Recommended Practice for Electric Submersible Pump Testing

API RECOMMENDED PRACTICE 11S2
SECOND EDITION, AUGUST 1997

EFFECTIVE DATE: OCTOBER 1, 1997

American Petroleum Institute

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Exploration and Production Department

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FOREWORD

This publication is under the jurisdiction of the API Subcommittee on Field Operating Equipment.

This document presents recommended practices for centrifugal pump performance testing of electric submersible pumping systems.

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This standard shall become effective on the date printed on the cover but may be used voluntarily from the date of distribution.

CONTENTS

Recommended Practice for Electric Submersible Pump Testing

1 Scope

1.1 GENERAL

This recommended practice provides guidelines and procedures covering electric submersible pump performance testing intended to establish product consistency. These recommended practices are those generally considered appropriate for the majority of pump applications.

1.2 COVERAGE

This recommended practice covers the acceptance testing of electric submersible pumps (sold as new) by the manufacturer, vendor, or user to the following prescribed minimum specifications. This recommended practice does not include other electric submersible pump system components.

2 Definitions

2.1 acceptable test point: Test points that fall within the allowable pump test acceptance criteria.

2.2 affinity laws: Relationships between pump performance and pump speed ratios. For test purposes, the speed ratios are between rated rpm and test rpm.

a. Speed adjusted flow $= \frac{\text{rated rpm}}{\text{test rpm}} \times \text{test flow}$

b. Speed adjusted head $= \left(\frac{\text{rated rpm}}{\text{test rpm}}\right)^2 \times \text{test head}$

c. Speed adjusted brake horsepower

$$= \left(\frac{\text{rated rpm}}{\text{test rpm}}\right)^3 \times \text{test brake horsepower}$$

2.3 allowable head-flow rate performance band: A region on either side of a published head-flow rate performance curve (see Figure 2). The limits of this band are defined by a series of vectors with their origin on the published head-flow rate performance curve (see Figure 3). The vectors are defined by application of the head and flow tolerances in Table 2.

2.4 best efficiency point (BEP): Defines pump performance parameters at the maximum value on the efficiency curve.

2.5 brake horsepower (BHP): The power required by the pump corrected for a fluid with a specific gravity of 1.0.

2.6 efficiency (EFF): A measure of power out divided by power in. For the pump only:

$$\text{EFF} = \frac{\text{head} \times \text{flow rate}}{C \times \text{BHP}}$$

Where C is for units conversion.

2.7 flow rate: The volumetric rate of fluid delivered by the pump.

2.8 open flow: The pump flow rate at zero head.

2.9 rated flow: The flow rate at the recommended operating point of the pump. The flow rate is generally at BEP.

2.10 recommended operating range: Located between the maximum and minimum recommended flow rates.

2.11 shut off head: The head at zero flow.

2.12 test open flow: The maximum pump flow rate attainable on test. This rate is between the maximum recommended flow rate and open flow.

Note: This value may be limited by test facilities or pump design.

2.13 test shut off: The minimum pump flow rate attainable on test. This point is between zero flow and the minimum recommended flow.

Note: This value may be limited by test facilities or pump design.

2.14 total head: The difference between the pump outlet and inlet head in feet. This is the vertical distance, in feet, from the pumping fluid level to the centerline of the pressure gauge, plus the pressure gauge reading converted to feet, plus the friction loss between the pump discharge and pressure gauge in feet.

3 Data and Charts: Pump Performance Curves

Note: See Figure 1.

3.1 The published curves show the discharge head, brake horsepower, and efficiency of the pump as a function of flow rate. Although tests are made on multistage pumps, the published curves represent performance for one or more stages of each pump type. All curves are based on multistage performance tests and do not include horsepower of other components such as gas separators or seal chambers.

3.2 The curves are based on fresh water at 60°F (S.G. = 1.0), give a recommended operating range for the pump, and are commonly available for both 50 Hertz (Hz) and 60 Hertz (Hz) operation.

3.3 Manufacturers typically publish representative polynomial equations for head and brake horsepower curves. Numerical representation for efficiency is a calculated value from these head and brake horsepower polynomials at a given flow rate. Using polynomial equations is more accurate than

using published curves; therefore, when possible, polynomials should be used to verify conformity with certified test points.

4 Test Procedure

4.1 TEST POINTS

4.1.1 Performance tests shall be conducted at the following five points on the published pump performance curve:

a. Test open flow.
b. Maximum recommended flow rate.
c. Rated flow (generally BEP).
d. Minimum recommended flow rate.
e. Test shut-off.

