

# CENTRIFUGAL PUMPS INSPECTION AND TESTING

by

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## INTRODUCTION

The general requirements for inspection and testing of centrifugal pumps are presented. The successful completion of inspection and testing verifies pump design and specification compliance prior to release of pump for shipment and helps avoid field problems.

Scope: A general overview of inspection and testing requirements and guidelines is established for the following:

- Inspection and testing requirements based on ASME/ANSI Standards ANSI B73.1M and B73.2M—1991 Horizontal and Vertical Centrifugal Pumps, and API 610, 7th edition.

- Specifying inspection and testing requirements.
- Shop test acceptance criteria.
- Preparation and use of Inspection and Testing checklist.
- Review of shop performance and NPSH test procedures.
- Shop test reporting.

Prior to issue of the pump bid inquiry, the requirements of inspection and testing of pumps shall be clearly established in the pump specification and data sheets. These requirements are subdivided into the following categories: *Inspection Requirements*; *Shop Test Requirements*; *Inspection and Testing Checklist for Centrifugal Pumps*; and *Shop Test Procedures*.

### *Inspection Requirements*

- Materials (physical properties and chemical composition)
- Castings
- Casting Repairs
- Welding
- Nondestructive Testing
- Impact Tests
- Visual Inspection

### *Shop Tests Requirements*

- Hydrostatic Tests
- Shop Performance and NPSH Tests
- Acceptance Criteria

### *Inspection and Testing Checklist for Centrifugal Pumps*

- Single Stage ANSI and General Service Pumps
- Heavy Duty Centrifugal Pumps (API)

### *Shop Test Procedures*

- Performance Test Procedure
- NPSH Test Procedure
- Test Report

**INSPECTION REQUIREMENTS**

*Materials*

*General*

The materials of the major pump components shall be identified in the pump data sheets with ASTM or ANSI Standards based on API Standard 610, 7th edition, Appendix H or equivalent. When such designation is not available, a tabulation of the physical properties and the chemical composition shall be provided by vendor in the proposal.

Tests for physical properties and chemical composition from the heat from which material is supplied, i.e., for pressure containing parts, shafts and impellers are normally recommended for:

- Internals of pump component exposed to hydrogen sulfide (H<sub>2</sub>S) including traces of H<sub>2</sub>S.
- Pumps in highly corrosive service.
- Pumps in cryogenic service (below -50°C).

The material of construction can be further classified as per following:

- Cast iron pressure casing material is generally limited to cooling water and similar services to avoid brittle failure caused from thermal shock.
- Sour water service shall be constructed from cast steel material as a minimum.
- The material of specific components in hydrogen sulfide service shall conform to NACE Standard MR-01-75.

*Castings*

Castings shall be free from any defect such as porosity, cracks, blow holes, shrink holes, scale, and similar injurious defects.

For critical pump services, pumps application in cryogenic services, or for a specialty casting, inspection is recommended for any major casting defect repair as follows:

- Check mill test reports for physical properties and chemical composition property compliance.
- Check post repair heat treatment charts.
- Check/witness nondestructive examination as required and specified.
- Check/review welding procedures.

*Classification of Casting Repairs*

Major repairs can be defined per ASTM Standards as follows:

- The casting failure to meet hydrostatic test requirements.
- Repairs for which the depth of any cavity prepared for repair by welding exceeds 20 percent of the wall thickness or 1.0 in (25 mm), whichever is less.
- The cavity prepared for welding is greater than approximately 10 in<sup>2</sup> (65cm<sup>2</sup>).
- Any repair to cast iron components “may” be considered as major repair.

*Procedure for Major Repairs*

In general, all major repairs as previously defined require written acceptance of repair procedure by purchase prior to proceeding with the repair. The procedure generally should cover:

- Type of defect and how it was discovered.
- Sketch or drawing showing location and depth of the defect.
- Method of repair (welding, plugging, etc.)

- Step by step procedure of repair including heat treatment where applicable and method of inspection after repair.

No repairs by peening, plugging or impregnation are allowed to any ferrous pressure containing parts except cast gray iron or nodular iron may be repaired by plugging within the limits of ASTM A278, 536, or 395, respectively. Weldable grades of steel castings may be repaired based on Section VIII, Division 1, and Section IX of the ASME code.

*Welding*

Welding of pressure containing parts, wetted parts, piping, and any weld repairs to these components shall be performed and inspected in accordance with the requirements of Section VIII, Division 1, and Section IX of the ASME Code.

All pressure containing welds, including suction and discharge nozzles of pumps with fabricated casings are generally full-fusion, full penetration welded, and the quality of welding is verified by nondestructive examination.

Fabricated casing welds require post weld heat treatment in accordance with Section VIII, Division 1, of the ASME Code.

