Foreword

The pursuance of this standard, Agricultural Machinery – Centrifugal, Mixed Flow and Axial Flow Water Pumps – Methods of Test, was initiated by the Agricultural Machinery Testing and Evaluation Center (AMTEC) under the project entitled "Enhancing the Implementation of AFMA Through Improved Agricultural Engineering Standards" which was funded by the Bureau of Agricultural Research (BAR) of the Department of Agriculture (DA).

This revised standard was reviewed by the Technical Committee for Study 1- Development of Standards for Agricultural Production Machinery and was circulated to various private and government agencies/organizations concerned for their comments and reactions. This standard was presented to the Philippine Society of Agricultural Engineers (PSAE) and subjected to a public hearing organized by the National Agriculture and Fisheries Council (NAFC). The comments and reactions received during the presentation and public hearing were taken into consideration in the finalization of this standard.

This standard has been technically revised in accordance with PNS 01:Part 4:1998 - Rules for the Structure and Drafting of Philippine National Standards.

In the preparation of this standard, the following documents/publications were considered:

AMTEC 13:1984 – Procedures of Inspection and Test for Centrifugal, Mixed Flow and Axial Flow Pumps

KUBOTA Pump Handbook Vol. 1 Technical Manual

Basic Hydraulics by Andrew Simon (1981)

Water Supply 2nd edition by A. C. Twort, R.C. Hoather and F.M. Law (1974)

McPherson's Pump Handbook

Water-pumping Devices – A handbook for Users and choosers by Peter Fraenkel (1986)

Agricultural Machinery – Centrifugal, Mixed Flow and Axial Flow Water Pumps – Methods of Test

1 Scope

This standard specifies the methods of test for centrifugal, mixed flow and axial flow water pumps. Specifically, the test consists of the following:

1.1 Performance Test

1.2 Cavitation Test

1.3 Priming Test (for self-priming pumps)

2. References

The following normative documents contain provisions, which, through reference in this text, constitute provisions of this Standard:

PAES 103:2000, Agricultural Machinery – Method of Sampling.

PAES 114:2000, Agricultural Machinery – Centrifugal Pump – Specifications.

3 Definitions

For the purpose of this standard, the definitions given in PAES 114 and the following shall apply:

3.1
axial flow pump
type of pump which develop most of the suction and discharge head by propelling or lifting action of the impeller vanes on the water

3.2
base plane
datum elevation
for horizontal shaft pumps, the distance from the level of water source to the centerline of the pump shaft; for vertical single suction pumps (volute and diffusion vane type), the distance from the entrance eye to the first stage impeller; for vertical double suction pumps, the distance from the level of water source to the impeller discharge horizontal centerline

3.3
cavitation
formation of cavities filled with water vapor due to local pressure drop and collapse as soon as the vapor bubbles reach regions of high pressure

3.4
centrifugal pump
type of pump with vanes or impellers rotating inside a close housing which draws water into the pump through a central inlet opening and forces water out through a discharge outlet at the periphery of the housing by means of centrifugal force

3.5
discharge
volume of water pumped per unit time

3.6
friction head, h_f
equivalent head required to overcome the friction caused by the flow through the pipe and pipe fittings

NOTE It is specifically defined by the expression

$$h_f = k \frac{l\,Q^2}{C^2\,D^2}$$

where:
l is the length of the pipe, m
Q is the discharge, m^3/s
C is the coefficient of friction for pipe (1.0 for steel, 1.5 for concrete, 0.8 for plastics)
D is the internal diameter of pipe, m
k is equal to 10

3.7
head
quantity used to express a form (or combination of forms) of the energy content of the liquid per unit weight of the liquid referred to any arbitrary datum

3.8
mixed flow pump
type of pump which combines some of the features of both centrifugal and the axial flow pump and in which head is developed partly by the centrifugal force and partly by the lift of the vanes on the water

3.9
net positive suction head-NPSH (h_{sv})
total suction head determined at the suction nozzle (corrected to pump center line) minus the vapor pressure of water at the pumping temperature

3.10
net positive suction head available (NPSHA)
NPSH as determined from the actual suction piping conditions

$$NPSHA = \left(\frac{P_a - P_{vp}}{\gamma} \right) - H_s$$

where: P_a is the atmospheric pressure, kg/m^2

P_{vp} is the vapor pressure, kg/m^2

γ is the specific weight of water, kg/m^3

H_s is the total suction lift/head, m

3.11
net positive suction head required (NPSHR)
performance characteristic required of the pump and is the NPSH at the pump inlet

NOTE It is the statement of the minimum suction conditions required to prevent cavitation.