4.1.2 Certified data: Data for Items 4.1.1.b through 4.1.1.d will be certified.

Tests for these points must be conducted within ±2 percent of the specified flow.

The head and brake horsepower will be reported at the actual test flow rate rather than the specified flow rate.

4.2 EFFICIENCY

4.2.1 The efficiency of the pump will be calculated at the rated flow test point.

4.2.2 An example of an efficiency calculation using a typical published pump performance curve is shown below (see Figure 1):

Flow rate = 1160 BPD
Head = 28.7 feet
Horsepower = 0.386 HP
Specific gravity = 1.0
Unit conversion

$$= \frac{1{,}440 \text{ min/day} \times 33{,}000 \text{ ft-lb/HP-min}}{350 \text{ lbs/bbl}} = 136{,}000 \text{ bbl ft/HP day}$$

$$\text{Eff.} = 1160 \text{ BPD} \times 28.7 \text{ ft}/(136{,}000 \times 0.386 \text{ HP}) = 0.634$$

4.3 SPECIAL TESTING CONSIDERATIONS

4.3.1 Where sections of tandem pumps are tested as individual units, each section should be evaluated as an independent pump.

4.3.2 When testing pumps with few stages (usually less than 10), the intake losses should be considered.

4.3.3 The use of fresh water for testing can result in damage caused by freezing or corrosion during shipping and storage.

4.4 TEST ORIENTATION

The published performance curves are based on vertical testing. If horizontal testing is conducted, differences in performance may result. The experience of the industry tends to indicate the head is not appreciably changed but the horsepower may increase during horizontal testing. This small difference is normally within the range of operator, equipment, and calibration error. In addition, industry experience has shown that pumps tested by one orientation routinely test within the specifications of Section 5 when tested in the other direction.

4.5 TEST FLUID

The published pump performance curves are based on fresh water at 60°F. If alternate fluids are used for testing, performance test results must be corrected to the fresh water performance.

Other fluids introduce factors (such as viscosity and specific gravity) that require the test data to be corrected. The relationships to convert from one test fluid to a standard water test are illustrated as follows:

$$\text{Head}_{water} = \text{total head}_{test} \times H_{vis}$$
$$\text{Flow}_{water} = \text{flow}_{test} \times Q_{vis}$$
$$\text{BHP}_{water} = \frac{\text{BHP}_{water}}{\text{Sp. Gr.}} \times \text{BHP}_{vis}$$

Viscosity corrections (H_{vis}, Q_{vis}, BHP_{vis}) for fluids other than water are empirically derived. Correction factors must be developed for a range of temperatures.

4.6 TEST RUN-IN TIME

The test should be established in the recommended operating range and the equipment run long enough to achieve stable head and horsepower readings.

4.7 SPEED VARIATIONS

4.7.1 Pumps may be tested with standard motors other than the actual motors used in application. As a result, there may be some speed variations from the nominal value of 3500 rpm for 60 Hz power.

All pump tests should be corrected back to the nominal speed of 3500 rpm. The affinity laws are used to correct to the rated value or for other power line frequencies.

If tests are desired for frequencies other than 60 Hz, the same procedures are to be applied with proportional adjustments (e.g., use 2916 rpm for 50 Hz with the same percentage tolerances).

4.7.2 An example of speed correction calculations using test data and rated rpm is shown:

Test flow	= 1160 BPD
Test head	= 27.7 feet
Test brake horsepower	= 0.36 BHP
Test rpm	= 3520
Rated rpm	= 3500

Using the definition of affinity laws (see 2.2), the following equations can be established:

Speed adjusted flow
= (3500 rpm/3520 rpm) × 1160 BPD= 1153 BPD

Speed adjusted head
= (3500 rpm/3520 rpm)^2 × 27.7 feet = 27.39 feet

Speed adjusted brake horsepower
= (3500 rpm/3520 rpm)^3 × 0.36 BHP = 0.354 BHP

4.8 INLET PRESSURE REQUIREMENTS

The inlet pressure to the pump must be above the minimum required by the manufacturer. If there are any inlet or discharge pressure limitations, these should be specified by the manufacturer.

4.9 INSTRUMENTATION ACCURACY

All measurements are inevitably subject to inaccuracies. Table 1 provides the maximum tolerance for instruments used during test.

