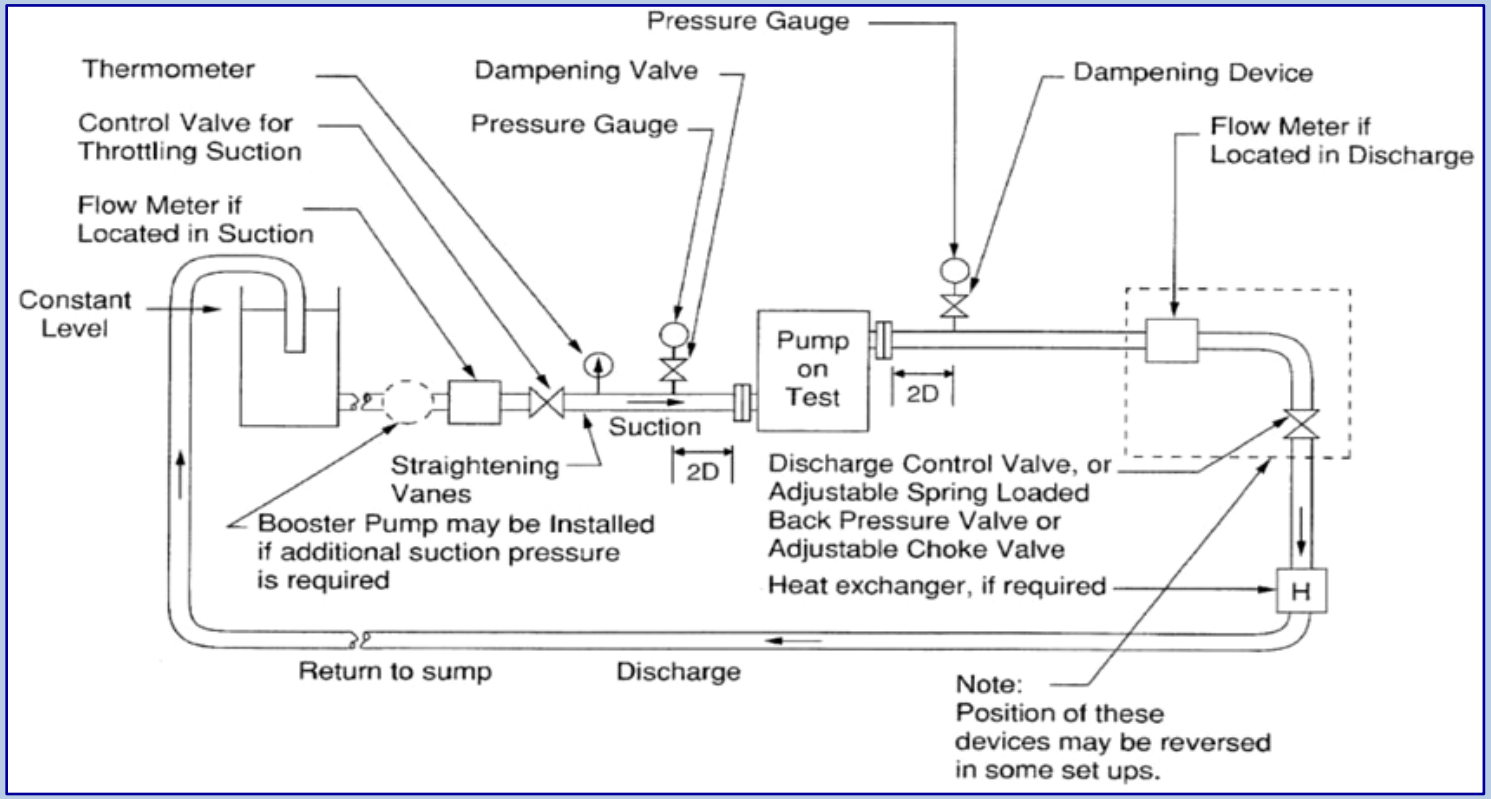
Session 13 – “Performance Testing & Inspection of API 610 Pumps”

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

PUMP TESTING

The WHAT, the WHY, & the HOW of Centrifugal Pump Testing

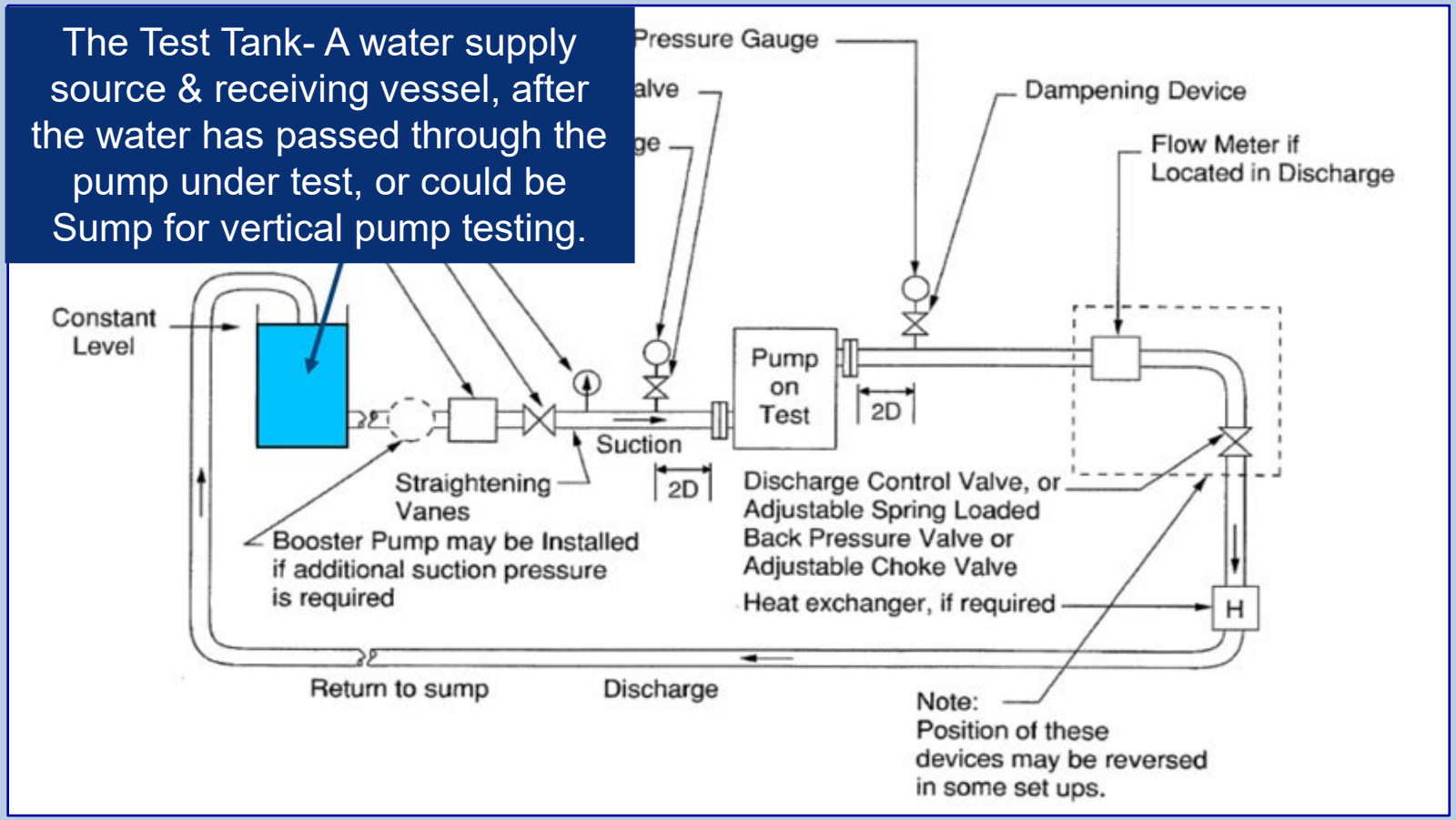


A schematic of a typical Test Bed setup, as shown in the Hydraulic Institute standards.