Piping-to-casing welds are often stress relieved locally. All welds shall be post weld heat treated in accordance with Section VIII, Division 1, UW40 of the ASME Code. Welding of the pressure containing components shall be done by qualified welders in accordance with Section IX of the ASME Code.

All welding not covered by Section VIII, Division 1, of the ASME Code such as all noncritical welding, i.e., structural welding, baseplates, etc., shall be performed in accordance with American Welding Society (AWS) D1.1 Standard, as a minimum.

Critical pump services, and any major repairs as defined earlier, generally require review and written acceptance of welding procedure and procedure qualification.

*Nondestructive Testing*

The extent of nondestructive examination is normally determined by the pump size, type, materials of construction, or criticality of the pump application.

Nondestructive testing is normally applied to nozzle welds, castings, repairs and critical pump materials for components such as casings, impellers, and shafts to determine defects in fabrication, welding, casting, and any repairs.

Nondestructive testing shall be performed in accordance with ASME Code, prior to the hydrostatic test as per the guidelines in Table 1.

*Table 1. Nondestructive Testing Guidelines.*

NDT INSPECTION TYPE	APPLICABLE CODE	ACCEPTANCE STANDARD ASME CODE	APPLICATION
Magnetic Particle	ASME E 709	Castings - ASTM E 125 Welding - ASME Section VIII, Div. 1, Appendix 6 (API TABLE 10)	Weld Inspection
Dye Penetrant	Sec. V Art. 6 ASTM E165	Castings-ASME Section VIII, Div. I, App. 7 Welding - ASME Section VIII, Div.I, Appendix 8	When magnetic particle inspection is not feasible.
Radiography	ASTM E 94 & ASTM E 142 Casting E446, E186, E280	Castings - ASME Section VIII, Div. 1, Appendix 7 Welding - ASME Section VIII, Division 1 W52	Critical Areas - Abrupt Section Changes, High Stress Areas, Weld Ends, Nozzle Weld Repair, Etc.
Ultrasonic	Section V, Article 5 ASTM A609	Castings - ASME Sec. VIII, Div. I, App. 7, Welding - ASME, Section VIII, Div. I, Appendix 12	When Radiography is Not Feasible & When Section Thickness Exceeds 2" (50 mm)

**Impact Test**

Carbon steel materials in low temperature service below the ductile-brittle transition require careful selection to avoid brittle failure.

For low temperature pump application such as -20°F (-29°C) and below, selected carbon steel material shall meet the minimum Charpy V notch impact energy requirements at the lowest specified temperature in accordance with paragraph UG-84 of ASME Section VIII, Division 1.

**Visual Inspection**

All surfaces of castings including castings for flanges and other piping components, etc., will be visually inspected to ensure conformity with the requirement of MSS SP-55 and will be free from any scale buildup, cracks, hot tears, etc.

**SHOP TESTS**

**Hydrostatic Tests**

All pressure containing parts, including auxiliary systems shall be hydrostatically tested with liquid at 1.5 times the maximum allowable pressure and as per the following:

- Limit chloride content of hydrostatic test liquid to maximum 50 parts per million for stainless steel materials.
- Split pressure level testing (inlet and discharge casing ends tested at different pressures) for double casing barrel pumps should be mutually agreed between purchaser and vendor prior to order placement.
- All cooling passages shall be hydrostatically tested at a minimum pressure of 115 psig (7.9 barg) or as specified by purchaser.
- Mechanical seals shall not be used during hydrostatic testing.
- The hydrostatic test should be considered satisfactory when no seepage or leak is observed for at least:
  - 30 minutes (API 610 Standard).
  - 10 minutes (ANSI Standard and Process Industry Practice for ANSI Pumps).
  - Three minutes (< 100 hp) Hydraulic Institute Standard.
  - 10 minutes (> 100 hp).
- The purchaser's written approval is required prior to any repairs performed because of a failed hydrostatic test.

**Shop Running Tests**

Shop running tests are performed to prove the mechanical integrity of the unit, alignment, vibration level, and to verify pump performance.

The requirements for pump performance, vibration, and NPSH testing should be clearly defined in applicable specification/standards and in data sheets prior to bid inquiry issue. For detailed summary of testing requirements as specified in API 610, ANSI B73.1M/B73.2M, and Hydraulic Institute Standard refer to Table 2.

These requirements vary depending on the pump standards used and requirements specified by EPC contractors and pump users as per following.