3.12
performance curve
curve which represents the interrelationship between capacity, head, power, NPSH and efficiency of the pump

3.13
pump
device that is used to lift or transfer water from one source to another

3.14
priming
filling up the pump with water to displace or evacuate the entrapped air through a vent and create a liquid seal inside the casing

3.15
pump efficiency (η_p)
ratio of the power output to the power input of the pump (see Annex G)

3.16
shaft power
power required at the pump shaft

NOTE It is the input power to the pump.

3.17
static discharge head (h_d)
vertical distance from the centerline of the pump to the discharge water level (see Figure 1)

3.18
static suction head (h_s)
vertical distance from the free suction water level to the center line of the pump (see Figure 1)

NOTE It exists when the source of water supply is above the center line of the pump.

3.19
static suction lift (h_s)
vertical distance from the free suction water level to the center line of the pump (see Figure 1)

NOTE It exists when the source of water supply is below the centerline of the pump.

3.20
total discharge head (H_d)
sum of static discharge head, friction, and exit losses in the discharge piping plus the velocity head and pressure head at the point of discharge (see Figure 1 and Annex G)

NOTE As determined on test, it is the reading of a pressure gauge at the discharge pipe of the pump referred to datum plus velocity head at the point of gauge attachment.

3.21
total head (TH)
measure of energy increase imparted to the water by the pump and the algebraic difference between the total discharge head and total suction head (see Figure 1 and Annex G)

NOTE Total head, as determined on test where suction lift exists, is the sum of the total discharge head and total suction lift. Where positive suction head exists, the total head is the total discharge head minus the total suction head.

3.22
total suction head (H_s)
vertical distance from the center line of the pump to the free level of the water to be pumped minus all friction losses in suction pipe and fittings, plus any pressure head existing on the suction supply (see Figure 1 and Annex G)

NOTE As determined on tests, it is the reading of a gauge at the suction of the pump referred to datum plus the velocity head at the point of gauge attachment. Suction head exists when the total suction head is above atmospheric pressure.

3.23
total suction lift (H_s)
sum of static suction lift, friction and entrance losses in the suction piping (see Figure 1 and Annex G)

NOTE As determined on the tests, it is the reading of the pressure gauge at the suction nozzle of the pump corrected to the datum minus the velocity head at the point of gauge attachment. Suction lift exists where the total suction head at pump datum is below atmospheric pressure which the flow source vented to atmosphere.

3.24
velocity head (h_v)
pressure expressed in meters required to create the velocity of flow (see Figure 1)

NOTE It is specifically defined by the expression

$$h_v = \frac{v^2}{2g}$$

where: v is the velocity in the pipe and is obtained by dividing the discharge by the actual area of the pipe cross-section and determined at the point of gauge connection, m/s
g is the acceleration due to gravity, m/s^2