PUMP TESTING

The WHAT, the WHY, & the HOW of Centrifugal Pump Testing

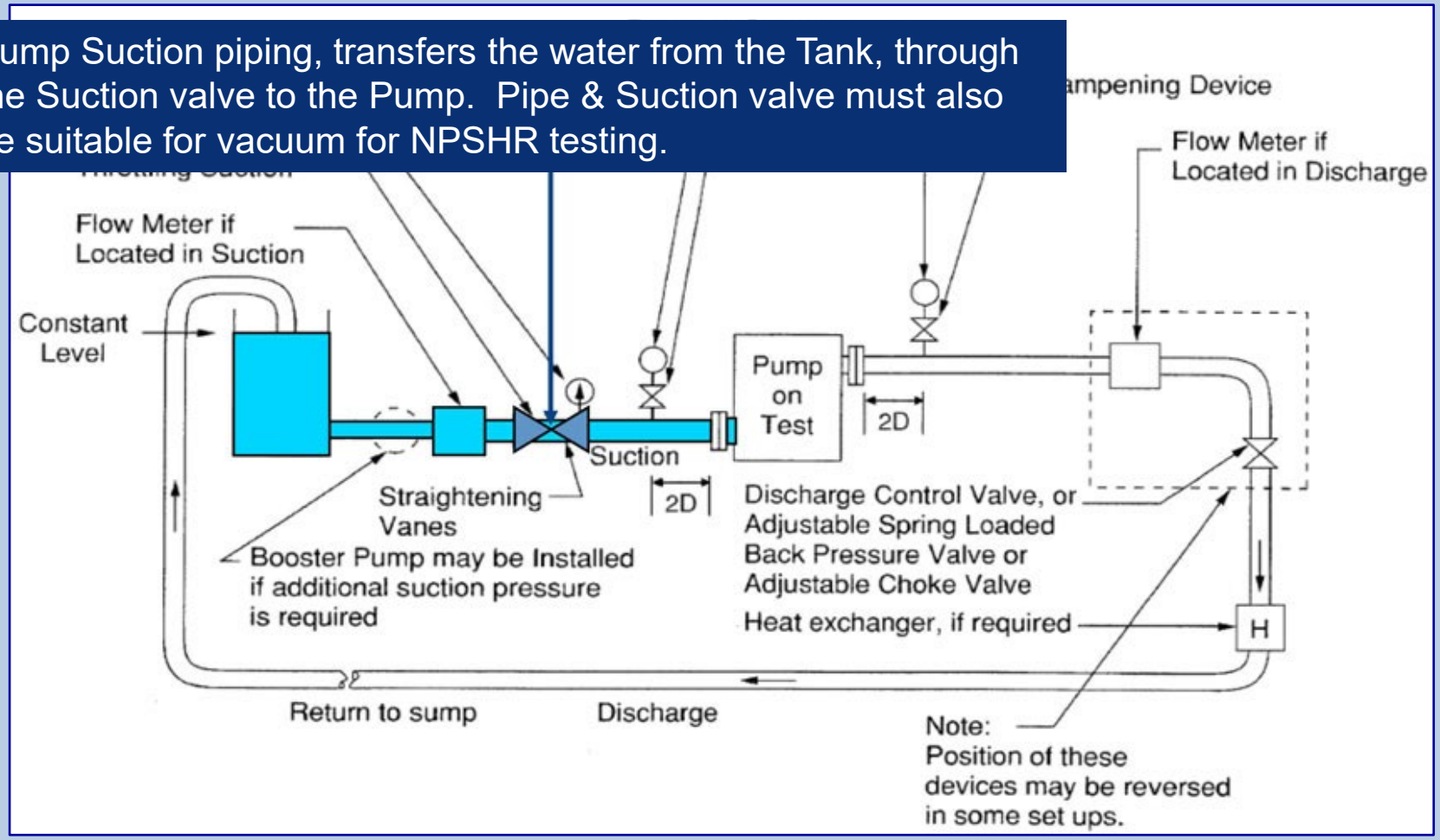
The Test Tank- A water supply source & receiving vessel, after the water has passed through the pump under test, or could be Sump for vertical pump testing.



PUMP TESTING

The WHAT, the WHY, & the HOW of Centrifugal Pump Testing

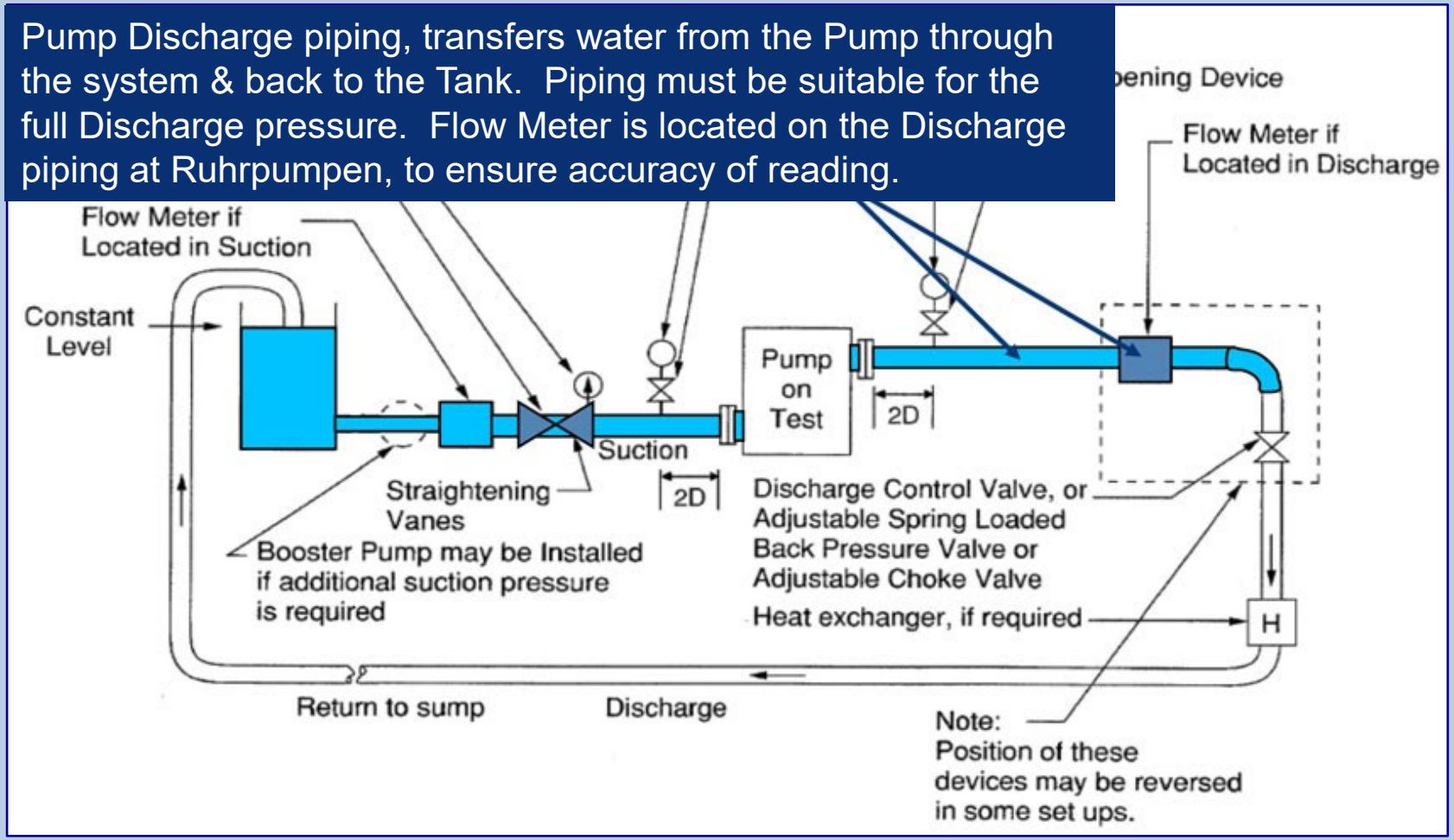
Pump Suction piping, transfers the water from the Tank, through the Suction valve to the Pump. Pipe & Suction valve must also be suitable for vacuum for NPSHR testing.