- ANSI/ASME B73.1M and B73.2M (1991) specification for horizontal end suction and vertical inline centrifugal pumps do not mandate performance, mechanical, or NPSH testing. However, when testing is specified, the acceptance criteria is that of Hydraulic Institute Standards, unless more stringent limits are imposed. Often, pumps built per ANSI specifications are manufactured as

**Table 2. Comparison of Centrifugal Pump Testing Requirements.**

TEST TYPE	PUMP SPECIFICATION REQUIREMENTS				REMARK(S)
	HYDRAULIC INSTITUTE	ANSI	API 610 7th edition	PIP (ANSI PUMPS)	
PERFORMANCE TEST	Optional	Optional (Hyd. Inst. Test Std) (Level A - 7 Points) (Level B - 5 Points)	Mandatory (5 Points)	• Not > 11,000 • Parallel Operation • When Normal Flow is < 10% above min. cont. flow	
VIBRATION TEST	Optional	Optional	Mandatory (Rated Point)	When Performance Test is conducted	
NPSH TEST	---	---	NPSHA - NPSHR < /> 2 ft (< /> 0.6 M)	NPSHA - NPSHR < /> 6.0 ft (1.8 m)	
COMPLETE UNIT TEST	---	---	Optional	---	
AUXILIARY EQUIPMENT TEST	---	---	Optional	---	
SOUND LEVEL TEST	---	---	Optional	---	

standard products and sold as off the shelf commodities without any shop tests.

- API 610, 7th Edition mandates all pumps to be tested for mechanical and hydraulic performance verification.
- The process industry practices (PIP) for ANSI pumps recommends that the performance test be carried out if any of the following conditions are met:
  - Pumps operating in parallel
  - Suction specific speed above 11,000
  - Normal flow is less than 10 percent above minimum continuous flow.

An NPSH test is generally required when available NPSH is within two to six feet of NPSH<sub>R</sub>. Refer to test specification summary Table 2.

Complete unit tests are not normally specified except for extremely critical pumping systems, and when driver size and voltage level are compatible with that available in the vendor's shop.

**Shop Test Acceptance Criteria**

Typical Shop Test Acceptance Criteria are listed in the Hydraulic Institute Standard and API 610. For summary of test acceptance criteria, refer to Tables 3 and 4.

**INSPECTION AND TESTING CHECKLIST FOR CENTRIFUGAL PUMPS**

Typical inspection and testing checklists are shown in Tables 5, 6, 7, and 8 for:

**Table 3. Comparison Centrifugal Pump Performance Test Acceptance Criteria.**

DESIGN CHARACTERISTICS	PUMP SPECIFICATION REQUIREMENTS			REMARK(S)
	API 610 7th edition	HYDRAULIC INST. STD, ANSI AND PIP	ACCEPTANCE LEVEL	
RATED DIFFERENTIAL HEAD	CONDITION	RATED POINT	SHUTOFF	
	100 ft head (30.5 m) 50-1000 ft (15.2-305 m) 50-1000 ft (15.2-305 m) Over 1000 ft (305 m)	-2 +3 -2 +3	+10 -10 -8 -6 +5 -5	Total Head Tolerance: Under 200 ft and 2999 GPM: +8, -0% -18, -3% Under 200 ft but 3000 GPM and over: +5, -0 -5, -3 From 200 ft to 500 ft, any GPM: +5, -0 -5, -3 500 ft and over, any GPM: +3, -0 -3, -0
CAPACITY AT RATED HEAD	---	Class A: +10, -0% Class B: +5, -3%	Class A: No Negative Tolerance Class B: 1 / (1.02 / 1.05) - (0.2) where Hp = Contract Efficiency	
EFFICIENCY	-0.5%	Class A: No Negative Tolerance Class B: 1 / (1.02 / 1.05) - (0.2) where Hp = Contract Efficiency		
RATED POWER	+1%			
NPSHR	+0	4 Points - 2% Head Drop	2% Head Drop	
RETEST	When reduction in impeller diameter exceeds 5% of the original diameter.		When reduction in impeller diameter exceeds 5% of the original diameter.	
MECHANICAL SEAL LEAKAGE RATE	As determined by mutual agreement between Purchaser and Pump / Seal vendor.		Seal leakage rate not stated.	

Table 4. Centrifugal Pumps Vibration Acceptance Criteria Summary.

LOCATION	PUMP SPECIFICATION REQUIREMENTS				REMARK(S)
	HYDRAULIC INSTITUTE (3600 RPM)	ANSI	API 610 7th edition (3600 RPM)	PIP	
BEARING HOUSING Vibration Velocity - Peak Unfiltered ----->	---	0.25 in/sec	0.3 in/sec	0.25 in/sec	
	Filtered ----->	0.3 in/sec	---	0.2 in/sec	---
Vibration Displacement (Peak to Peak)	---	2.5 mils	1.75 mils	---	
	Filtered ----->	1.65 mils	---	1.1 mils	---
SHAFT (Sleeve Bearings) Vibration Displacement (Peak to Peak)	---	---	2.0 mils	---	
	Filtered ----->	---	1.8 mils	---	
NOTES	Refer to vibration chart per Figure 75 of H standard.	---	Refer to vibration chart per Figure 6A and 6B of API	---	

- Single stage ANSI and general service pumps (Table 5 and 6).
- Heavy duty centrifugal pumps. (API) (Tables 7 and 8).

