PTC 7.1 - 1962

Reaffirmed 1969

E-37-03
E-37-09

Displacement Pumps

POWER TEST CODES

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
345 EAST 47th STREET NEW YORK 17, N.Y.

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Printed in the United States of America

Foreword

THE Test Code for Displacement Pumps covers all displacement pumps other than reciprocating steam-driven displacement pumps which still are covered by the Test Code for Reciprocating Steam-Driven Displacement Pumps (PTC 7-1941). The latter code is of greater historical than practical interest since it mentions only briefly Displacement Pumps driven by prime movers other than Reciprocating Steam Engines.

When Power Test Codes Committee No. 7 on Displacement Pumps was reorganized in 1951, it was recognized that the primary need was for a test code covering mechanically driven displacement pumps and the standing Power Test Codes Committee, therefore, changed the scope of the technical committee to cover both reciprocating and rotary displacement pumps.

This new test code (PTC 7.1-1962), covering pumps handling water or other liquids of medium viscosity, was distributed widely throughout industry in draft form in 1958 and a revised draft was submitted to the Power Test Codes Committee late in 1959. Wherever practical the code includes the resulting suggestions and PTC Committee No. 7 will welcome further help in modifications to this document to cover adequately volatile or more viscous liquids.

The code was approved by the Power Test Codes Committee on June 1, 1960. Final publication was delayed, however, until a number of suggestions made by the standing Committee were considered and satisfactorily resolved. It was approved and adopted by the Council as a standard practice of the Society by action of the Board on Codes and Standards on June 4, 1962.

June, 1962

Personnel of PTC Committee No. 7 on Displacement Pumps

E. F. Wright, *Chairman*
G. V. Edmonson, *Secretary*

J. J. Brown, Assistant Chief Engineer, Badger Manufacturing Company, 230 Bent Street, Cambridge 41, Mass.

G. V. Edmonson, Associate Dean, College of Engineering, University of Michigan, 247 West Engineering Building, Ann Arbor, Mich.

David A. Mooney, Chief Mechanical Engineer, Jackson & Moreland, Inc., 31 St. James Avenue, Boston 16, Mass.

J. F. Murray, Director of Engineering, Pesco Products Division, Borg-Warner Corporation, 24700 North Miles Road, Bedford, Ohio

F. W. Peterson, Division Engineer, Equipment Division, The M. W. Kellogg Company, 711 Third Avenue, New York 17, N. Y.

Frederick Sommer, Reciprocating Pump Division, Union Pump Company, Battle Creek, Mich.

R. J. Sweeney, Consultant, 825 Linden Street, Allentown, Penna.

Irving Taylor, Senior Engineer, Refinery Division, Bechtel Corporation, 25 First Street, San Francisco, Calif.

E. F. Wright, Chief Engineer, High Pressure Pump Engineering Section, Worthington Corporation, Harrison, N. J.

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ASME POWER TEST CODES

Test Code for

Displacement Pumps

CONTENTS

Section 1, Object and Scope

1.01 This code provides standard directions for conducting and reporting tests on displacement pumps.

1.02 The object of the code is to establish rules for conducting tests on pumps to determine, under specified conditions, one or more of the following quantities:

(a) Pump capacity or rate of flow
(b) Power input
(c) Efficiency
(d) Inlet requirements.

1.03 Pumps covered by this code shall be defined as displacement pumps that obtain their pumping action by repeated alternate filling and emptying of volume elements.

1.04 Pumps shall be classified for test under this code as follows:

(a) General purpose pumps, *not* lubricated by the liquid being pumped, for handling liquids having very little or no lubricating value.

(b) General purpose pumps lubricated by the liquid being pumped, for handling liquids having some lubricating value.

(c) Special purpose pumps for handling a specific type of liquid or for special operating conditions, such as temperature or viscosity.

1.05 The liquids to be used for test under this code shall be as follows:

(a) General purpose pumps which may be operated with water shall be tested with clean water at some temperature between 60 and 130 F.

(b) General purpose pumps which may not be operated with water shall be tested with a clean petroleum oil having a viscosity of 250 SSU at some temperature between 60 and 130 F, or a similar liquid having sufficient lubricating value to prevent scoring or wear of parts.

(c) Special purpose pumps shall be tested with the type of liquid for which the pump was designed and at the temperature and viscosity specified, within the limits of acceptable deviations indicated in Table 1.

If the liquids recommended above are considered by either party to the test to be unsuitable or impractical for the test, another liquid shall be selected by mutual agreement before conducting the test.

1.06 While this code provides a test procedure and instrumentation for determining the quantities that are the object of the test, it does not exclude other procedure or instrumentation or determination of other quantities or qualities. If other procedures or instrumentation are used, or additional quantities or qualities are to be determined, these must be agreed to in writing by the parties to the test prior to the test. However, only tests which do not violate the mandatory requirements of this code may be designated as tests conducted in accordance with the ASME Power Test Code.

1.07 References to other codes, unless otherwise specified, refer to ASME Power Test Codes. Should specific directions in this code for any particular measurement differ from those given in other ASME Power Test Codes for similar measurements, the instructions of this code shall prevail.

1.08 The Code on General Instructions (PTC 1-1945) shall be studied and followed where applicable. The mandatory provisions of Parts III and IV of the Code on General Instructions (PTC 1-1945) shall be part of this code, even though such provisions are not explicitly stated herein.

1.09 The Code on Definitions and Values (PTC 2-1945) defines certain technical terms and numerical constants which are used throughout the present code with the significance and value therein established.

1.10 It is the intent of this code that the meaning of the terms: pressure, capacity, power input, efficiency and inlet requirements shall be determined as herein specified, and that such terms shall be understood only as thus defined.

1.11 When specified in contracts requiring acceptance tests, the test conditions and procedures described in this code shall be the basis for evaluating guaranteed characteristics.

1.12 The requirements of accuracy underlying these guarantees are established in this code by prescribing limiting conditions for those methods which provide measurements of pressure, speed, rate of flow, power input, and inlet requirements.

1.13 Where the actual test conditions do not fall within the limits set by this code for the method of measurement to be used, agreement shall be made between representatives of both parties to the test as to the allowable test conditions. Such agreement shall be reached before conducting the test.

1.14 Descriptions of instruments and apparatus beyond those specified in this code, but necessary to the conduct of tests under this code, may be found in the ASME Power Test Code Supplements on Instruments and Apparatus, herein designated by the abbreviation "I & A."

1.15 This code applies to the test of the pump proper only, and the terms power, efficiency, pressure, etc., are to be taken as referring to the pump proper. However, the recorded data and final report may include information on the complete unit, including driving and auxiliary equipment.

1.16 The tests specified in this code may be conducted in the manufacturer's shops, on the user's premises, or elsewhere as agreed upon, provided such tests meet the requirements of this code.

SECTION 2, DEFINITIONS AND DESCRIPTION OF TERMS

2.01 Letter Symbols. The following table lists the letter symbols for terms used in this code, with their units (dimensions) and the number of the paragraphs in which they are defined or first appear.