PUMP TESTING

The WHAT, the WHY, & the HOW of Centrifugal Pump Testing

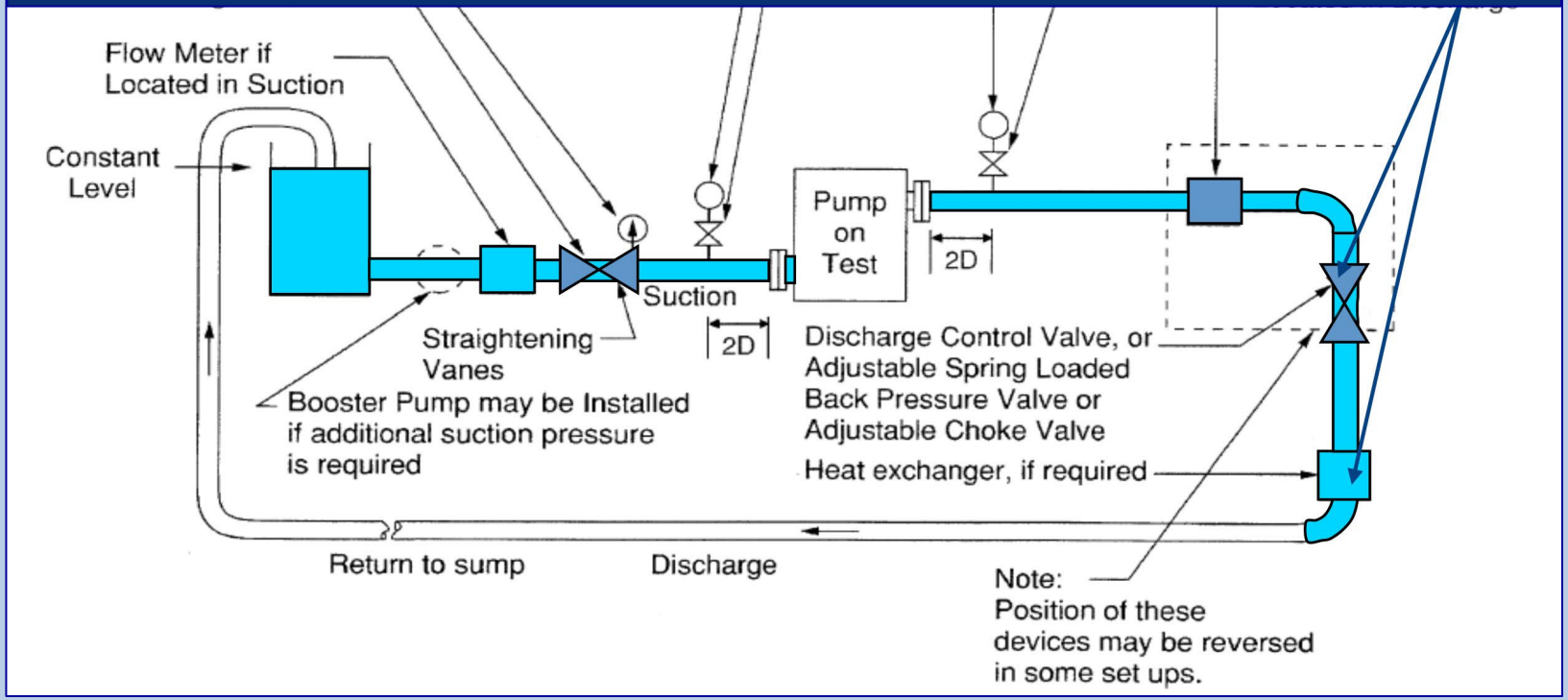
Pump Discharge piping, transfers water from the Pump through the system & back to the Tank. Piping must be suitable for the full Discharge pressure. Flow Meter is located on the Discharge piping at Ruhrpumpen, to ensure accuracy of reading.



PUMP TESTING

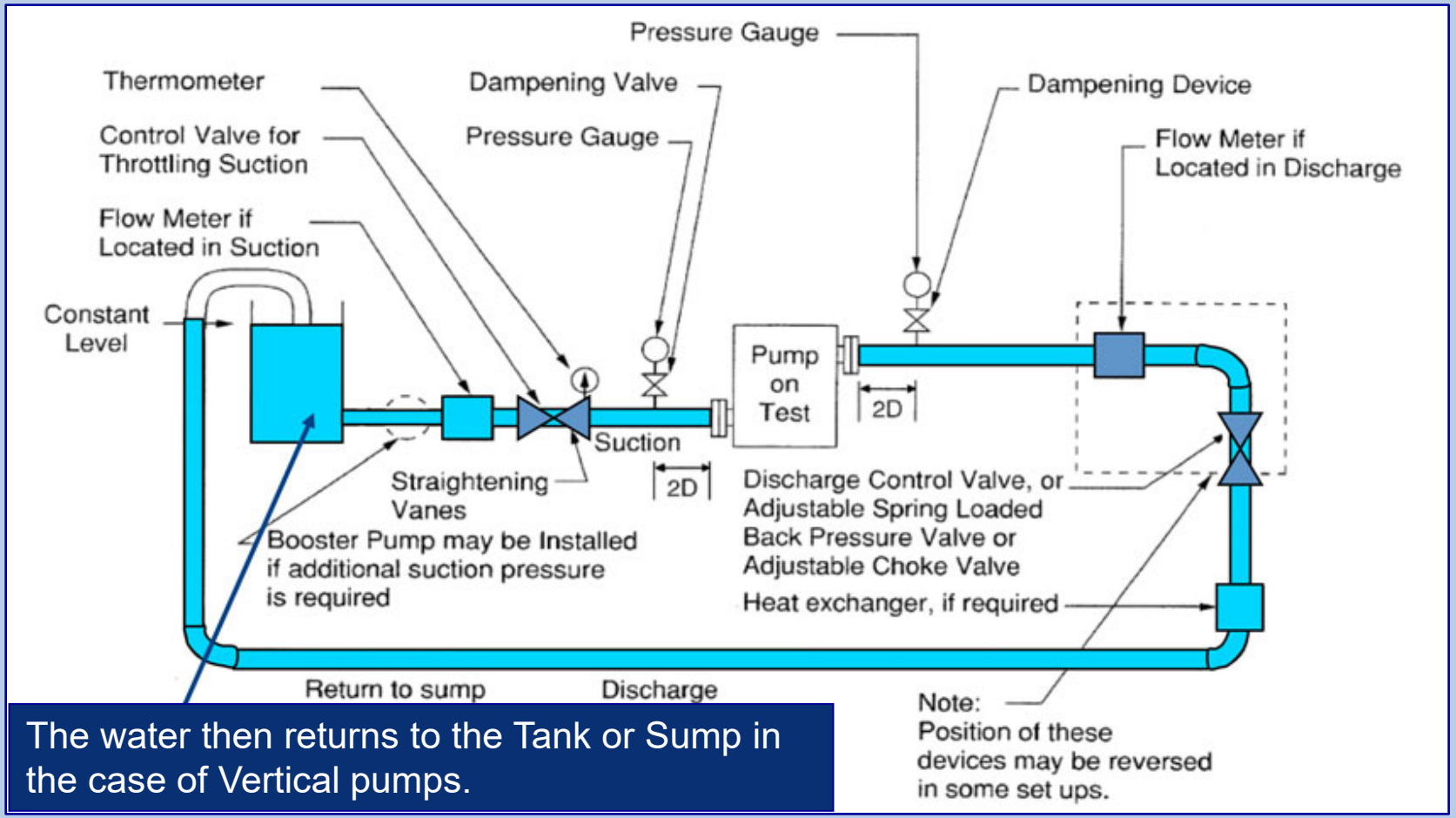
The WHAT, the WHY, & the HOW of Centrifugal Pump Testing

The water flows through the Discharge valve, which provides Flow control by throttling. The water may also be cooled to reduce the temperature to be within the API610 limit of 130F (55C), if extended duration runs are required. This would be achieved either by flowing through a Cooler, or the Tank may have a cool recycled flow.