The checklists provide a convenient way to specify test and inspection requirements and extent of purchaser's participation. This document can be included in the bid inquiry to communicate requirements to the vendor.

Table 5. Centrifugal Pumps Inspection and Testing Checklist. (Single stage ANSI and general service.)

NUMBER	DESCRIPTION	ITEM NUMBERS	LEGEND
1	<b>INSPECTION AND TESTING REQUIREMENTS</b>		
2			
3			
4			
5			
6			
7			
8	Description of Examination		Comments
9			
10			
11	<b>SHOP INSPECTION LEVEL</b> (Note 1)		
12	1. Pump, baseplate, auxiliaries		
13	2. Driver		
14			
15			
16	<b>FABRICATION INSPECTION</b>		
17	3. Pre-Inspection Meeting		
18	3.a) Fabrication sequence and test plan		
19	3.b) Manufacturing Schedule & status reporting procedure		
20	3.c) Weld Repair Procedures (Note 2)		
21	3.d)		
22			
23			
24			
25	4. Visual and Dimensional Check		
26	4.a) Casting inspection		
27	4.b) Customer connections		
28	4.c) Baseplate foot print/foundation bolt holes size and locations		
29	4.d) Piping Fabrication and Installation		
30	4.e)		
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33			
34	5. Non-destructive Examination		
35	5.a) Nozzle Weld Inspection		
36	5.b) Casting Inspection		
37	5.c)		
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SHOP TEST PROCEDURES

Introduction

Both EPC contractors and users of centrifugal pumps require shop tests that not only must comply with industry standards for

Table 6. Centrifugal Pumps Inspection and Testing Checklist. (Single stage ANSI and general service.)

NUMBER	DESCRIPTION	ITEM NUMBERS	LEGEND
1	<b>INSPECTION AND TESTING REQUIREMENTS</b>		
2			
3			
4			
5			
6			
7			
8	Description of Examination		Comments
9			
10			
11	<b>SHOP TESTS</b>		
12	6.) Hydrostatic Test		
13	7.) Alignment Check		
14	8.) Impeller Dynamic Balance		
15	9.) Performance (Note 3)		(Test procedure review by Purchaser is required)
16	10.) Vibration Measurement (Note 3)		( - D I T T O - )
17	11.) NPSH (Note 3)		( - D I T T O - )
18	12.) Noise Test		
19	13.) Disassembly / Inspection		
20	14.) Certified Copies of Test Report		
21			
22			
23	<b>PREPARATION FOR SHIPMENT INSPECTION</b>		
24	15.) Painting/Coating		
25	16.) Preservation and Packing		
26	17.) Inspection Release Certificate		
27			
28			
29	<b>NOTES:</b>		
30	1) Levels of inspection are as defined below:		
31	Level #1 : Final inspection only and issue of Inspection Release Certificate.		
32	Level #2 : Pre-Inspection Mtg, random inspection witness major tests, review documentation, and issue of Inspection Release Certificate.		
33	Level #3 : Same as Level #2 except regular inspection visits are more frequent based on milestones, witness/hold points as agreed at Pre-Inspection Meeting.		
34	2) Repair Plan must be approved by Purchaser prior to start of repairs.		
35	3) Test results require approval by Purchaser prior to shipment release.		
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centrifugal pumps, but must also comply with their specifications. Shop tests are more involved now than they were a few years ago. This is due to enhancement of pump reliability programs and major advancements in test equipment, personal computers, and software. Performance and NPSH shop testing has always been a part of the centrifugal pump industry. Testing methods may vary slightly for each manufacturing facility. If shop test results are within acceptance criteria guidelines, and the pump is properly installed, then the pump should function correctly during field operation.

Related Specifications and Standards

The majority of all specifications and standards refer to either API Standard 610 or Hydraulic Institute Standards when shop testing requirements are needed. Other testing standards that may be used are ANSI/AWWA E101-88 and ANSI/ASME B73.1M-1991. Prior to shop testing of pumps, ensure that purchaser and responsible vendor test personnel are in agreement with the test procedure and acceptance criteria.

Test Objectives

Centrifugal pumps are shop tested to determine if they fall within the acceptance criteria specified by the purchase order. Acceptance criteria for dynamic testing may cover various types of tests:

- Performance test
- NPSH test
- Complete unit test
- Auxiliary equipment test

Table 7. Inspection and Testing Checklist—Heavy Duty Centrifugal Pumps (API).