Symbol	Term	Unit (Dimension)	Par. No.
A	Area	sq in.	2.09
D	Pump displacement	cu in./revolution	5.07
g	Gravitational acceleration	ft per sec per sec	2.09
h_g	Liquid column or manometer reading	ft	Fig. 5
bhp	Pump power input	hp	2.16
V	Mean liquid velocity	ft per sec	2.09
V_d	Mean velocity at discharge	ft per sec	2.10
V_s	Mean velocity at inlet	ft per sec	2.11
X	Elevation of gage	ft	Fig. 5
Z	Elevation of measuring section	ft	Fig. 5
Z_d	Elevation of discharge measuring section above Datum	ft	2.10
Z_s	Elevation of inlet measuring section above datum	ft	2.11
γ	Specific weight of liquid pumped	lb per cu ft	2.05
η	Over-all efficiency	per cent	2.22

Symbol	Term	Unit (Dimension)	Par. No.
η_g	Driver efficiency	per cent	2.21
η_P	Pump efficiency	per cent	2.20
η_v	Volumetric efficiency	per cent	2.23
tdhp	Theoretical displacement power	hp	5.10
dihp	Driver power input	hp	2.15
whp	Pump power output	hp	2.19
N	Pump speed	rpm	Table 1
p_a	Atmospheric pressure	psia	2.07
p_d	Discharge pressure	psig	2.10
p_o	Static pressure above or below atmosphere	psig	2.08
p_s	Inlet pressure	psig	2.11
p_{sv}	Net positive inlet pressure	psi	2.13
p_{td}	Pump total differential pressure	psi	2.12
p_v	Velocity pressure	psi	2.09
p_{vp}	Liquid vapor pressure	psia	2.13
Q	Capacity or rate of flow	gpm	2.09
Q_d	Displacement capacity, $\frac{DN}{231}$	gpm	5.09
S	Internal slip or leakage	gpm	5.09
sp gr	Specific gravity	ratio	2.06

2.02 Definitions of Unit Abbreviations are given below:
psi = Pounds per square inch
psig = Pounds per square inch gage
psia = Pounds per square inch absolute
sq in. = Square inches
gpm = Gallons per minute
rpm = Revolutions per minute
hp = Horsepower
lb/cu ft = Pounds per cubic foot

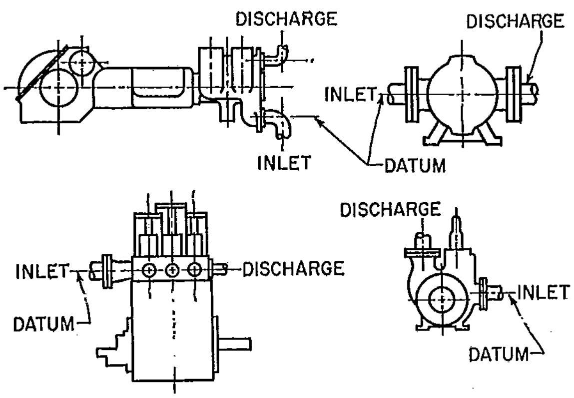

FIG. 1 TYPICAL ELEVATIONS

2.03 The Pump is defined as the composite machinery which encloses the path of the liquid between a section adjacent to the inlet of the pump casing and a section adjacent to the outlet, together with the necessary mechanical parts to point of power input.

2.04 The Datum shall be taken at the elevation of the center line at the face of the pump inlet. If the pump has more than one inlet, a mean elevation between them shall be used. The correction of datum is positive when the measuring point is above the datum and it is negative when the measuring point is below the datum. Various examples of the datum line are shown in Fig. 1.[1]

2.05 The Specific Weight (γ) of a liquid is its weight per unit volume. It shall be expressed in pounds per cubic foot.

2.06 Specific Gravity (sp gr) of a liquid is the ratio of its specific weight to 62.30 pounds per cubic foot.

Pressure

2.07 Pressure is the compressive stress in a liquid at a given point. It has the units of force

[1]Due to the large variety of pumps covered by this code the *Datum* has been taken at the center line of the inlet connection. For actual inlet requirement guarantees or for performance comparison, this should be corrected to the highest point within the pump which must be filled by the incoming liquid. For a piston or plunger pump with suction and discharge valves, this is the highest point of the seating surface of the discharge valve. For rotary pumps this is the highest point in the inlet chamber adjacent to pump rotor or rotors.

per unit area and will be reported in pounds per square inch (psi).

The ambient atmospheric pressure (p_a) shall be the zero pressure datum. Pressure measurements relative to this datum will be positive or negative, *and shall be measured in pounds per square inch gage (psig).*

2.08 Static Pressure (p_0) is the pressure exerted on a wall and perpendicular to the wall by a fluid at rest or flowing parallel to the wall.

2.09 Velocity Pressure (p_v) is defined by the following expression:

$$p_v \text{ (in psi)} = \frac{\gamma V^2}{144 \times 2g} = 0.433 \text{ (sp gr) } \frac{V^2}{2g}$$

The velocity (V) is a mean velocity computed by dividing the volume rate of flow by the pipe area at the measuring section and is expressed in feet per second.

$$V = \frac{0.321Q}{A}$$

2.10 Discharge or Outlet Pressure (p_d) is the algebraic sum of the static pressure and velocity pressure as measured at the pump outlet, corrected to datum.

$$p_d \text{ (in psig)} = p_0 + \frac{\gamma}{144}\left(Z_d + X_d + \frac{V_d^2}{2g}\right)$$

$$= p_0 + 0.433 \text{ (sp gr) } \left(Z_d + X_d + \frac{V_d^2}{2g}\right)$$

The exact location of the measuring section at the pump discharge shall be decided upon between the parties to the test in advance of the test. In the absence of such agreement, this location shall be at or adjacent to the pump discharge opening.

2.11 Inlet Pressure (p_s) is the algebraic sum of the static pressure and the velocity pressure as measured at the pump inlet, corrected to datum.

$$p_s \text{ (in psig)} = p_0 + \frac{\gamma}{144}\left(Z_s + X_s + \frac{V_s^2}{2g}\right)$$

$$= p_0 + 0.433 \text{ (sp gr) } \left(Z_s + X_s + \frac{V_s^2}{2g}\right)$$

The term p_0 may be positive or negetive with reference to atmospheric pressure. The term p_s may therefore be positive or negative. The term is called *inlet pressure* when positive and *inlet vacuum* when negative.

The exact location of the measuring section at the pump inlet shall be decided upon by the parties to the test in advance of the test. In the absence of such agreement, this location shall be at or adjacent to the pump inlet opening. There shall be no elbows, bends or sudden changes in section between the measuring section and the pump inlet.

2.12 Pump Total Differential Pressure (p_{td}) is the algebraic difference between the discharge pressure and the inlet pressure, and is expressed in pounds per square inch. All terms must be expressed in the same units.

$$p_{td} = p_d - p_s$$

2.13 Net Positive Inlet Pressure (p_{sv}) is the algebraic sum of the inlet pressure, as defined in Par. 2.11, and the barometric pressure minus the vapor pressure of the liquid corresponding to its temperature at the pump inlet. This term is also known as pressure proximity. It is expressed in pounds per square inch.

$$p_{sv} = (p_s + p_a) - p_{vp}$$

For the determination of vapor pressure, temperature shall be measured at the pump inlet.