PUMP TESTING

The WHAT, the WHY, & the HOW of Centrifugal Pump Testing

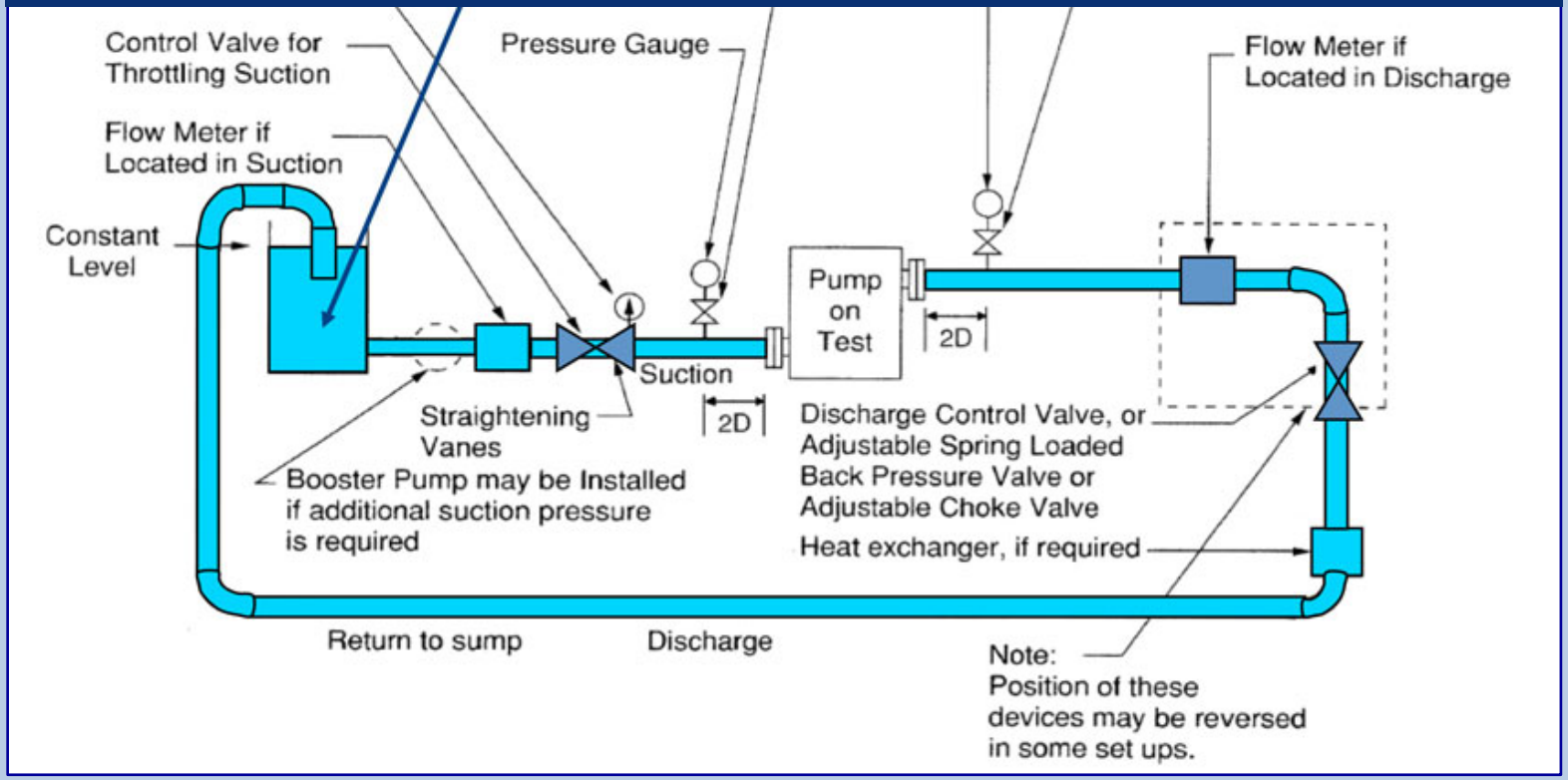


The water then returns to the Tank or Sump in the case of Vertical pumps.

PUMP TESTING

The WHAT, the WHY, & the HOW of Centrifugal Pump Testing

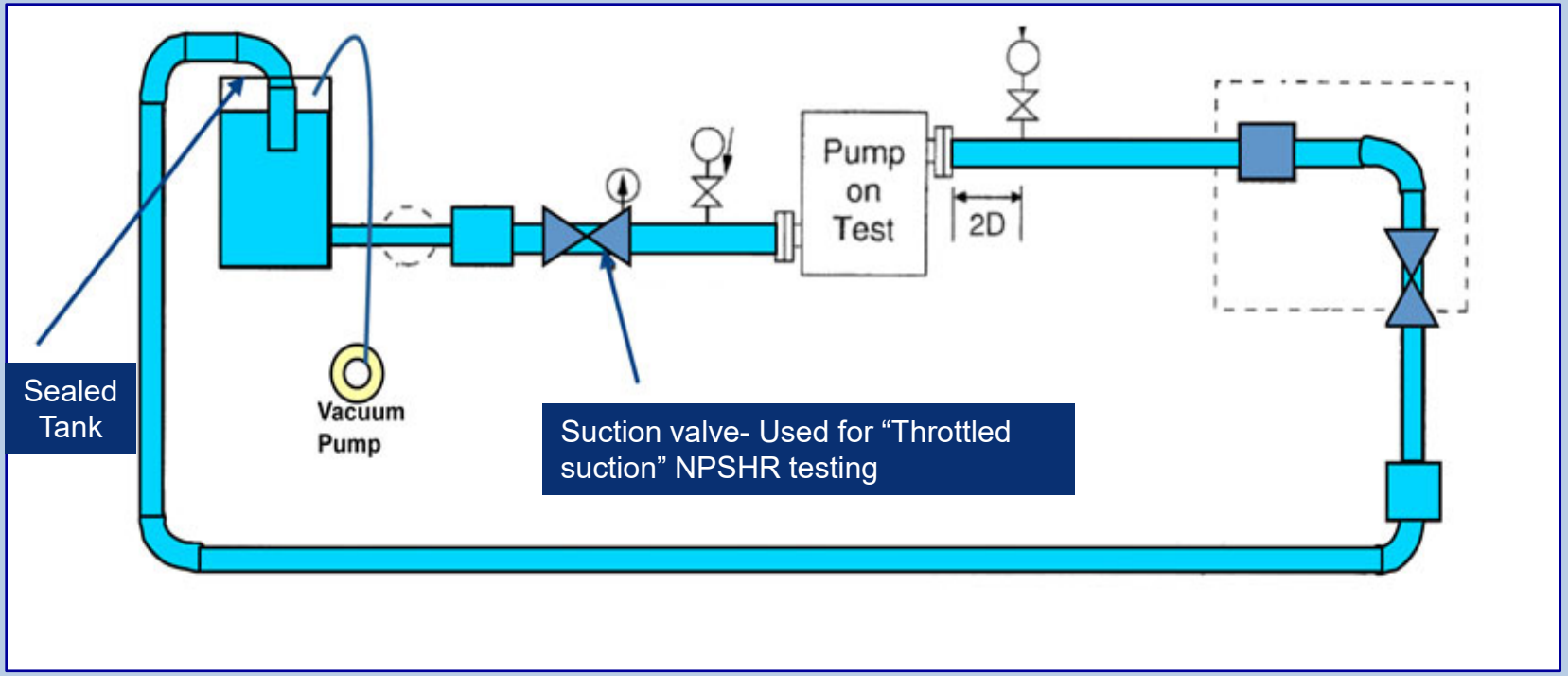
The Tank & the Sump are sized to allow a retention time of an average of 2 Minutes, to allow turbulence and aeration to settle down, before any given particle of liquid begins the cycle again.



PUMP TESTING

The WHAT, the WHY, & the HOW of Centrifugal Pump Testing

For NPSH Testing



PUMP TESTING

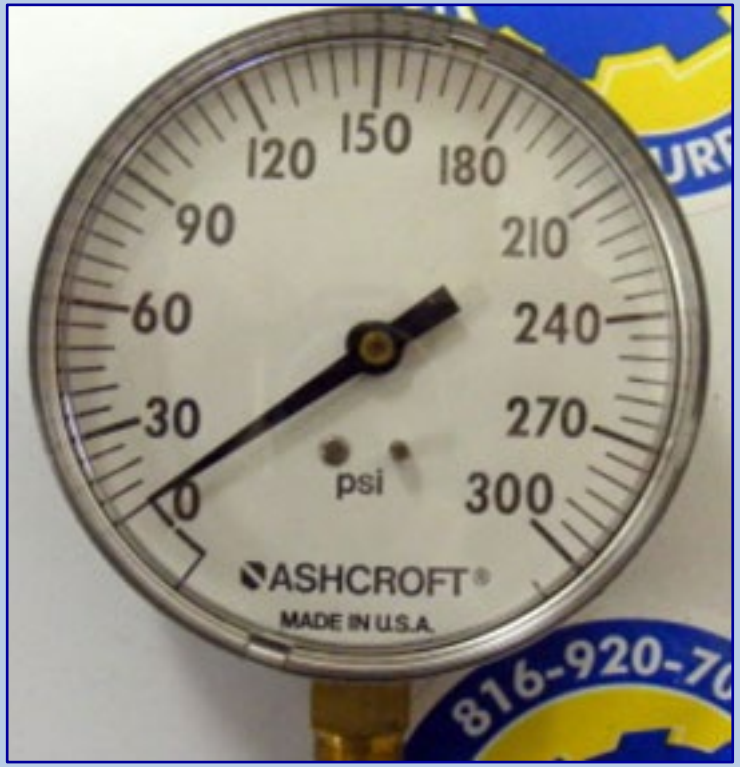
The WHAT, the WHY, & the HOW of Centrifugal Pump Testing