NUMBER	DESCRIPTION OF EXAMINATION	ITEM NUMBERS	COMMENTS
<b>SHOP INSPECTION LEVEL (Note 1)</b>			
1.)	Pump		
2.)	Driver		
3.)	Gear		
4.)	Auxiliaries		
4.a)	Baseplate		
4.b)	Piping		
4.c)	Lube Oil System		
4.d)			
<b>FABRICATION INSPECTION</b>			
5.)	Pre-Inspection Meeting		
5.a)	Fabrication sequence and test plan		
5.b)	Manufacturing Schedule & status reporting procedure		
5.c)	NDT Procedures		
5.d)	Weld Repair Procedures (NOTE 2)		
5.e)	Sub-order (provide copies of sub-orders)		
5.f)			
6.)	Visual and Dimensional Check		
6.a)	Casting inspection		
6.b)	Customer connections		
6.c)	Baseplate foot print/foundation bolt holes size and locations		
6.d)	Piping Fabrication and installation		
6.e)			
7.)	Non-destructive Examination		
7.a)	Nozzle Weld Inspection		
7.b)	Casting Inspection		
7.c)			

Table 8. Inspection and Testing Checklist—Heavy Duty Centrifugal Pumps (API).

NUMBER	DESCRIPTION OF EXAMINATION	ITEM NUMBERS	COMMENTS
<b>SHOP TESTS</b>			
8.)	Hydrostatic Test		
9.)	Alignment Check		
10.)	Impeller(s) Dynamic Balance		
11.)	Rotor Balance		
12.)	Performance Test including vibration and bearing oil/hour's temp measurement (Note 3)		[Test procedure review by Purchaser is required.]
13.)	NPSH (Note 3)		[ - DITTO - ]
14.)	Functional Test of Lube Oil System		
15.)	Noise Test		
16.)	Disassembly / Inspection		
17.)	Certified Copies of Test Report		
<b>PREPARATION FOR SHIPMENT INSPECTION</b>			
18.)	Painting/Coating		
19.)	Preservation and Packing		
20.)	Inspection Release Certificate		
<b>NOTES:</b>			
1) Levels of inspection are as defined below:			
Level #1: Final inspection only and issue of Inspection Release Certificate.			
Level #2: Pre-Inspection Meeting, random inspection, witness major tests, review documentation, and issue of Inspection Release Certificate.			
Level #3: Same as Level #2 except regular inspection visits are more frequent based on milestones, witness/hold points as agreed at Pre-Inspection Meeting.			
2) Repair Plan must be approved by Purchaser prior to start of repairs.			
3) Test results require approval by Purchaser prior to shipment release.			

If test results do not fall within acceptance criteria, then the user must decide to accept the test or retest after necessary corrections are made by the manufacturers.

**Performance Test Procedure**

Horizontal and vertical pumps are performance tested in various configurations. Different configurations are usually due to the result of limitations of the shop test stand.

A typical horizontal pump test stand configuration (Figure 1) may utilize either a shop driver or a contract driver. Some shops may use open loop configurations with and without booster pumps.

Vertical pumps may be tested in a closed loop test stand configuration (Figure 2) or an open loop test stand configuration (Figure 3). Shop test stand limitation may allow testing of the bowl assembly only. If pump length is not excessive, then the complete unit could be tested with or without the contract driver.

Typical shop test stand limitations are follows:

- Loop pressure
- Loop flowrate
- Well depth and volume
- Crane height
- Crane load capacity
- Available NPSH
- Driver power and speed
- Supply power (voltage and current)

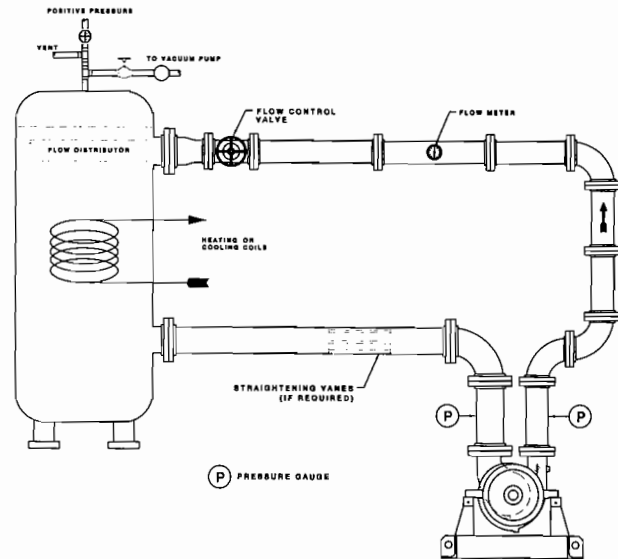


Figure 1. Horizontal Pump Test Stand Configuration.