Power

2.14 Power shall be expressed in units of horsepower (hp): One horsepower is 33,000 foot-pounds per minute.

2.15 Driver Power Input (dihp) is the power input to the driver, expressed in horsepower.

2.16 Pump Power Input (bhp) is the power delivered to the pump shaft, expressed in horsepower.

2.17 Standard Unit of Volume shall be the U. S. gallon. One U. S. gallon contains 231 cubic inches. One imperial gallon equals 1.2 U. S. gallons.

2.18 The Capacity of the Pump (Q) is the volume rate of flow produced by the pump under specified conditions. It shall be expressed in gallons per minute (gpm).

2.19 Pump Power Output (hydraulic power) (whp) is defined by the following expression:

$$\text{whp} = \frac{Qp_{td}}{1714}$$

when p_{td} is in psi.

2.20 Pump Efficiency (η_p) is the ratio of the pump power output to the pump power input, expressed in per cent.

2.21 Driver Efficiency (η_g) is the ratio of the pump power input to the driver power input, expressed in per cent.

2.22 Over-all Efficiency (η) is the ratio of the pump power output to the driver power input, expressed in per cent.

2.23 Volumetric Efficiency (η_v) is the ratio of the actual pump delivery to the pump displacement capacity, expressed in per cent.

Section 3, Guiding Principles

3.01 In code tests, all parties to the test shall be represented and shall have equal rights in determining the methods and conduct of the test.

3.02 Items on which agreement shall be reached prior to conducting the test are:

(a) Object of test
(b) Intent of pump rating as to operating conditions and guarantees
(c) Test arrangement
(d) Method of maintaining steady test conditions
(e) Instrumentation
(f) Arrangement for calibration of instruments
(g) Arrangements for examination of the pump and the time interval between the initial service and the test.

3.03 Careful inspection shall be made before and after the test to insure the proper operation of the pump and measuring instruments. Particular attention is to be given the internal pumping elements and fluid passages, the pump and driver alignment, the pressure tap openings, shaft seal adjustment and leakage, electrical connections, the lubricating system, liquid leakage out of, or air leakage into, the pump passages, and important clearances.

3.04 Instruments or apparatus installed for the purpose of measurements must not affect the pump performance. Any doubt as to the effect of such apparatus may be resolved by comparative tests with the apparatus removed and installed, other conditions remaining consant.

3.05 All instruments shall be calibrated before the tests, and calibration and correction curves or tables shall be prepared in advance. After the tests all instruments shall be recalibrated. Only the readings of those instruments for which the two calibrations agree within reasonable limits shall be used in computing the results. When the calibration of an instrument made before the test shows significant difference from that made after the test, the test shall be repeated. Exception may be made if analysis shows distinctly the point at which the shift occurred, so that corrections can be made.

3.06 The test shall not be considered to have started until a satisfactory preliminary run has

Table 1—Acceptable Deviations of Test Conditions from Specified Conditions and Fluctuations of Test Readings

Item Measured	Acceptable Deviations from Specified Conditions	Acceptable Fluctuations
Pump total differential pressure, p_{td}	Not less than rated maximum	
Discharge pressure, p_d	Adjust to make total differential pressure (p_{td}) not less than rated	$\pm 5\%$ p_d*
Inlet pressure, p_s	Adjust to make net positive inlet pressure (p_{sv}) not more than rated and not less than the limiting inlet pressure by test	$\pm 6\%$ p_s*
Capacity or flow, Q	Not less than minimum rated	$\pm 1\%$ Q
Pump speed, N	$\pm 10\%$ of specified speed (See Note 1)	$\pm 1\%$ N (See Note 2)
Pump power input, bhp	Not more than rated when adjusted to rated speed	$\pm 2\%$ bhp
Driver power input, dihp	Not more than rated when adjusted to rated speed	$\pm 2\%$ dihp
Temperature (liquid supply)	± 10 F of rated temperature	± 2 F (See Note 2)

Note 1—In all cases, the capacity and power shall be corrected as described in Section 5, Par. 5.10.
Note 2—These fluctuations apply during one test run. The speed may vary 2% and temperature may vary 10 F from average throughout a series of runs in which these conditions are intended to be constant.

*As measured by a pressure measuring system having a frequency response of not more than 25 cycles per second.

been made to assure the proper operation of the pump and test equipment, and the correct routine of observations has been established.

3.07 Each test run shall begin only when reasonably steady test conditions have been established. The duration of a test run shall be sufficient to demonstrate the maintenance of reasonably steady conditions.

3.08 During a run, fluctuations of test readings are to be recorded and compared with Table 1 to determine acceptability.

3.09 All readings shall be taken against time, and, when necessary, by signal. All quantities determined from a series of readings shall be computed as the average of observations made at equal time intervals. Results shall be computed during the course of the test and any errors thus detected shall be corrected immediately or the test run discarded. Complete records of all information and results shall be furnished to all parties to the test.

3.10 In addition to the tabulation of test data, information should be given on matters of general interest, such as the type of service the pump is to perform, the manufacturer's serial number, the arrangements, the means of identification of the pump and driver, and the dimensions and physical conditions of all associated parts of the plant which have any bearing on the outcome of the test, but not subject to the test.

3.11 The tabulation may contain records on the elements of an over-all test beyond the scope of this code.

Section 4, Instruments and Methods of Measurement

4.01 This section presents detailed information on instruments and methods of measurement most commonly used in testing displacement pumps.

4.02 In the process of testing, it is required to establish specified conditions and to measure:

(a) Pressure (inlet, discharge, barometric)
(b) Temperature (liquid, and local ambient air)
(c) Volume rate of flow
(d) Pump speed
(e) Power input to the pump or driver

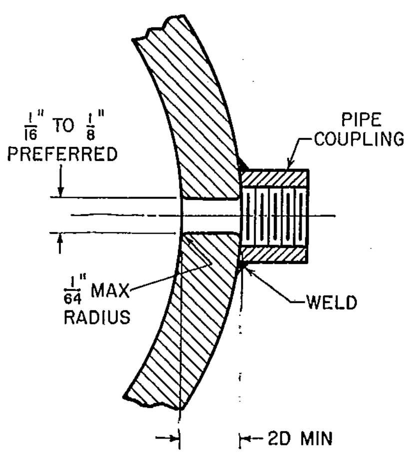

Fig. 2 Pressure Taps

4.03 Instruments and indicating devices acceptable for this test are given in the following list, with reference to the various parts of the Supplements on Instruments and Apparatus (I & A) where these instruments and their uses, calibration, etc. are described:

(1) Barometers (see Part 2)
(2) Thermometers (see Part 3)
(3) Pressure gages, liquid U-tubes, or manometers (see Part 2). For widely fluctuating pressures, recording pressure gages or oscilloscopes may be used. These may read total or static pressures.
(4) Differential gages (see Part 2)
(5) Impact tubes, pitot tubes (see Part 2)
(6) Nozzles (see Part 5)
(7) Venturi tubes (see Part 5)
(8) Orifices (see Part 5)
(9) Displacement Meters (see Part 5)
(10) Tachometers, revolution counters, or other speed counting devices (see Part 13)
(11) Electrical instruments (see Part 6)
(12) Dynamometers for measuring power (see Part 7)

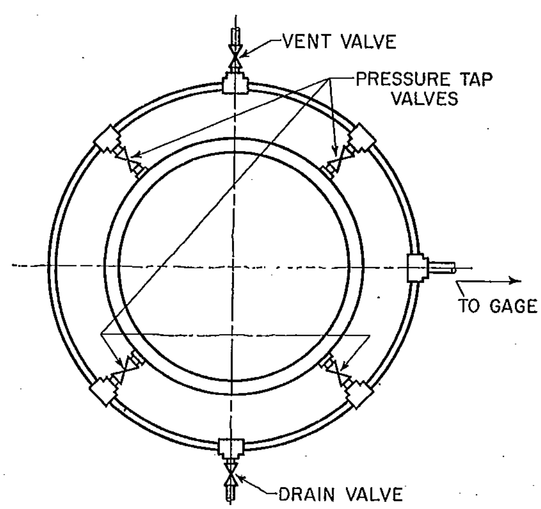

Fig. 3 Loop Manifold Connecting Pressure Taps

(13) Viscosity measuring devices (see Part 17)
(14) Density measuring devices (see Part 16).

Pressure Measurements

4.04 The Measurement of pressure is carried out by pressure-sensitive indicating devices (manometers, gages) connected with the liquid passage through pressure taps. (See Figs. 2 and 4.)

4.05 It is important that undisturbed flow conditions exist at the gage connections (pressure taps). Table 1 of allowable deviations and fluctuations shows the limits to which such deviations and fluctuations may be disregarded in considering the flow conditions.

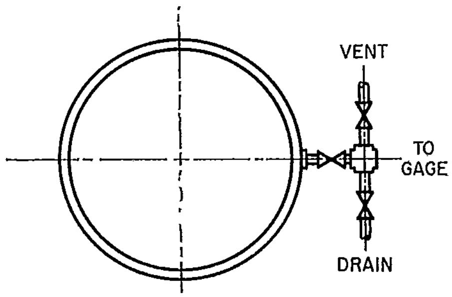

Fig. 4 Single Tap Connection

4.06 For high-velocity flow, where the velocity pressure is a significant fraction of the total pressure, particular care is necessary to avoid errors in the measurement of static pressure. This involves the use of the smallest practical diameter of pressure-tap hole, as illustrated in Fig. 2, close inspection of the condition of the inside of the tap hole, with respect to burrs, sharpness of edge and absence of tubercles, etc., in the neighborhood of the tap hole. It may be necessary to provide several taps on the same circumference, for checking as in Fig. 3. Equality of pressure readings at several taps is reasonable assurance of the absence of errors due to abnormal turbulence.

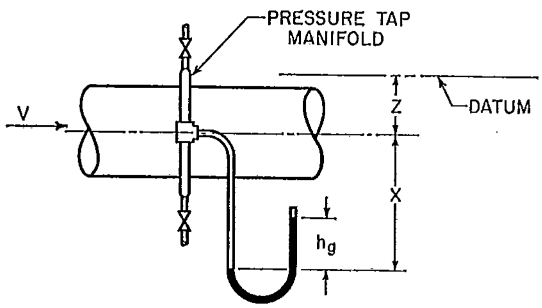

Fig. 5 Wet-Tube Manometer

4.07 The Pressure Indicating Devices shall, when practicable, be mercury manometers or Bourdon gages. For low pressures, mercury manometers are preferable. (See Figs. 5 and 6.) Where desired, liquids other than mercury may be substituted upon mutual agreement between parties to the test.

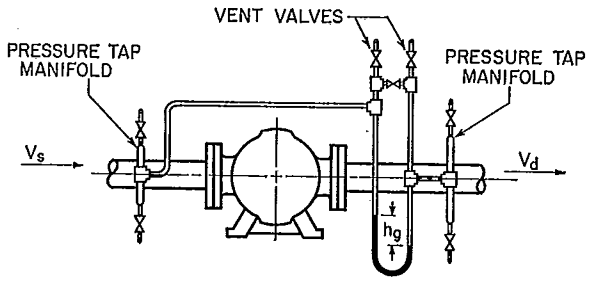

Fig. 6 Differential Manometer

Where manometers cannot be used, gages operating on the principle of the deadweight tester or calibrated mechanical pressure gages of the bourdon type shall be used. (See Fig. 7.)

Inlet Requirements of the Pump

4.08 It is recommended that a test be made to determine the minimum net positive inlet pressure needed to avoid excessive loss in the pump capacity due to incomplete filling of the pump displacement chambers. If agreed the inlet requirement test may be conducted using degasified liquid. If more than one pump speed is specified for test, separate inlet requirement tests shall be made at each specified speed. If the pump is to be operated at variable speed, it is the intent of the code that the inlet requirement test should be made at the maximum pump speed specified.

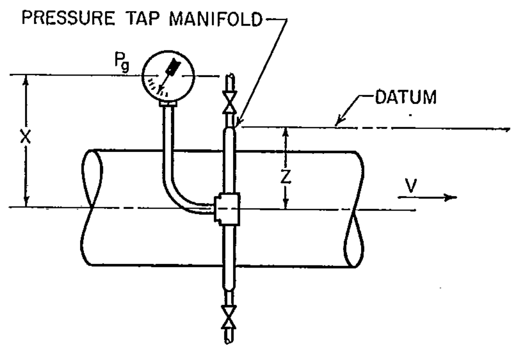

Fig. 7 Calibrated Bourdon Gage

4.09 Arrangements for making these tests are shown in Figs. 8(*a*), (*b*), and (*c*). In all cases extreme care must be taken to avoid air leaks in the inlet line, especially at the stem of a throttling valve if used. When the inlet conditions are not critical, the inlet pressure may be controttled by placing a variable restriction, such as a valve, in the inlet line to the pump, Fig. 8(*a*). A screen or a set of straightening vanes should be used after the valve to break up turbulence induced by the throttling. Results more

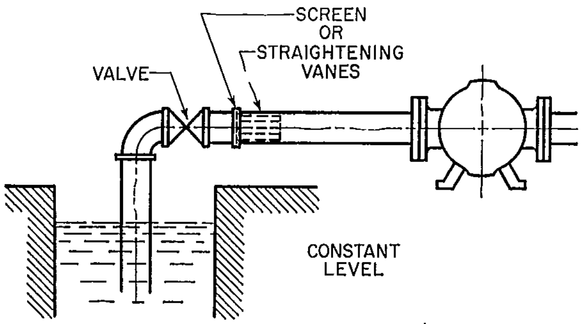

Fig. 8(*a*) Inlet Requirement Test

nearly duplicating actual service conditions may be obtained by lowering the level in the supply sump as indicated in Fig. 8(*b*). The closed system shown in Fig. 8(*c*) uses a constant level in the supply tank with some means to vary the absolute pressure of the air or gas above