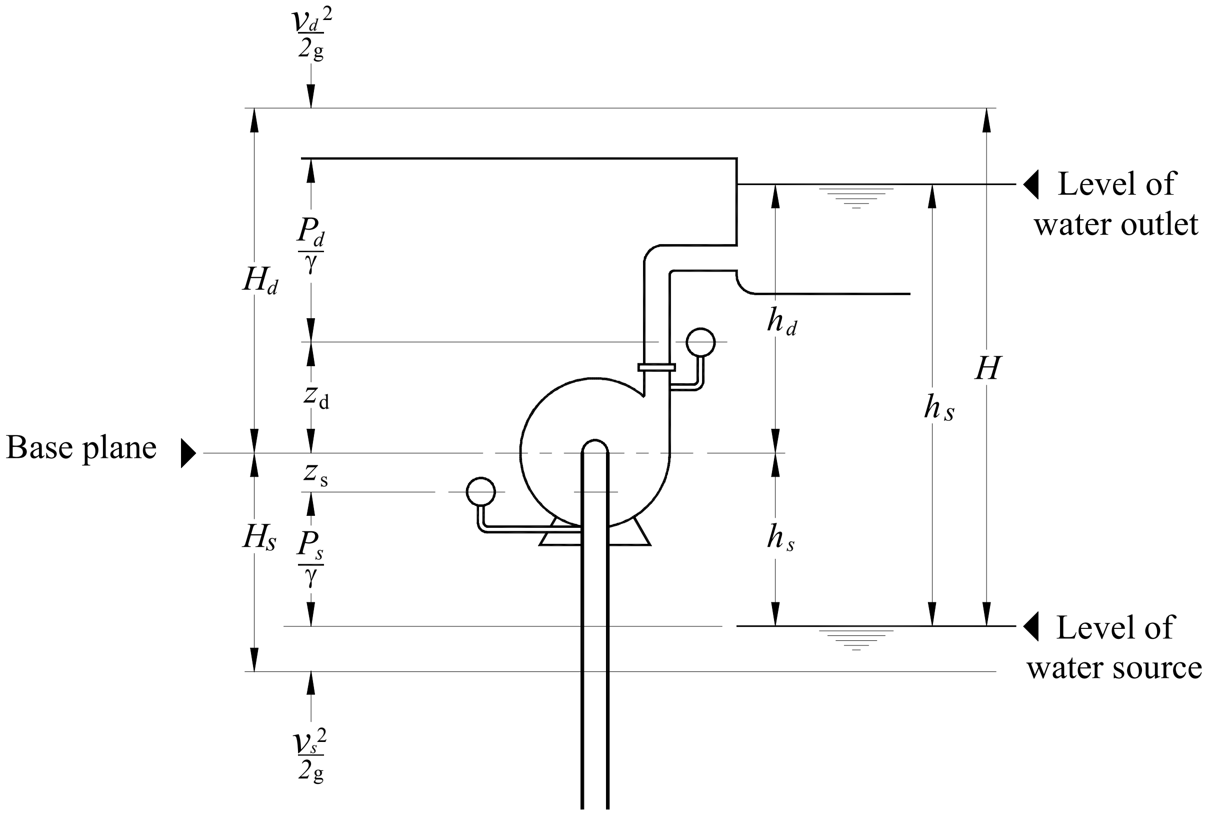


Figure 1 – Measurement of different heads

3.25
water power
theoretical power required for pumping

NOTE It is the head and capacity of the pump expressed in kilowatt. (see Annex G)

4 General Conditions for Test and Inspection

4.1 Pump on Test

The pump on test shall be commercially produced or prototype unit of pumps depending upon the test objective. In the case of testing for commercially manufactured pumps, the pump submitted for test shall be sampled in accordance with PAES 103.

4.2 Responsibility of Manufacturer/Dealer

The manufacturer/dealer shall make the pump for testing available to an authorized testing agency together with its specifications and other relevant information (see Annex A). An authorized manufacturer's/dealer's representative shall be appointed to prepare, handle, adjust and witness the test. It shall be the duty of the representative to make all decisions on matters of adjustment and preparation of the machine for testing. The manufacturer shall abide with the terms and conditions set forth by the authorized testing agency.

4.3 Site of Test

The pump shall be tested in a laboratory using a test rig. In the case of pump permanently installed, it shall be tested at the site where it is installed.

4.4 Materials and Equipment

4.4.1 Water

The water to be used during the test shall be clean with a temperature range of 10 – 40 ºC.

4.4.2 Measuring Instruments

4.4.2.1 The gauges to be used for head measurements shall be water columns or manometers. For a relatively high pressure, mercury manometer, bourdon gauges, electrical pressure transducers or dead weight gauge testers shall be used. Pressure gauges shall be attached as specified in Annex B.

4.4.2.2 For measuring discharge, the equipment to be used for relatively small flow rates shall be weighing tank. For relatively large flow rates, the weir, venturi, nozzle, orifice plate and Pitot tube shall be used.

4.4.2.3 For measuring pump input power, a dynamometer or a calibrated primemover shall be used.

4.4.2.4 All instruments to be used for test shall be calibrated.

4.5 Suction Lift / Head

The testing of pump shall be conducted on the smallest attainable suction head/lift to attain the basic performance curve of the pump.

4.6 Ambient Conditions

The ambient conditions such as atmospheric pressure, temperatures (dry bulb and wet bulb) and relative humidity shall be recorded at equal interval during the test.

4.7 Suspension of Test

If during the test run, the pump stops due to breakdown or malfunction so as to affect the pump's performance, the test shall be suspended at the discretion of the test engineer and concurred by the company representative.

5 Tests and Inspection

5.1 Verification of Manufacturer's Technical Data and Information

5.1.1 This inspection is carried out to verify the mechanism, main dimensions, materials and accessories of the pump in comparison with the list of manufacturer's technical data and information.