The test will require various types of equipment and instrumentation. Test loop will be constructed of the following types of equipment:

- Storage tank or pit for test fluid
- Test stand to support the pump, driver and auxiliary equipment

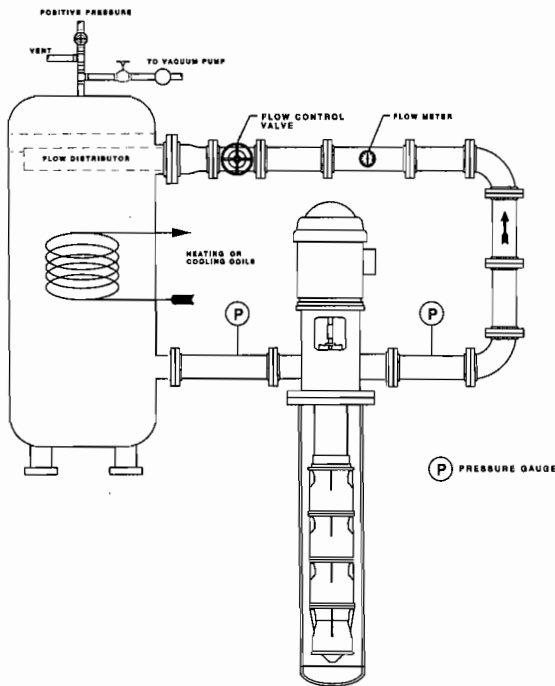


Figure 2. Vertical Pump—Closed Loop Configuration.

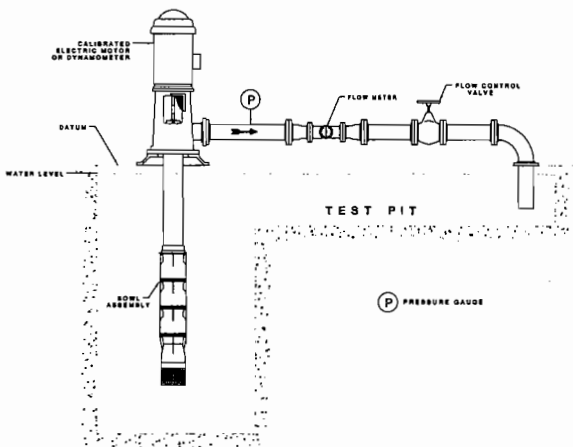


Figure 3. Vertical Pump—Open Loop Configuration.

- Piping system equipped with a flow control valve and flowmeter
- A negative and positive pressure source mounted on storage tank for NPSH testing
- Power source for pump driver

The following types of instrumentation could be used:

- Monitor pressure with bourdon gauge, liquid manometer, or electronic transducer.
- Monitor flowrate with venturi meter, pitot tube, orifice meter, weight tank, propeller meter, or magnetic meter.
- Monitor electrical power input with watt-hour meter or watt meter.
- Monitor horsepower required at pump shaft with a torque-meter or calibrated motor.

- Monitor speed with a stroboscope, hand held tachometer, or key phasor with readout meter.
- Monitor voltage and current with voltage and current transformers connected to a readout device.
- Monitor vibration with noncontacting proximity probes or with seismic type velocity sensors mounted on the bearing housing or held by hand.

All instrumentation must be calibrated at intervals of six months or less, or as determined by the shop testing facility. A certificate of calibration must be kept on file. A calibration sticker should also be attached to each piece of instrumentation.

#### Test Stand Setup and Performance Testing

The pump is first connected to the test stand mounting base and piping loop. Driver is then mounted to the pump. Alignment between pump and driver is adjusted to a value within acceptance criteria. Mechanical seal piping for shop testing is connected. Vibration probes are placed at agreed locations to monitor pump and motor bearing housing vibration levels and shaft displacement levels. Flow, pressure, speed, and power monitoring instrumentation is selected and activated. The pump is then started and test data can be recorded once the pump and motor temperatures stabilize.

Recorded test data will usually consist of the following information:

- Flowrates
- Discharge pressure
- Suction pressure
- Elevation corrections
- Test fluid temperature
- Test fluid specific gravity
- Power reading
- Voltage at the driver
- Current to the driver
- Frequency of supply voltage
- Vibration levels
- Speed

Five to seven test points are taken to cover the flow range from zero flow to 120 percent of design flow, depending on which test standard is specified. The number of vibration reading taken also depends on which test standard is used. See Table 2 for details on typically used test standards. When the test is completed, all recorded data must be converted into a format (Figures 4 and 5) that can be easily compared to acceptance criteria. All pressure readings must be converted to head values. Pump efficiency must be calculated from power readings at each flowpoint. Shop test results may have to be speed corrected to the predicted operational field speed. An as tested performance curve is then prepared and included with test report.