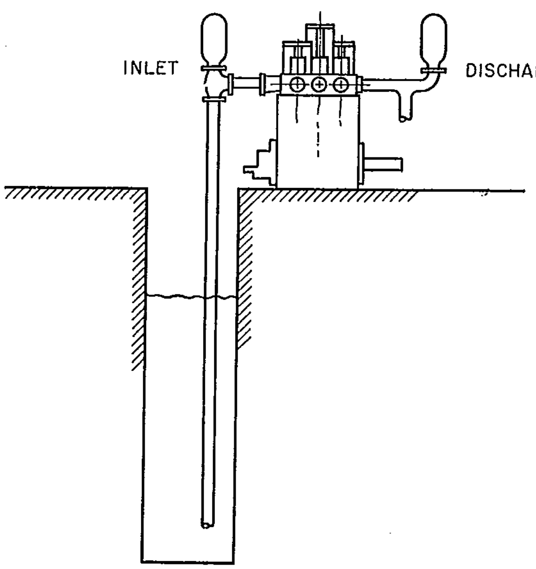

Fig. 8(*b*) Inlet Requirement Test

the liquid to control the inlet pressure at the pump. The closed system tends to strip the liquid of dissolved air or gases and hence more nearly duplicates a service condition where the supply is at or near its vapor pressure in a closed vessel.

Care should be taken to avoid excessive turbulence in the supply tank and in the inlet line to the pump. The tank outlet and the return pipe for the pump discharge must be below the liquid level in the tank at all times during the test. Surge chambers may be placed in the inlet and discharge lines to dampen pressure and flow fluctuations.

Before starting an inlet requirement test requiring degasified liquid, the pump may be run at minimum discharge pressure, in a definitely cavitating condition, for sufficient time to effect degasification. The purpose of this preliminary run is to strip most of the dissolved air from the liquid to obtain more stable and uniform results during the inlet requirement test. Alternatively the liquid may be degasified by boiling.

Note: The test setups illustrated in Figs. 8(*a*), (*b*), and (*c*) are representative of methods used in testing this type of pump. Because of the wide variety of installations, it is impossible to list acceptable variations.

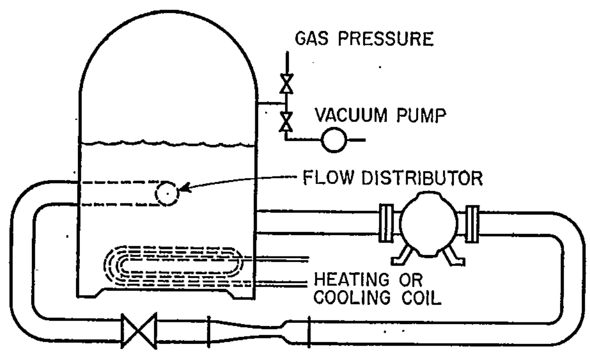

Fig. 8(*c*) Inlet Requirement Test

4.10 The inlet requirement test is made at a constant rated differential pressure and pump speed by measuring the capacity at different inlet pressures. The test should be started with sufficient inlet pressure to establish the normal capacity with adequate net positive inlet pressure and continued at lower and lower inlet pressures until five to ten per cent loss of capacity is registered. The increments between different inlet pressures at which capacity readings are taken shall not be greater than one psi. The temperature should be maintained essentially constant throughout the test and if there is a variation, the possible need for a correction for change in vapor pressure of the liquid should be investigated.

Directions for plotting the results of inlet requirement tests and determining the limiting inlet pressure are given in Section 5, Par. 5.02.

Capacity Measurements

4.11 Capacity tests shall be made at a constant pump speed by measuring the liquid delivery of the pump at different discharge pressures, from the minimum pressure obtainable with the test arrangement to the maximum pressure selected for test. Measurements shall be made at not less than four different pressures, approximately equally spaced. If more than one pump speed is specified, separate capacity tests shall be made at each specified speed. If the pump is to operate at variable speed, or constant speed, and variable displacement, capacity tests shall be made at not less than four conditions including the minimum and maximum conditions selected for test. The discharge or outlet pressure may be controlled by a valve in the outlet pipe. This valve must be properly located beyond the discharge pressure measuring section consistent with the pressure measuring method. A recommended spacing between the discharge pressure measuring section and the valve is six pipe diameters, but in no case less than twelve inches.

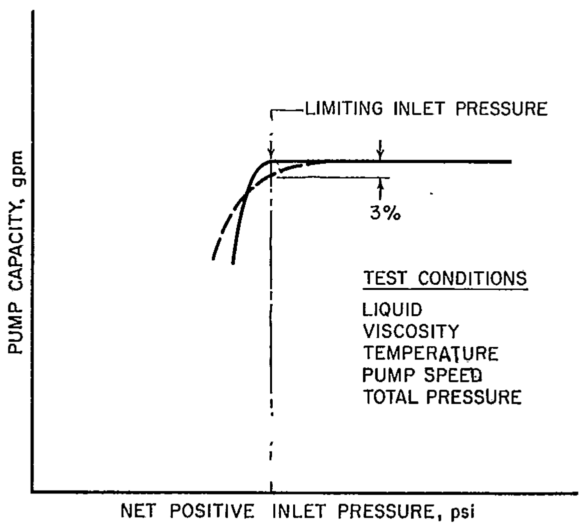

FIG. 9 INLET REQUIREMENT TEST

The preferred method of controlling inlet pressure is to control the level in the supply reservoir if it is open to the atmosphere or to control the air or gas pressure above a constant liquid level if the reservoir is closed. (See Fig 8(*c*).) When it is necessary to use a throttle valve in the inlet line, provision must be made to regain normal velocity distribution at the pump inlet and measuring section.

4.12 The Measurement of Volume Rate of Flow (Capacity) is carried out by liquid meters classified into two functional groups; quantity type and rate of flow type. It is preferred that the capacity be determined by a quantity type meter.

4.13 Capacity Measurement by Weight. Measurement of capacity by weight depends upon the accuracy of the scale used and the accuracy of the measurement of time. Accuracy of weight measurement to one quarter of one per cent is readily obtainable. The computed rate of flow from weight measurement is dependent upon the selection and accuracy of the scales, time measuring device, and the time interval of the test.

Selection of a scale of high order of subdivision of the dial or beam and a timer which provides the highest order of subdivision of scale will help in obtaining the accuracy desired. Selection of a time interval for any test point must be made such that the highest order significant reading of the scale and timer does not introduce an appreciable error. Interpolation either of scale or timer reading is not recommended.

The scale shall be calibrated with standard weights before and after the test.

The timer shall be calibrated against an accepted time standard before and after the test.

The timer interval for any test point shall be agreed upon by the parties to the test and the accuracy of measurement established, based upon the scale and timer machanisms available.