Factory Locations & NPSHR Test Type Carried Out.				
FACTORY LOCATION →	TULSA	MONTERREY, MEXICO	WITTEN, GERMANY	EGYPT
NPSHR TEST TYPE				
SUPPRESSION TYPE VACUUM TESTING	X			
THROTTLED-SUCTION TYPE TESTING		X	X	X

PUMP TESTING

Suction and Discharge pressures are measured on the test bed at each test flow point, using gauges similar to those shown below. These are located either side of the pump, sufficiently far away to be unaffected by turbulence, and the readings are standardized to the same height.

Typical compound Suction pressure Gauge.



Typical Discharge pressure Gauge.

PUMP TESTING

The WHAT, the WHY, & the HOW of Centrifugal Pump Testing

The electrical power flowing into the Test Motor driving the pump is measured by the Test bed Wattmeter, similar to the unit shown below.

The pump power being absorbed is calculated by multiplying the Wattmeter reading by the Motor Efficiency, at each of the test flow points.

Typical Wattmeter

PUMP TESTING

The WHAT, the WHY, & the HOW of Centrifugal Pump Testing

Alternative Method of Measuring the Pump Power:-

Another method of measuring the Pump absorbed power, is by using a Torque Transducer.

This is a more accurate method as it directly measures the pump torque & speed, and so directly establishes the pump absorbed Power. Here is the HP Formula.

HP=2x Pi x N x T /33,000,

(Because 1HP= 33,000 Ft.Lbs/Minute,

Pi=3.142 & N= RPM & T= The TORQUE Measured).

Typical Torque Transducer

PUMP TESTING

The WHAT, the WHY, & the HOW of Centrifugal Pump Testing

Performance Testing the Pump:

The actual action of testing the pump, and calculating the results is actually quite simple, although the pump setup for a large unit can take time.

The procedure for performance testing pumps are:-

1. Determine how many flow points are needed to meet the test standard, eg. API, HI, etc, and what the value of the Flows are.

2. Run the pump at each Flow point and record the values shown on the next slide…..

PUMP TESTING

The WHAT, the WHY, & the HOW of Centrifugal Pump Testing

Performance Testing the Pump:

At initial setup, after recording all contract & pump details, then record the:-

- Height of these gauges above the pump centreline or a known datumn
- Suction and Discharge pipe size * connected to the pump, at the Gauge take-off points
- Impeller diameter(s), including any underfile details

Also, at each flow point record the:

- Flow
- Suction pressure
- Discharge pressure
- Speed (rpm)
- Water temperature
- Wattmeter reading, giving electrical power flowing into the motor
- Vibration levels

PUMP TESTING

The WHAT, the WHY, & the HOW of Centrifugal Pump Testing

Performance Testing the Pump:

From these readings the pump Flow, Speed, differential Head produced & the absorbed Power are calculated at the various flow rates, including the Rated guaranteed point.

These values and the raw data that produced them, are then shown on the Test Log, and pump Curves are produced, and both these are sent to the customer.

Also, Vibration readings are collected, measured at the standard locations on the pumps, which are:-

- For Horizontal pumps:- At the Bearing Housings.
- For Vertical pumps:- At the top flange of the Discharge Head, where the motor is bolted to the pump.

PUMP TESTING

The WHAT, the WHY, & the HOW of Centrifugal Pump Testing

Performance Testing the Pump:

• The first test is carried out with a slightly larger trim diameter Impeller than estimated.

• Then, by evaluating the test results using experience and Affinity Laws, the final test trim needed to reach the Rated duty within the Test tolerances, is calculated.

• The impeller is then trimmed to this slightly smaller diameter, re-balanced, and the pump retested.

• Some test standards state that if, after the first test, it is predicted that the impeller diameter reduction required is 5% or lower, then predicted test values are adequate, without the needing an actual retest. (*API 610 allows this as standard*).

PUMP TESTING

The WHAT, the WHY, & the HOW of Centrifugal Pump Testing

Performance Testing the Pump:

- **Test Tolerances:**

Of course, the acceptability of the test results for the customer, will depend on the results meeting the target values promised when the pump is sold, Plus or Minus the agreed test tolerances.

These tolerances will vary depending on the Test Standard the customer has selected.

Typical Test standard tolerances are shown in the next few slides.

- **After test completion:**

After all test data has been tabulated and plotted, the results are submitted to the customer as the Test Log package.

PUMP TESTING

The WHAT, the WHY, & the HOW of Centrifugal Pump Testing

TEST TOLERANCES: API 610 LATEST EDITION

TABLE 16 – PERFORMANCE TOLERANCES

CONDITION	RATED POINT %	SHUTOFF %
RATED DIFFERENTIAL HEAD: 0 m to 75 m (0 ft to 250 ft) >75 m to 300 m (>250 ft to 1,000 ft) > 300 m (1,000 ft)	± 3 ± 3 ± 3	± 10 (a) ± 8 (a) ± 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 characteristics.
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 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).

PUMP TESTING

The WHAT, the WHY, & the HOW of Centrifugal Pump Testing

Test Tolerances: Hydraulic Institute 14.6

Test parameter	Guarantee requirement	Grade	Grade 1			Grade 2		Grade 3
		Δt_Q	10%			16%		18%
		Δt_H	6%			10%		14%
		Symbol	Acceptance grade					
			1B	1E	1U	2B	2U	3B
Rate of flow	Mandatory	t_Q (%)	± 5%	± 5%	0% to + 10%	± 8%	0% to +16%	± 9%
Total head	Mandatory	t_H (%)	± 3%	± 3%	0% to + 6%	± 5%	0% to +10%	± 7%
Power[a]	Optional (either/or)	t_P (%)	+ 4%	+ 4%	+ 10%	+ 8%	+ 16%	+ 9%
Efficiency[a]		t_η (%)	– 3%	– 0%	– 0%	– 5%	– 5%	– 7%

Table 1 — ANSI/HI 14.6 performance acceptance grade table

[a] Efficiency is a calculated value that is dependent on pump power input and, therefore, either minimum efficiency or maximum pump power input at the guarantee point can be specified, but not both.

PUMP TESTING

The WHAT, the WHY, & the HOW of Centrifugal Pump Testing

Test Tolerances: Hydraulic Institute

Six pump performance test acceptance grades are used: 1B, 1E, 1U, 2B, 2U and 3B. Grade 1 is the most stringent, and the “U” specifies having a unilateral tolerance band.
The “B” specifies having a bilateral tolerance band. Acceptance grade 1E can be used when energy efficiency is of importance and is also bilateral.