For a summary of acceptance criteria in the Hydraulic Institute Test Standards and the API Standard 610, refer to Tables 3 and 4. These tolerances usually cover flowrate, head, efficiency, vibration levels, brake horsepower, speed, and oil temperatures in bearing housings. Seal piping arrangement for shop test may differ from field arrangement. During shop test, seals are inspected for leakage. Leakage rate is a function of test fluid, pressure output of pump, test speed, and temperature. Seals are normally tested for zero visible leakage; however, if leakage rate appears to be excessive, the seal must be repaired or replaced. If a pump fails the shop test, the manufacturer must take corrective action with a

PUMP SIZE AND TYPE				GUARANTEED PUMPING CONDITIONS										TYPE BY	
MODEL NO.	DIAMETER	INCH	LENGTH	INCH	SPEED	CAPACITY	HEAD	EFF.	NPSH	BAR	MPA	CUSTOMER	NO.	DATE	TEST NO.
7.65E	3				1770	700	230	80.7%			7.500	GENERAL			
7.581	3														

DISCHARGE HEAD	SUCTION HEAD	HEAD	CAPACITY	POWER		VELOCITY	VIBRATION	TEMP.	SPEC. GRAV.	VAPOR PRESS.	BAROMETRIC PRESS.				
				HP	KW										
1774.0	175.4	175.67	407.2	5.28	0	412.4	0	0	49.0	24.8	45.09	36.9	0		
1777.0	159.4	159.72	370.2	0.7	335.5	189.0	18.1	48.7	24.6	25.71	36.61	37.3			
1775.0	149.2	149.57	325.8	0.8	331.4	186.0	17.7	49.6	25.1	40.58	37.3	63.8	0.89	0.57	79.5
1773.0	119.5	119.81	277.9	0.6	283.8	162.0	16.1	52.5	26.6	43.90	39.5	76.5			
1772.0	96.3	96.75	224.3	0.5	230.8	133.0	15.7	53.6	27.2	43.97	40.3	81.6	0.63	0.42	81.0
1772.0	81.5	82.35	190.9	0.4	197.5	103.0	15.4	53.4	27.1	43.81	40.2	79.4			
1773.0	65.8	66.25	153.6	0.3	160.5	73.0	15.2	52.3	26.5	42.84	39.3	73.4	0.57	0.45	80.5
1774.0	45.8	46.22	107.1	0.2	114.5	43.0	15.0	49.8	25.2	40.74	37.5	60.7			

Figure 4. Pump Test Data.

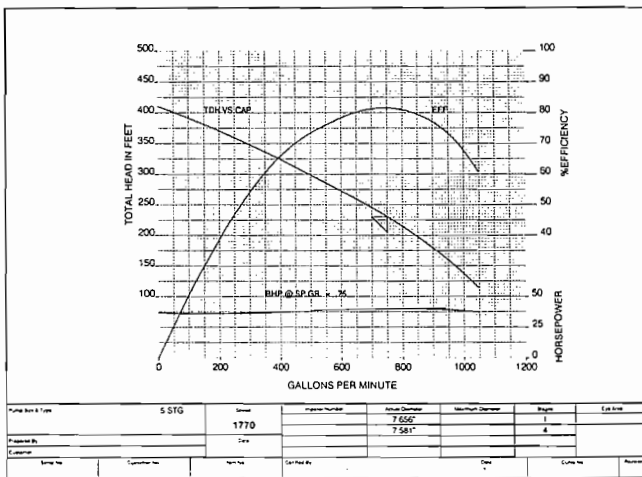


Figure 5. Pump Test Performance Curve.

possible retest. The most common causes of these failures are: Incorrect impeller diameter, rotating elements incorrectly balanced, poor pump-to-motor alignment; uncalibrated instrumentation, poor quality surface finish on impeller and cases, testing errors and misinterpretation of test requirements, or acceptance criteria.

The test log will consist of recorded test data, calculated results and an as tested performance curve. The performance curve will consist of a graph of the test data with the total differential head, pump efficiency, NPSH required, and brake horsepower plotted as ordinate with flowrate as abscissa.

**NPSH Testing**

Test stand configurations for horizontal pumps and vertical pumps are usually in closed loop systems as shown in Figures 1 and 2. Some testing facilities may use open loop configurations if pump NPSH requirements are not too excessive. In open loop configurations, the suction pressure to pump is usually adjusted with a suction throttle valve. The equipment and instrumentation specified previously for performance testing are also used during NPSH testing.

The test log will consist of recorded test data, calculated results and an as tested NPSH curve. Graphical presentation for each

flowpoint will be plotted with total differential head and NPSH required as the ordinate and flowrate as abscissa.