Table 1—Overall Instrument Accuracy

Quantity	Limit (Percent of Full Scale)[a]
Flow rate	±1.0%
Total head	±1.0%
Electrical power input	±2.0%
RPM	±0.5%

[a]Good engineering practice requires test readings to be as close to the instrument full scale values as possible.

Pump brake horsepower will have a ±3.0 percent accuracy. Calculated pump efficiency, being a composite of other accuracies, should not exceed ±5.0 percent.

5 Test Certification

5.1 LIMITS

The limits listed in Table 2 shall apply to manufacturer's published performance curves. The limits are graphically shown in Figures 2 and 3.

5.2 ACCEPTANCE

5.2.1 The pump head-flow rate performance is acceptable if the certified test points are within the allowable head-flow rate performance band (see 2.3 for definition).

5.2.2 The pump brake horsepower performance is acceptable if the pump horsepower is within the tolerance limits at the certified test points.

5.2.3 The pump efficiency calculated from test results is acceptable if it is greater than the specified limit at rated flow.

5.2.4 When tests are conducted using instruments meeting the accuracy criteria, and the values observed during the test meet test certification criteria, the pump test is acceptable.

Table 2—Pump Test Acceptance Limits From Published Curve

Curve	Limits	Where Applicable
Head—flow rate	±5% Head ±5% Flow rate	Over recommended operating range[a]
BHP—flow rate	±8% BHP	Over recommended operating range[a]
Pump efficiency—flow rate	90% of efficiency	At rated flow

[a]The recommended operating range is defined as the manufacturer's published maximum operating range. If this range is not defined, use ±20% of the rated flow.