HI have a good white paper you can download
“Understanding the Effects of Selecting a Pump Performance Test Acceptance Grade”
Here is the link:
https://europump.net/uploads/HI%20White%20Paper%20-%20Understanding%20the%20Effects%20of%20Selecting%20a%20Pump%20Performance%20Test%20Acceptance%20Grade.pdf

PUMP TESTING

The WHAT, the WHY, & the HOW of Centrifugal Pump Testing

Performance Testing the Pump:

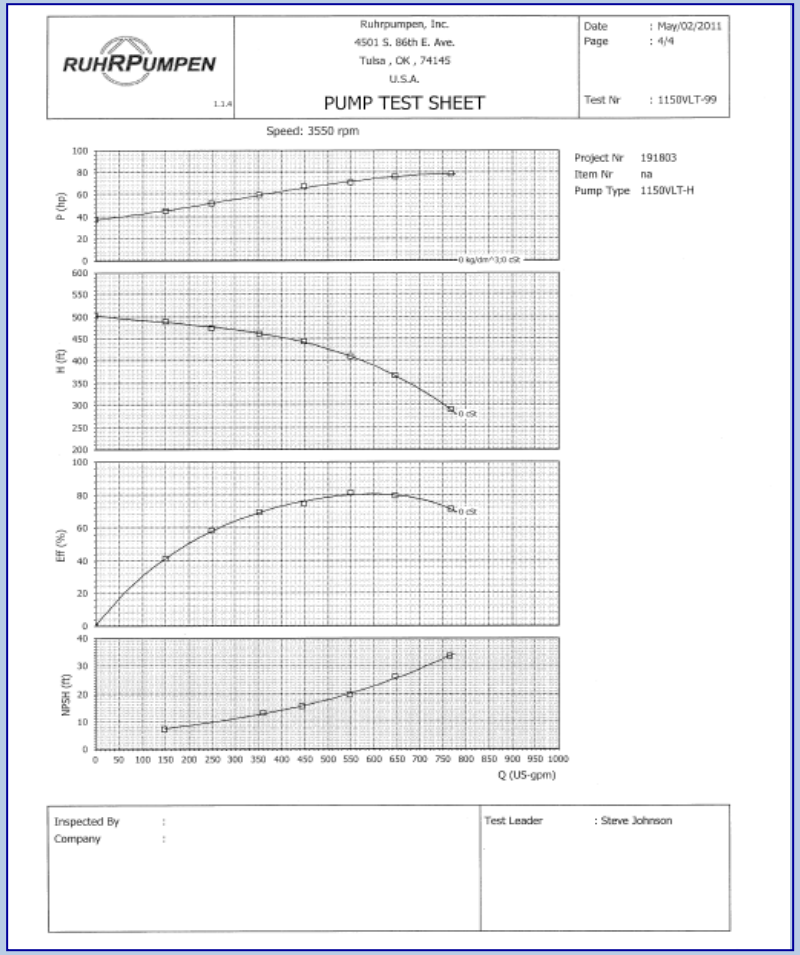
- **Performance Test printout.**

Here we see a typical printout of a Performance Test.

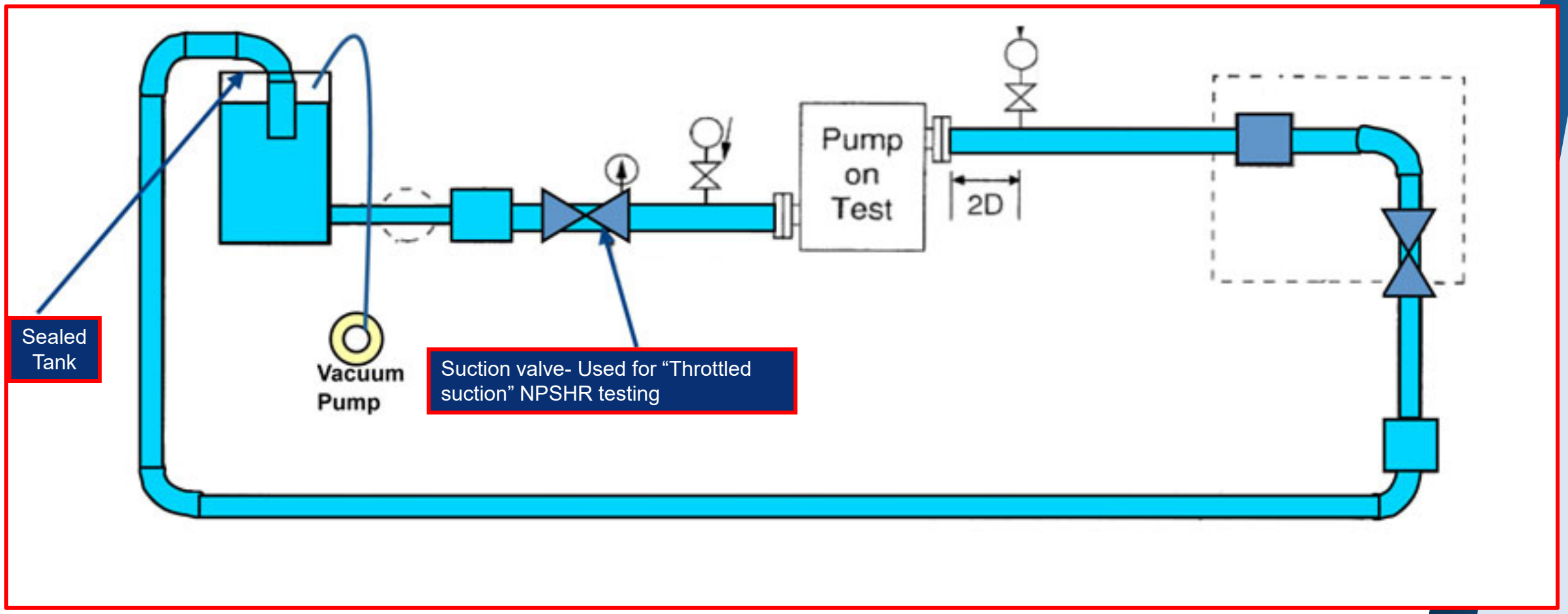
Note that as NPSHR tests have also been carried out, a full NPSHR curve is also shown.

This has been developed from the NPSHR head drop-off tests shown later in these slides.

This sheet, and the Tabulated Data, are sent to the customer as part of the data package.