Typical recorded test data will usually consist of the following information:

- Flowrate
- Discharge pressure
- Suction pressure
- Elevation corrections
- Test fluid temperature
- Test fluid specific gravity
- Test fluid vapor pressure
- Speed
- Barometric pressure

**NPSH Testing**

The most common method used for NPSH testing is to run the pump at constant flowrate and speed while lowering suction pressure. The suction pressure (static head) is decreased until specified reduction in head is reached at each flowrate. The number of readings may range from five to twelve. Depending on the test standard used, the number of flowrates could vary from one to four.

For a typical NPSH test log and curves, refer to Figures 6 and 7 which indicate head reduction for each flowrate point.

PUMP SIZE AND TYPE				GUARANTEED PUMPING CONDITIONS										TYPE BY	
MODEL NO.	DIAMETER	INCH	LENGTH	INCH	SPEED	CAPACITY	HEAD	EFF.	NPSH	BAR	MPA	CUSTOMER	NO.	DATE	TEST NO.
7.65E	3				1770	700	230	80.7%			7.500	GENERAL			
7.581	3														

DISCHARGE HEAD	SUCTION HEAD	HEAD	CAPACITY	POWER		VELOCITY	VIBRATION	TEMP.	SPEC. GRAV.	VAPOR PRESS.	BAROMETRIC PRESS.				
				HP	KW										
1774.0	175.4	175.67	407.2	5.28	0	412.4	0	0	49.0	24.8	45.09	36.9	0		
1777.0	159.4	159.72	370.2	0.7	335.5	189.0	18.1	48.7	24.6	25.71	36.61	37.3			
1775.0	149.2	149.57	325.8	0.8	331.4	186.0	17.7	49.6	25.1	40.58	37.3	63.8	0.89	0.57	79.5
1773.0	119.5	119.81	277.9	0.6	283.8	162.0	16.1	52.5	26.6	43.90	39.5	76.5			
1772.0	96.3	96.75	224.3	0.5	230.8	133.0	15.7	53.6	27.2	43.97	40.3	81.6	0.63	0.42	81.0
1772.0	81.5	82.35	190.9	0.4	197.5	103.0	15.4	53.4	27.1	43.81	40.2	79.4			
1773.0	65.8	66.25	153.6	0.3	160.5	73.0	15.2	52.3	26.5	42.84	39.3	73.4	0.57	0.45	80.5
1774.0	45.8	46.22	107.1	0.2	114.5	43.0	15.0	49.8	25.2	40.74	37.5	60.7			

Figure 6. NPSH Test Data.

The Hydraulic Institute Standards define NPSH<sub>R</sub> (start of cavitation) as any change in performance, i.e., either a drop in head, power or efficiency at a given capacity or a change in the sound level or vibration. However, because of the difficulty in determining just when the change starts, a drop in head of three per cent is usually accepted as evidence of performance impairment. For multistage pumps, total head is divided by number of stages to approximate first stage head. Dismantling to correct NPSH<sub>R</sub> requires retest.

**Pump Disassembly After Test**

Pump disassembly for bearings and seal inspection is generally not required or recommended except in special circumstances such as inconsistent test results, prototype pump design, etc.

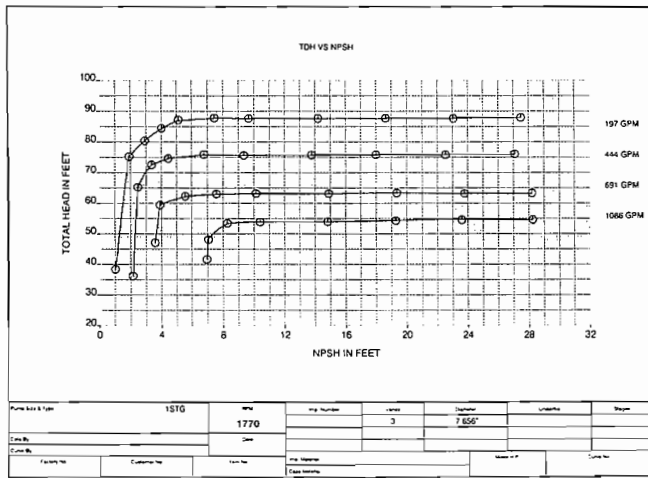


Figure 7. NPSH Test Curve.

**Test Report**

This report should contain all graphic representations and test log sheets for both the performance and NPSH tests. All test results should be certified by the testing facility. Test results must comply with acceptance criteria specified in the purchase order. Adjustments may be made to actual test results to simulate the "as built" pump performance characteristics, i.e., friction loss or viscosity correction or speed adjustment.

**CONCLUSION**

Specifying correct inspection and testing requirements, plus verification of pump performance during shop tests, are equally

important as the pump design specification and selection of the right pump for the specified service.

Several alternatives available for centrifugal inspection and testing were explored.

The review of the typical pump performance and NPSH test procedures and actual shop practices further emphasize the importance of inspection and testing prior to release of pumps for shipment.

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