4.14 Capacity Measurements by Volume. Measurements of volume may be established by collection of the liquid in a reservoir. Accuracy of measurement to one-quarter of one per cent is possible providing careful selection of the reservoir and accompanying hook or point gage is made.

Accuracy of measurement depends upon the change of height in the reservoir such that the highest order significant reading of the vernier scale on the hook or point gage represents a high degree of accuracy. Unless the accuracy of dimension of the reservoir is agreed upon by the parties to the test, the reservoir shall be calibrated by weighing. In all cases the liquid shall be conducted to the volumetric tank by means of a suitable diverter. The tank shall be equipped with stilling wells in those cases where surface disturbance will affect the reading of the gages.

The liquid level shall be measured by a hook or point gage. Selection of a hook or point gage shall be made based upon the highest order significant reading of the vernier of the gage. Interpolation of the vernier gage is not recommended.

Selection of a timer of high order subdivision of scale is necessary for accuracy. Selection of a time interval for any test point must be made such that the highest order significant reading of the timer does not introduce an appreciable error. Interpolation of the timer reading is not recommended.

4.15 Suitable displacement meters may be used for capacity measurement. This type of meter is particularly useful when test liquids are either viscous or volatile. The timer used in connection with a displacement meter must be selected on the same basis as for other quantity methods of measurement. Displacement meters must be calibrated before and after the test under conditions comparable to the test conditions.

4.16 When quantity methods are used for capacity measurement, it is recommended that electrical or mechanical interlocking be used between the quantity meter and the timing device, to insure simultaneous starting and stopping of the timer and the meter. The photographic technique to insure that simultaneous readings are taken is a further recommended procedure.

4.17 Capacity Measurement by Venturi Meter. This type of meter, when properly calibrated and installed is an acceptable instrument for code tests. Accuracies better than one-half of one per cent can be expected only by individual calibration.

A certified curve showing the coefficient of the meter and its accuracies shall be required. The certification must state the conditions for which the meter curve applies and whether the calibration was obtained from models or the actual meter itself. Where the calibration was made at a considerable time prior to the test, or where the physical condition of the meter is suspected to be different than during the calibration, the meter shall be recalibrated before it is used in a code test.

For a detailed discussion of these meters, their installation and calibration, the user is referred to Fluid Meters—Their Theory and Application, Fifth Edition, 1959, and to I & A, Part 5, Chapter 4 on Flow Measurement, (PTC 19.5;4-1959).

Considerations of accuracy shall recognize unavoidable individual differences between ostensibly duplicate meters. They do not refer to accidental errors of observation.

The pipe preceding the Venturi meter inlet must be free, at least through a distance greater than six diameters, from tubercules or other surface imperfections which would establish a disturbance in line with the pressure tap openings. The pressure tap openings must be flush with the interior of the meter body and free from burrs.

An undamped manometer shall be used for measuring the differential pressure across the meter inlet and throat. The proper use of manometers is set forth in I & A, Part 5, Chapter 4 on Flow Measurement.

4.18 Capacity Measurement by Nozzles. A circular nozzle of the converging type is an acceptable device for measuring liquid flow. Both submerged flow nozzles and free discharge nozzles are practical for code testing within their respective limitations. Accuracies better than one-half of one per cent can be expected only by individual calibration.

A certified curve showing the coefficient of the meter and its accuracy shall be required. The certification must state the conditions for which the meter curve applies and whether the calibration was obtained from models or the actual meter itself. Where the calibration was made at a considerable time prior to the test, or where the physical condition of the meter is suspected to be different than during the calibration, the meter shall be recalibrated before it is used in a code test.

For a detailed discussion of nozzles, their installation and calibration, the user is referred to Fluid Meters—Their Theory and Application, Fifth Edition, and I & A, Part 5, Chapter 4 on Flow Measurement.

For submerged flow nozzles, three diameters of straight pipe of the same size as the nozzle entrance are required following the nozzle throat.

An undamped manometer shall be used for measuring the pressure at or across the nozzle. The proper use of manometers is set forth in I & A, Part 5, Chapter 4 on Flow Measurement.

4.19 Capacity Measurement by Orifice Plate. The square-edged concentric orifice plate, when used as prescribed herein, is approved for capacity determination under this code.

Accuracies better than one-half of one per cent can be expected only by individual calibration. When this is not possible, a certified curve showing the coefficient of the meter and its accuracy shall be obtained. The certification must state the conditions for which the meter curve applies and whether the calibration was obtained from models or the actual meter itself. Where the calibration was made at a considerable time prior to the test, or where the physical condition of the meter is suspected to be different than during the calibration, the meter shall be recalibrated before it is used in a code test.

For a detailed discussion of orifice plates, their installation and calibration, the user is referred to Fluid Meters—Their Theory and Application, Fifth Edition, and I & A, Part 5, Chapter 4 on Flow Measurement.

Consideration of accuracy shall recognize unavoidable differences between ostensibly duplicate orifices.

The size of the orifice preferably shall be determined so that the velocity through the orifice shall be in excess of 10 ft per sec at the rated capacity of the pump to be tested.

4.20 Accuracy of Rate of Flowmeters. The rate-of-flowmeters described in I & A are steady-state flow devices and are calibrated accordingly. All such meters are affected by cyclic variation of pressure or flow at entrance to the meter. Cyclic variations are a common characteristic of all displacement machinery, the amplitude of the variation being dependent on the kind of machine. Use of such flow measuring equipment for code test must be contingent on agreement of the parties to the test on several points of importance.

Selection of a size of accumulator to dampen cyclic variation depends upon the net amplitude of volume variation delivered by the pump and the required air capacity above the surface of the fluid in the accumulator. Pressure fluctuation at the entrance to flowmeters as described in I & A will be reflected in the differential pressure measuring equipment used to determine flow rate through the meter.

Generally, rate-of-flow measuring equipment is recommended for tests where parties to the test can agree upon the accuracy, based upon consideration of size of accumulator, net amount of air above the accumulator, and the effect of damping of the differential pressure gage used in conjunction with the flowmeter.

Power Measurements

4.21 Power Measurements shall be made every time and at the same time that a capacity measurement is made. Directions for plotting are given in Section 5, Par. 5.04.

Measurement of power input to the pump, that is, the shaft horsepower to the pump, falls into two general classes:

(*a*) Measurements, which within themselves, determine the actual power or torque delivered to the pump and, therefore, are made entirely during the test by means of some form of transmission dynamometer.

(*b*) Measurements of power input, during the pump test, to the driving element, and the previous or subsequent determination of the relation of the power input to the power output of this driving element, under conditions identical to the pump test.

The use of transmission dynamometers or motors that have been calibrated with a transmission dynamometer or suitable water brake or cradled electrical dynamometer shall be considered to give a satisfactory measurement of input power to a pump.

4.22 Transmission Dynamometers. Cradled electric and torsion dynamometers shall not be employed for testing pumps with a maximum torque below one quarter of the dynamometer rated torque. Torsion dynamometers shall be calibrated after the test with the torsion member at the same temperature as during the test.