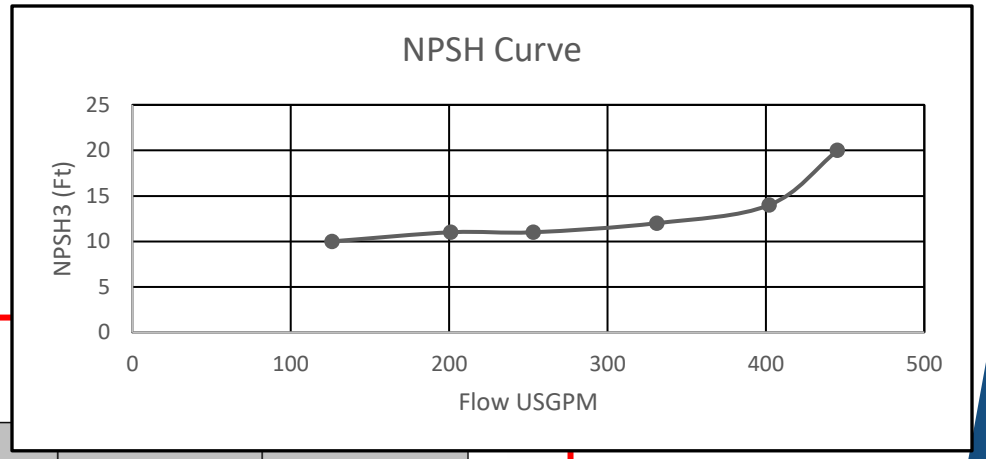
$NPSH_R$ NPSHR Testing Procedure

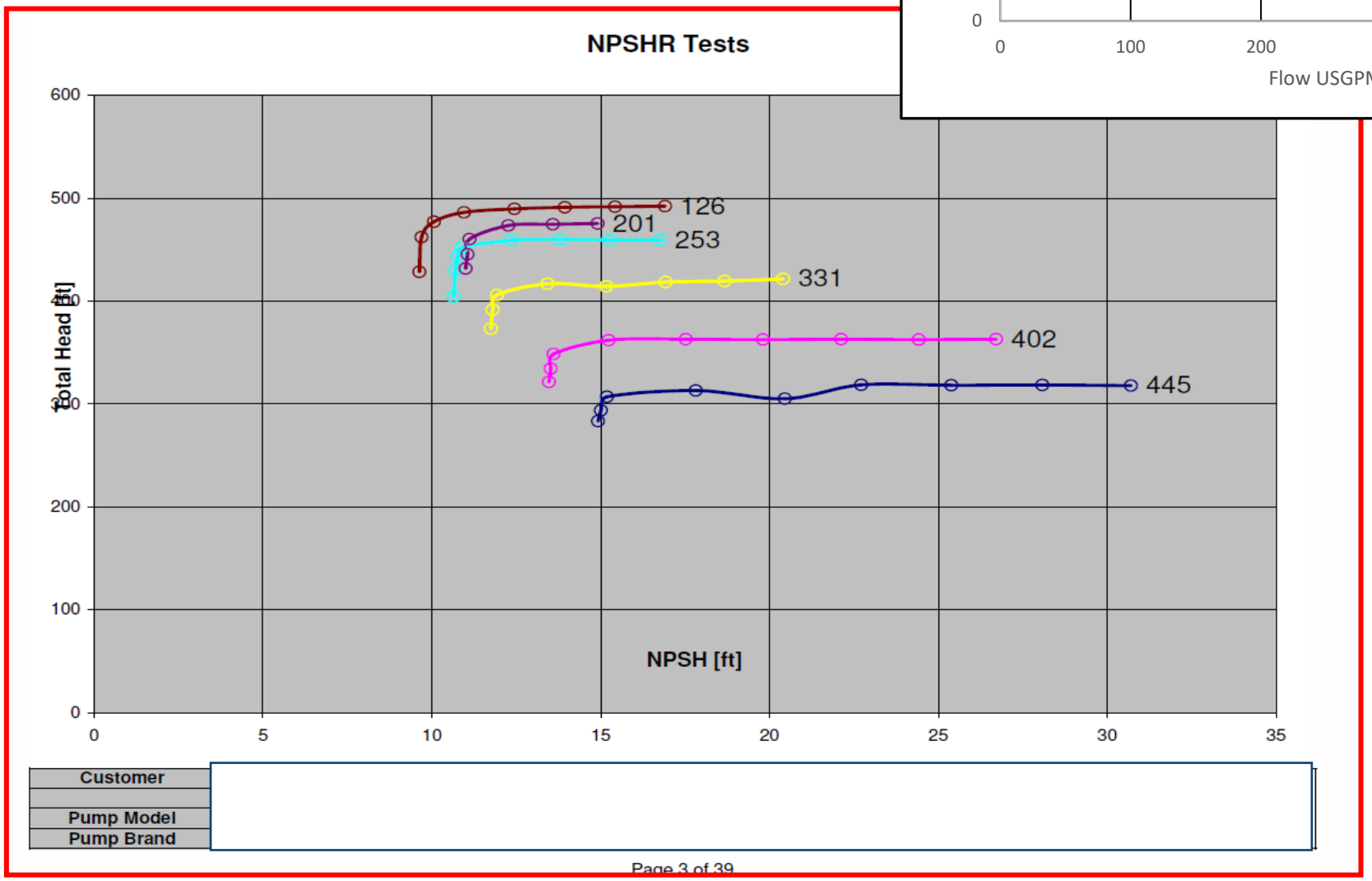


$NPSH_R$ NPSHR Testing Procedure

- The pump is set to the rated speed.
- At each flow point (typically 5 or 6 flows), while the Suction Pressure is reduced, the Discharge Valve is opened slightly to maintain the constant set Flowrate.
- At each NPSHR Test point, Flow, Head, Suction pressure & Water Temperature readings are taken at progressively lower and lower Suction pressures. Whether the reduction in Suction pressure is due to a Vacuum Suppression Test or a Throttled Suction valve Test.
- At some point, as the Suction Pressure is reduced more and more, the Pump Differential Head will get closer to a 3% Head reduction. So now the Suction Pressure Reduction values are taken closer together.
- After the Head drop has reached 3% at every Flowrate, the NPSH3 test is completed.

$NPSH_R$ NPSH Test Curve





PUMP TESTING

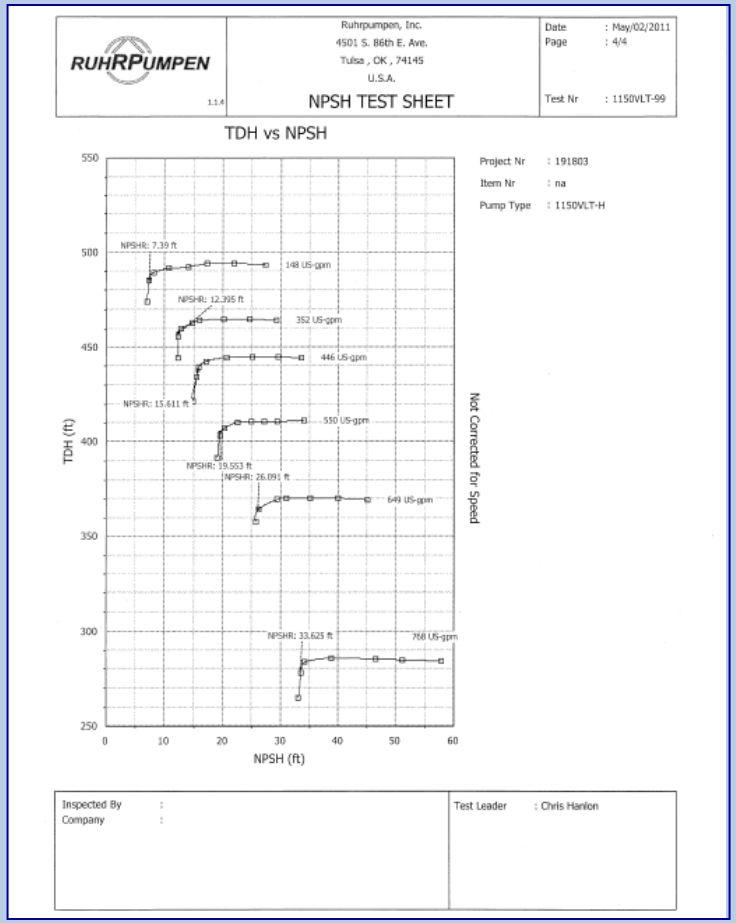
The WHAT, the WHY, & the HOW of Centrifugal Pump Testing

NPSHR Testing:

- **NPSHR Test procedure:**

Here we see a typical printout of an NPSHR head drop-off tests.

This sheet, and the Tabulated Test Data, are sent to the customer as part of the data package.



PUMP TESTING

The WHAT, the WHY, & the HOW of Centrifugal Pump Testing

NPSHR Testing:

Note:- 3% is the pump industry standard definition of NPSHR.

However, customers can re-define NPSHR.

For example:-

• “1% Head drop defines NPSHR”

• Occasionally even 0%, which is called the Inception of Cavitation

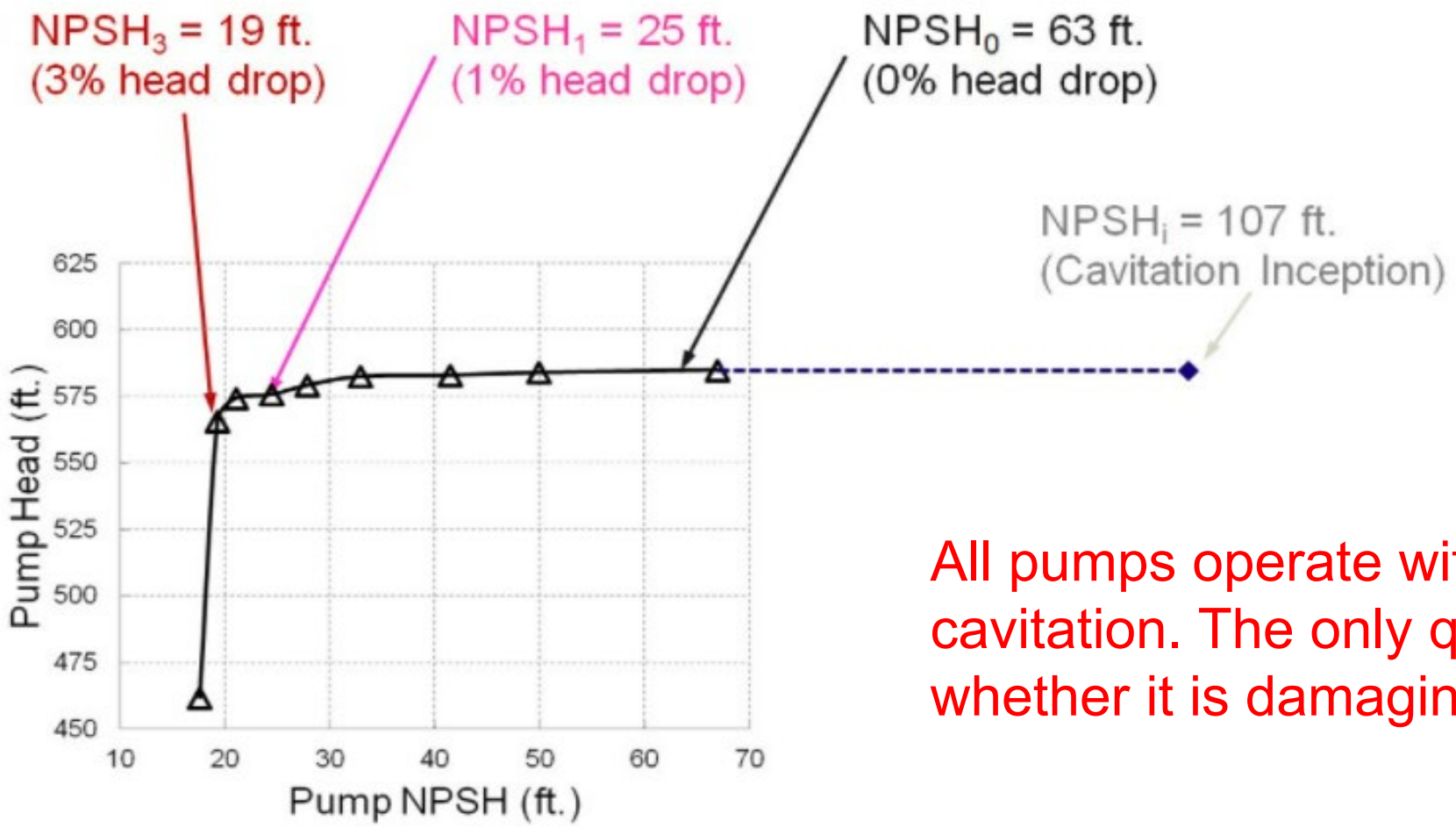
• ARAMCO often requires an NPSHR figure based on “ that value of NPSHR that will give a predicted Impeller life of 40,000 Hours”.

