our customers allow us to provide a complete range of pump systems to support **core markets** as:

RUHRPUMPEN

OUR PUMP LINES

Ruhrpumpen offers a broad range of highly engineered and standard pumping products that meet and exceed the requirements of the most demanding quality specifications and industry standards.

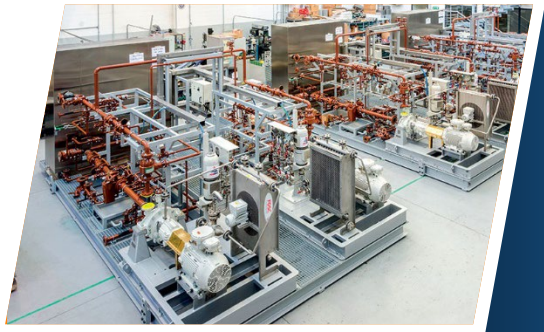
Our pumps can handle head requirements as high as 13,000 ft (4,000 m) and capacities up to 300,000 gpm (68,000 m^3/hr). Moreover, our pump designs cover temperatures from cryogenic temperatures of -310 °F (-196 °C) up to 752 °F (400 °C).

Products include:

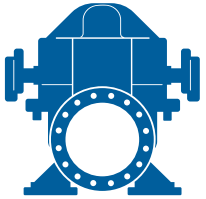
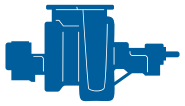
- Single Stage Overhung Pumps
- Between Bearings Pumps
- Horizontal Multi-Stage Pumps
- Vertical Multi-Stage Pumps
- Vertical Mixed Flow & Axial Flow Pumps
- Positive Displacement Pumps
- Full Range of Industrial Pumps
- Submersible Pumps
- Magnetic Drive Pumps
- Decoking Systems
- Packaged Systems
- Fire Systems

OVERHUNG PUMPS

CATEGORY	RP MODEL	DESIGN STANDARD
Sealless Magnetic Drive Pumps	**CRP-M / CRP-M-CC**	ISO 2858 & 15783 HI design (OH11)
	SCE-M	API 685
Foot Mounted OH1 and General End Suction Pumps	**IPP**	HI design (OH1)
	CPP / CPP-L	HI design (OH1) ANSI B73.1
	CPO / CPO-L	HI design (OH1) ANSI B73.1
	CRP	HI design (OH1) ISO 2858 & 5199
	GSD	HI design (OH0)
	SHD / ESK / SK / SKO SKV / ST / STV	HI design (OH1)
	SWP	HI design (OH3A)
Centerline Mounted	**SCE**	API 610 (OH2)
Vertical In-Line Pumps	**SPI**	API 610 (OH3)
	IVP / IVP-CC	HI design (OH4 / OH5)
	IIL	HI design (OH5) Dimensionally compliant with ANSI B73.2
	SPN	API 610 (OH5)



BETWEEN BEARING PUMPS

CATEGORY		RP MODEL	DESIGN STANDARD	
1 and 2 stage	Axially split	**HSC / HSD / HSL HSR / ZW**	HI design (BB1)	
		HSM	HI design (BB3)	
		ZM / ZMS ZLM / ZME	API design (BB1)	
	Radially split	**HVN / J**	API design (BB2)	
		RON / RON-D	API design (BB2)	
Multi-stage	Axially split	**SM / SM-I**	API design (BB3)	
		JTN	API design (BB3)	
	Radially split *single casing*	**GP**	API design (BB4)	
	Radially split *double casing*	**A LINE**	API design (BB5)	

VERTICAL PUMPS

CATEGORY		RP MODEL	DESIGN STANDARD	
Single casing	Diffuser	**VTP**	HI & API 610 (VS1)	
		VCT	HI & API 610 (VS1)	
		HQ	HI & API 610 (VS1)	
		VLT	HI & API 610 (VS1)	
	Volute	**DSV / DX**	HI & API 610 (VS2)	
	Discharge through column – Axial flow	**VAF**	HI & API 610 (VS3)	
	Separate discharge line	**VSP / VSP-Chem**	HI & API 610 (VS4)	
Double casing	Diffuser	**VLT / VMT**	HI & API 610 (VS6)	
	Volute	**DSV / DX**	HI & API 610 (VS7)	
Submersible pumps		**SMF**	HI design (OH8A)	
		VLT-Sub / VTP-Sub	HI design (VS0)	

SPECIAL SERVICE PUMPS

CATEGORY	RP MODEL	DESIGN STANDARD	
Pitot tube pumps	**COMBITUBE**	HI design	
Reciprocating pumps	**RDP**	API 674 ISO 13710	
Vertical turbine generator	**VTG**	HI design (VS6)	
Barge	**LS BARGE**	HI design	
Floating dock pumps	**ZVZ**	HI design	
	LVZ	HI design	
Cryogenic pumps	**SVNV**	-	
	VTG Cryogenic	-	
	VLT Cryogenic VLTV	-	
Pre-packaged fire pump systems	Fire systems incorporate pumps, drivers, control systems and pipework in a single container. They can be skid mounted, with or without enclosure and supplied with electric motor or diesel engine.	**NFPA-20-850** UL and FM approved components