The calibration of the torsion dynamometer shall be conducted with the torsion indicating means in place. Observations of the indicator shall be taken with a series of increasing loadings and then with a series of decreasing loadings, with the precaution that during the taking of readings with increasing loadings, the loading shall at no time be decreased. Similarly, during the taking of readings with decreasing loadings, the loading shall at no time be increased. The calculation of output shall be based on the average of the increasing and decreasing loadings as determined by the calibration. If the difference in readings between increasing and decreasing loadings exceeds one per cent, the dynamometer shall be deemed unsatisfactory.

For more detailed information concerning transmission dynamometers see Chapter 1, Pars. 79-100 of I & A, Part 7 on Measurement of Shaft Horsepower of Rotating Machines by Direct and Indirect Methods, (PTC 19.7-1961).

4.23 Calibrated Electric Motors. The majority of displacement pumps under test are driven by electric motors, and it is satisfactory to measure the electrical input to the motor, multiply such observations by the efficiency of the motor and thus to determine the power input to the pump shaft. Where a question exists as to the efficiency of the motor, its efficiency shall be determined by measurement of the electrical energy input and the mechanical energy output by means of a transmission dynamometer, or a suitable absorption dynamometer or by electrical methods indicated in Par. 4.24.

4.24 Squirrel cage induction motors, when operated at greater than half name plate rating, direct current motors, synchronous motors, or wound rotor induction motors with short circuited secondary resistance, may be employed for the determination of shaft input, provided the efficiencies or losses have been ascertained by an AIEE calibration.

4.25 The power input to the pump shaft of a direct connected motor-driven pump is equal to the product of the electric horsepower input to the motor and the motor efficiency at the observed load. The electric power input is the sum of (*a*) the electric power input at the motor terminals, (*b*) that portion of the excitation power externally supplied, and (*c*) the power for ventilating the motor if it is externally supplied. If the motor is externally excited, the excitation power, item (*b*) shall include the electrical losses of the field rheostats. If a synchronous motor with a directly driven (either connected or belted) exciter is employed, the true efficiency of the motor shall include the exciter loss.[2]

If suitable motor calibration data are available eliminating external losses such as separate ventilation or excitation, the net power input

[2]The exciter loss is the excitation power to the synchronous motor, as measured by a voltmeter and ammeter, divided by the exciter efficiency, less the excitation power.

may be used to determine shaft horsepower delivered to the pump.

The power input to the pump shaft of a direct connected motor driven pump may be obtained by employing the principles outlined in Chapter 2, Pars. 2–10 of I & A, Part 7 on Measurement of Shaft Horsepower of Rotating Machines by Direct and Indirect Methods (PTC 19.7-1961).

4.26 Accuracy of Power Measurement. The accuracy of results using a cradle dynamometer or other devices as described above is dependent upon the degree of cyclic variation of power required by the displacement machine. In most cases a degree of damping of the scale linkage of the dynamometer or the meter, as the case may be, is required. In any case, agreement by the parties to the test to accept the results obtained by the methods selected for power measurements is essential to a code test and should be concluded in advance of the running of the test. When power measurements are made by determining motor output power from watts input and motor efficiency and the cycle variation of the wattmeter reading is great, the use of a watthour meter should be considered. The watthour meter, combined with a suitable timer, will give an average power input to the motor.

Speed Measurements

4.27 Measurement of Speed. An accurate measurement of pump speed is considered essential. The speed shall be measured by a reliable revolution counter preferably included as an integral part of any timer circuit used for quantity measurement of capacity, or by a speed indicating device as permitted hereafter. Where the revolution counter is not included as a portion of the timer circuit, then the degree of simultaneous reading between the timer and the revolution counter must be considered in determining the net accuracy obtained in the calculation of speed in revolutions per minute.

Certain types of speed indicating equipment are considered satisfactory for use where the equipment is damped sufficiently to make it possible to get a reasonable reading of speed in revolutions per minute. In any case agreement between the parties to the test shall be made concerning the measurement of speed by these devices prior to the conducting of any test.

4.28 The pump speed shall be measured every time and at the same time that a capacity measurement is made.

Section 5, Computation and Plotting of Results

5.01 A complete presentation of the performance of a displacement pump must include a statement of the two cardinal quantities—capacity and power requirements. These quantities shall be stated for specific conditions of operation including inlet pressure, discharge pressure, speed and liquid.

Before final calculations are undertaken, the recorded data shall be scrutinized for consistency and constancy of the operating conditions. The fluctuations of readings during any one test run shall not exceed the limits prescribed in Table 1. In any test where the readings show fluctuations in excess of the limits prescribed in Table 1, the test shall be discarded.

5.02 Plotting of Inlet Requirement Test. Before plotting, all inlet pressure readings shall be corrected as described in Section 2, Pars. 2.11 and 2.13, to their equivalent net positive inlet pressure. A curve, similar to Fig. 9, shall be plotted showing pump capacity in gallons per minute (gpm) versus net positive inlet pressure in pounds per square inch (psi).

It is not always possible to determine precisely the limiting inlet pressure for the large variety of pumps and liquids which may be tested under this code. If there is a definite break in the curve as illustrated by Fig. 9, this shall be taken as the limiting inlet pressure. If the curve changes too gradually to show a specific point, the limiting inlet pressure shall be taken at a capacity loss of 3 per cent or at the inlet pressure at which cavitation noise in the pump becomes definitely audible, whichever occurs at the higher inlet pressure. The limiting inlet pressure will apply only for the specific liquid at the temperature and pump speed used in the test.

5.03 Plotting of Capacity Test. Before plotting, all discharge and inlet pressure measurements shall be corrected as described in Section 2, Pars. 2.10 and 2.11, and the total pressure rise across the pump shall be computed as described in Section 2, Par. 2.12.

A curve, similar to Fig. 10, shall be plotted showing pump capacity in gallons per minute (gpm) versus pump total differential pressure in pounds per square inch (psi).

5.04 Plotting of Power Test. The corrected power input to the pump shall be computed from the measurements made during the test, as described in Section 4, Pars. 4.21 to 4.26, and converted into horsepower. A curve, similar to Fig. 10, shall be plotted showing power input to the pump in horsepower (hp) versus total differential pressure in pounds per square inch (psi).

5.05 Plotting Relationship Between Power Input, Capacity, Rotational Speed, and Pressure Rise Across the Pump. To provide a concise and direct method of showing the relationship of these four parameters, it is recommended that curves be plotted as in Fig. 11, showing pump delivery in gallons per minute (gpm) versus power input to the pump in horsepower (hp) for constant rotational speeds and constant differential pressures across the pump.

5.06 Plotting Efficiency. The pump efficiency as defined in Section 2, Par. 2.20, shall be plotted as a curve, similar to Fig. 10, showing efficiency in per cent versus pump total differential pressure in pounds per square inch (psi).

If measurements are made of the driver power input, the over-all efficiency, as defined in Section 2, Par. 2.22, may be plotted in a similar manner.