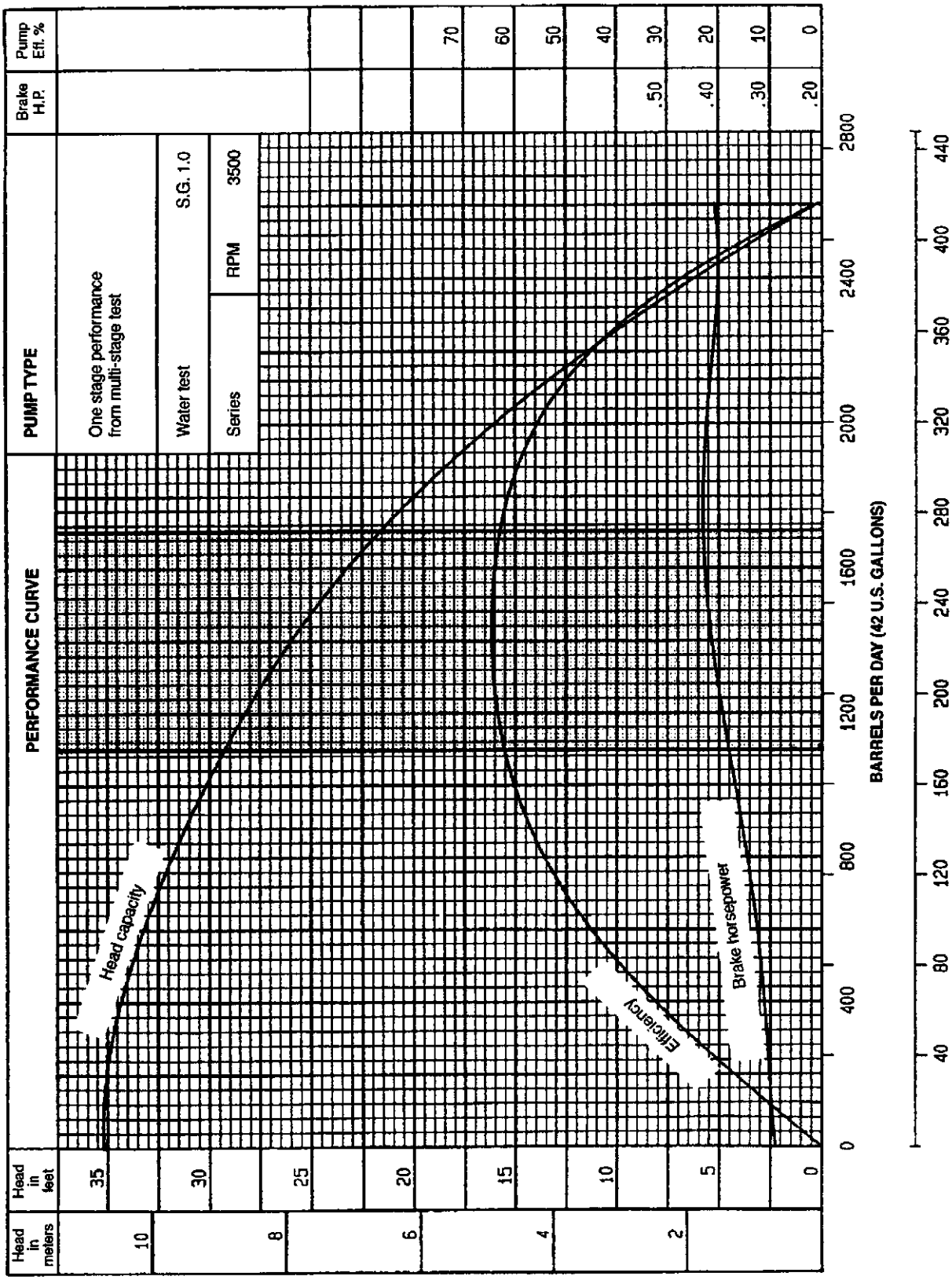

Figure 1—Typical Pump Performance Curve

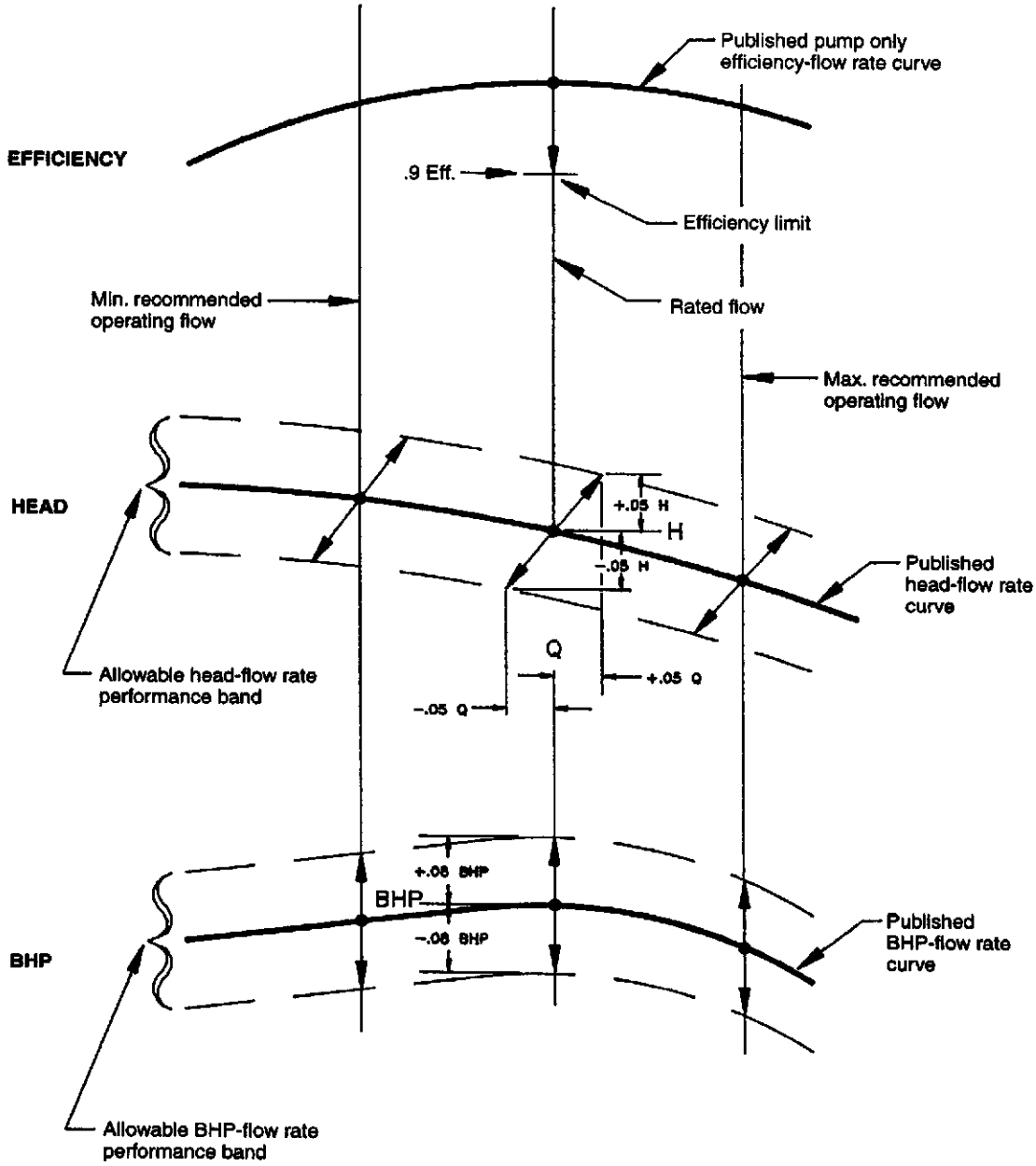

Figure 2—Pump Test Acceptance Limits From Published Curve