Note:-

The only values that can be proven on the test bed are NPSHR of 3% and 1%.

$NPSH_R$

Onset of Cavitation



All pumps operate with suction cavitation. The only question is whether it is damaging cavitation.

Source – Simon Bradshaw - Director Engineering, Pumps Americas at CIRCOR

$NPSH_R$

NPSH Testing of Vertically Suspended Pumps

During performance testing the pump is suspended in a below-ground suction tank or pit with an open suction bellmouth on the pump (no suction piping).

So clearly we cannot pull a vacuum on the pit or throttle the suction.

To carry out an NPSH Test you need to build the pump as a 1 stage pump and suspend it in the above ground sealed suction tank. You can then pull a vacuum on that tank to carry out the NPSH test.

This is what RP does in its Tulsa factory.

In some factories a VS6 pump might be tested, not in the pit, but in its own suction barrel in the same test loop as a horizontal pump.

Then you can carry out an NPSH test in the normal way either by vacuum suppression, or by suction throttling.

$NPSH_R$

NPSH Testing of Vertically Suspended Pumps

Pumpdown Test

It is often possible to offer a “Pumpdown Test” in an open sump configuration of a VS1 or VS3 pump (or a VS6 pump without its barrel)

The pump will be built for the test with test shop column sections, to get as close as possible to the Minimum Submergence level of the particular pump. Then the pump is run without recirculation of flow back to suction but sending it to drain instead.

This allows the level in the pit to drop until the pump discharge pressure drops indicating you have reached the minimum pumping level.

This is very wasteful of water and municipal water companies may well not allow it.

Performance Testing

Tulsa Test Loop

See attached PDF Photos

Performance Testing

Monterrey Test Loop

See attached PDF Photos

Performance Testing

Monterrey Test Loop

New Vertical Pump Test Pit under construction

Depth: 13 m (43ft)

Length 22m (72ft)

Width 4m (13ft)

Volume 2000m^3 (528,000 galls)

Coming Attractions ☺

"Performance Testing & Inspection of API 610 Pumps Part 2"

Thurs 10th 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 will look at the What, the Why and the How of Pump Performance Testing (Part 1) and also look at the various Inspections & Tests that are frequently specified on the Data Sheets (Part 2).

Future sessions : 31st March

– Start-up, Commissioning & Troubleshooting of Centrifugal Pumps

OVERVIEW OF PART 2

Purpose of this presentation

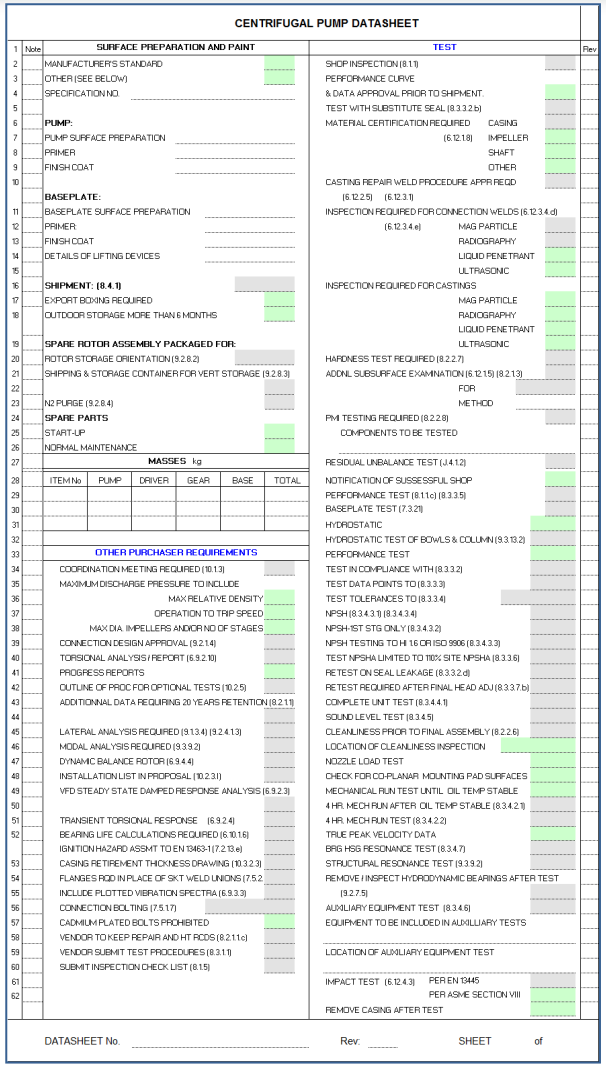
- To give an overview of the types of testing discussed in API 610 11th Edition
- Brief description of methodology and intention of tests and inspections
- Important points from perspective of sales and quotations

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
- Cell are color 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 CASING	
	PUMP SURFACE PREPARATION	(6.12.1.8) IMPELLER	
	PRIMER	SHAFT	
	FINISH COAT	OTHER	
		CASTING REPAIR WELD PROCEDURE APPR REQD	
	BASEPLATE:	(6.12.2.5) (6.12.3.1)	
	BASEPLATE SURFACE PREPARATION	INSPECTION REQUIRED FOR CONNECTION WELDS (6.12.3.4.d)	
	PRIMER	(6.12.3.4.e) MAG PARTICLE	
	FINISH COAT	RADIOGRAPHY	
	DETAILS OF LIFTING DEVICES	LIQUID PENETRANT	
		ULTRASONIC	
	SHIPMENT: (8.4.1)	INSPECTION REQUIRED FOR CASTINGS	
	EXPORT BOXING REQUIRED	MAG PARTICLE	
	OUTDOOR STORAGE MORE THAN 6 MONTHS	RADIOGRAPHY	
		LIQUID PENETRANT	
	SPARE ROTOR ASSEMBLY PACKAGED FOR:	ULTRASONIC	
	ROTOR STORAGE ORIENTATION (9.2.8.2)	HARDNESS TEST REQUIRED (8.2.2.7)	
	SHIPPING & STORAGE CONTAINER FOR VERT STORAGE (9.2.8.3)	ADDNL SUBSURFACE EXAMINATION (6.12.1.5) (8.2.1.3)	
		FOR	
	N2 PURGE (9.2.8.4)	METHOD	
	SPARE PARTS	PMI TESTING REQUIRED (8.2.2.8)	
	START-UP	COMPONENTS TO BE TESTED	
	NORMAL MAINTENANCE		
	MASSES kg	RESIDUAL UNBALANCE TEST (J.4.1.2)	
	ITEM No. PUMP DRIVER GEAR BASE TOTAL	NOTIFICATION OF SUSSESSFUL SHOP	
		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 ROD IN PLACE OF SKT WELD UNIONS (7.5.2)	STRUCTURAL RESONANCE TEST (9.3.9.2)	
	INCLUDE PLOTTED VIBERATION 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 RCDS (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