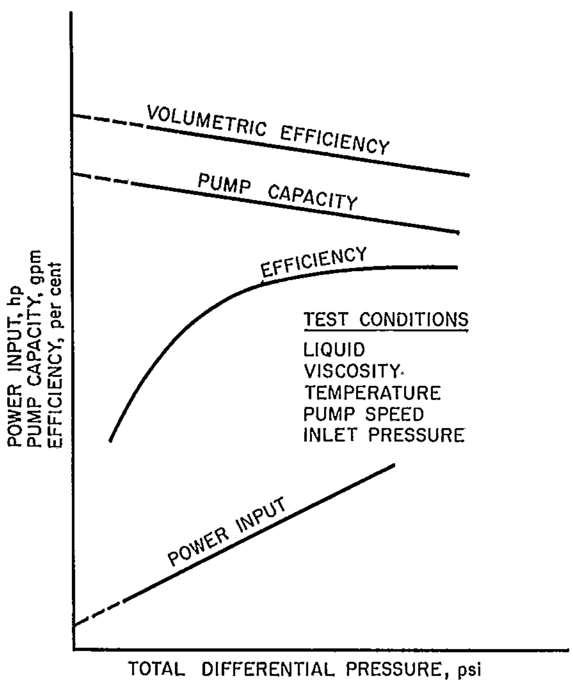

FIG. 10 PERFORMANCE CURVES

5.07 Pump Displacement. The displacement (D) of any displacement pump shall be given in cubic inches per revolution. The displacement shall be equal to one hundred per cent of the net volume displaced by the volume elements during one revolution.

If the pump capacity curve as plotted in Fig. 10 shall be projected to the zero pressure line, the corresponding pump delivery for that point should agree with the pump displacement for that speed within five per cent. A difference between the two values of greater than five per cent indicates an error, or that an appreciable amount of air or gas was entrained in the liquid during the test. Any such discrepancy should be investigated.

5.08 The Volumetric Efficiency η_v may be plotted as a curve, similar to that of Fig. 10,

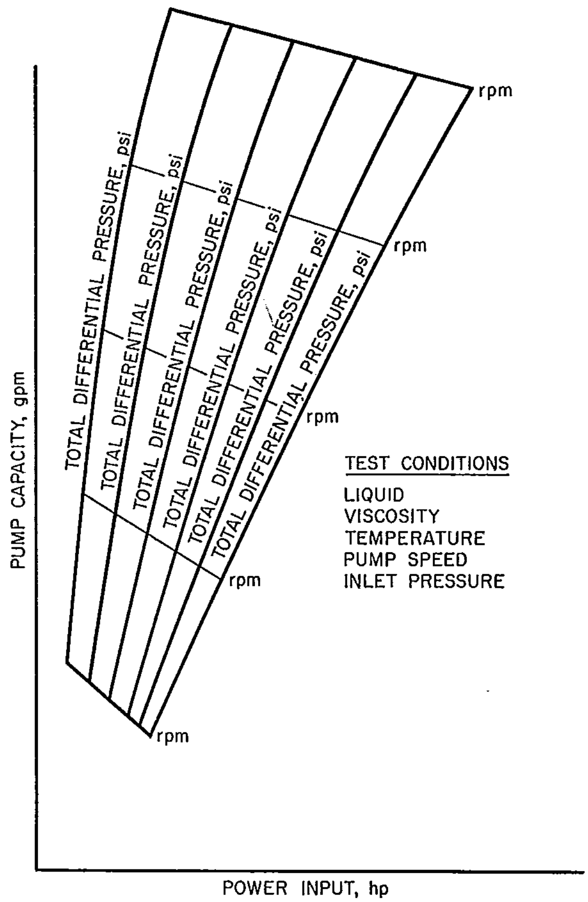

FIG. 11 PERFORMANCE CURVES

showing volumetric efficiency in per cent versus total differential pressure in pounds per square inch (psi).

5.09 Slip (S) is defined as the pump displacement capacity minus the actual pump delivery.

$$S = Q_d - Q$$

Slip is due to internal leakage and fluid compressibility.

5.10 Adjustment of Test Speed. The test speed shall be within ten per cent of the rated speed specified, as noted in Table 1. If any speed measurement varies from the rated speed, the corresponding delivery and power measurements taken at the same time as the speed measurement shall be adjusted according to the following formula. The subscript (t) refers to the values actually measured during the test, and the subscript (a) refers to the adjusted values corresponding to the adjusted speed.

The capacity shall be adjusted to the required speed by the following formula:

$$Q_a = \left[\frac{N_a}{N_t}(Q_t + S)\right] - S$$

The input power shall be adjusted to the required speed by the following formula:

$$\text{bhp}_a = \text{tdhp}\,\frac{N_a}{N_t} + \left[(\text{bhp}_t - \text{tdhp})\left(\frac{N_a}{N_t}\right)^{1.5}\right]$$

The theoretical displacement power (tdhp) is defined by the following formula:

$$\text{tdhp} = \frac{Q_d P_{td}}{1714}$$

when Q_d is in gallons per minute at the actual test speed and P_{td} is in pounds per square inch.

ASME POWER TEST CODES

Test Code for Displacement Pumps

SECTION 6, REPORT OF TEST

6.01 The following is a recommeded form for the reporting of all tests performed under this code.

A—General Information

1 Date of Test ....
2 Location ....
3 Owner ....
4 Builder ....
5 Test conducted by ....
6 Object of test ....
7 Pump service ....
8 Size and type of driving element.............Serial number..........................

B—Pump Data

9 Size and type of pump.....................Serial number..........................
10 General construction..
11 Rated Conditions
(*a*) Fluid pumped..
(*b*) Specific weight..at........F
(*c*) Kinematic viscosity..at........F
(*d*) Temperature of fluid at inlet..F
(*e*) Capacity.................gpm..cfs
(*f*) Speed.. rpm
(*g*) Inlet pressure.. psi
(*h*) Net positive inlet pressure..psi
(*i*) Discharge pressure..psi
(*j*) Pump power input (hp)..
(*k*) Pump efficiency..per cent

C—Test Data

(In reporting test data, all calibrations shall have been applied)

12 Results (recorded in same order as Part B, Item 11)
(*a*) ....
(*b*) ....
(*c*) ....etc.

D—Test Performance Adjusted to Rated Speed

Point No.	13 Adjusted Capacity	14 Adjusted Pressure	15 Adjusted Power Input
	gpm	psi	hp
1			
2			
...			
...			

E—Test Information

16 Method employed for measuring flow rate. . . . .
17 Method employed for measuring power. . . . .
18 Method employed for measuring pressure. . . . .
19 Duration of period of measuring flow rate. . . . .
20 Duration of period of measuring power. . . . .
21 Duration of period of measuring pressure. . . . .
22 Dimensions of measuring section at inlet. . . . .
23 Dimensions of measuring section at discharge. . . . .
24 Conditions other than those noted. . . . .

F—Performance at Rated Pressures and Speed

25 Capacity. . . . . .gpm. . . . . .cfs
26 Pump power input (hp) . . . .
27 Efficiency. . . . . .per cent

POWER TEST CODES

Power Test Codes Now Available