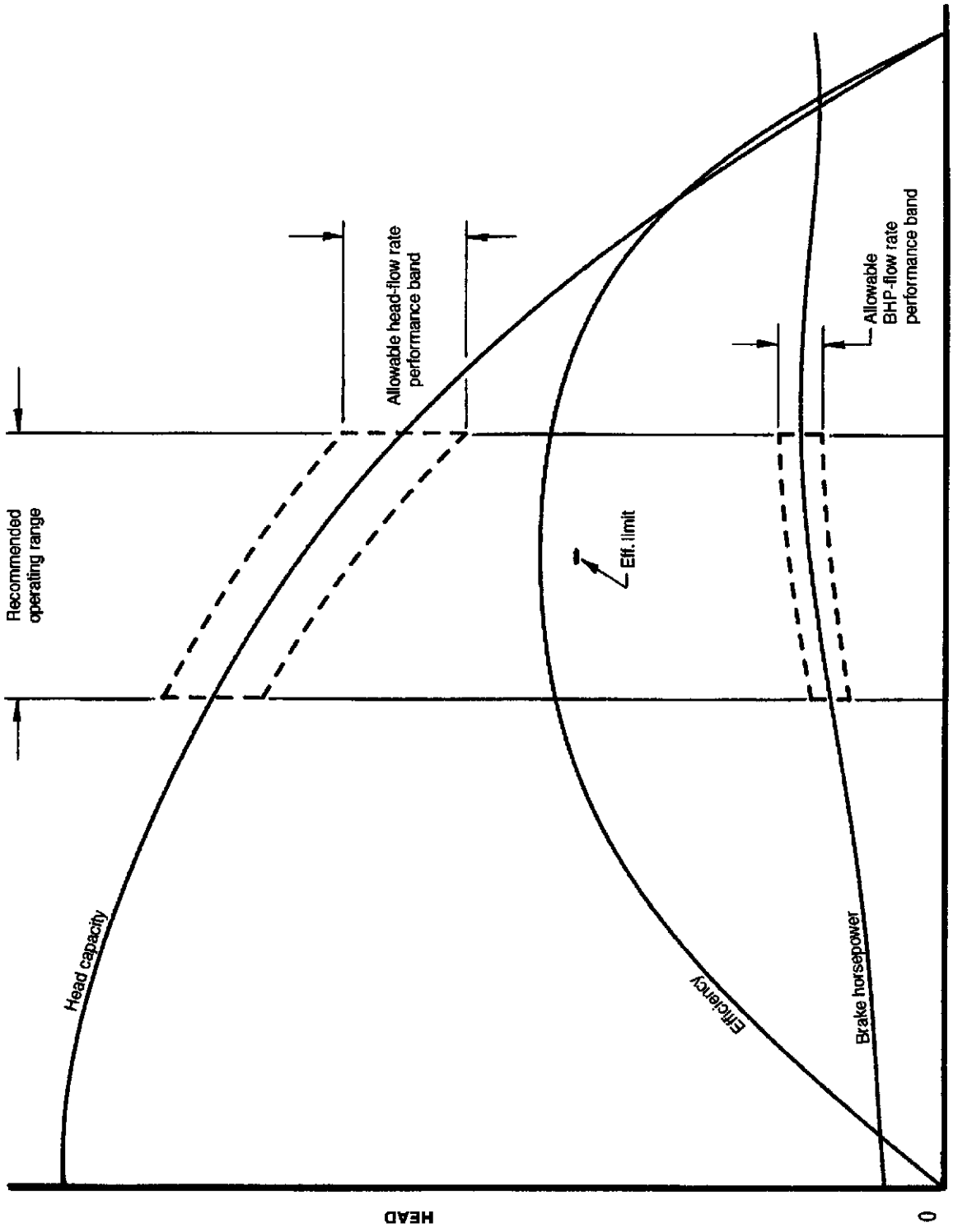

Figure 3—Typical Pump Performance Curve Showing Tolerance Bands

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