5.1.2 A plain and level surface shall be used as reference plane for verification of dimensional pump specifications.

5.1.3 The items to be inspected and verified shall be recorded in Annex A.

5.2 Performance Test

5.2.1 This is carried out to determine/establish the performance characteristics of the pump.

5.2.2 The test shall be conducted by operating the pump at manufacturer's recommended speed. The discharge and total head shall be varied by regulating the valve on the discharge side. In the case of pump to be tested in actual site, the actual measurements of the following shall be obtained:

5.2.2.1 Static suction lift

5.2.2.2 Static discharge head

5.2.2.3 Size and length of the pipes from coupling

5.2.2.4 Number of bends of piping

5.2.3 Data measurements shall be obtained at the following specified measuring points:

5.2.3.1 In the testing of a centrifugal pump, measurements shall be taken on not less than ten different discharge values starting from no-discharge state to the maximum flow rate possible, and at least of one these shall be measured at a head lower than the specified head.

5.2.3.2 In the testing of a mixed flow pump, measurements shall be taken on not less than ten different discharge values extending from the lower to the maximum flow rate possible within a range of over and below the specified head.

5.2.3.3 In the testing of an axial flow pump, measurements shall be taken on not less than ten different discharge values extending from full maximum to the minimum discharge values possible, and at least one of these shall be measured at a head higher than the specified head.

5.2.4 During the test, the following shall be taken:

5.2.4.1 Reading of vacuum gauge on the suction side

5.2.4.2 Reading of pressure gauge on the discharge side

5.2.4.3 Discharge (refer to Annex C)

5.2.4.4 Input power to pump

5.2.5 Magnitude of vibrations and presence of extra-ordinary noises shall be determined during operations.

5.2.6 Results shall be presented in tabular and graphical forms. The following curves shall be presented:

5.2.6.1 Total head vs. Discharge

5.2.6.2 Pump input power vs. Discharge

5.2.6.3 Efficiency vs. Discharge

5.2.6.4 Pump Speed vs. Discharge

5.2.6.5 NPSH vs. Discharge

5.2.7 Items to be measured and recorded are as given in Annex D.

5.3 Cavitation Test

5.3.1 This is carried out to determine the suction conditions of the pumps.

5.3.2 The conditions for testing shall be the following:

5.3.2.1 The pump shall be tested using the same set-up as in performance testing.

5.3.2.2 The water to be used during the test shall be clean with a temperature range of 10 – 40 ºC.

5.3.2.3 The pump shall be tested at the manufacturer's recommended speed.

5.3.3 The test shall be conducted by operating the pump at constant discharge and recommended speed. The suction pressure shall be varied starting from low to maximum suction pressure. Data on discharge, suction and discharge pressure, and power shall be recorded on every suction pressure setting.

5.3.4 Magnitude of vibrations and presence of extraordinary noises shall be determined.

5.3.5 Results shall be presented in tabular and graphical forms.

5.3.6 Items to be measured and recorded are as given in Annex E.

5.4 Priming Test

5.4.1 This is carried out to determine the priming time of a self-priming pump.

5.4.2 The pump shall be mounted on a test set-up with a static lift between the eye of the impeller and the water level of at least 3 m.

5.4.3 No check or foot valves shall be installed in the suction piping.

5.4.4 Before operation, fill the priming chamber with water at a temperature range of 10 – 40 ºC.

5.4.5 Operate the pump. The time elapsed between starting the unit and the time required to obtain a steady discharge gauge reading or full flow through the discharge nozzle shall be obtained and recorded as pump priming time.

5.4.6 Items to be measured and recorded are as given in Annex F.

6 Data Analysis

Measurements of heads and the formulas to be used during calculations and testing are given in Annex G.

7 Test Report Format

The test report must include the following information in the order given:

7.1 Name of Testing Agency

7.2 Test Report Number

7.3 Title

7.4 Summary

7.5 Purpose and Scope of Test

7.6 Methods of Test

7.7 Description of the Pump

7.8 Table 1 – Centrifugal Pump Specifications

7.9 Table 2 – Results of Performance Test

7.10 Table 3 – Results of Cavitation Test

7.11 Results of Priming Test

7.12 Observations

7.13 Name and Signature of Test Engineers

Annex A

Inspection Sheet for Pumps

Name of Applicant : ______________________________
Address : ______________________________
Telephone No. : ______________________________
Name of Distributor : ______________________________
Address : ______________________________
Name of Manufacturer : ______________________________
Factory Address : ______________________________

GENERAL INFORMATION

Brand: ______________ Model : ______________
Serial No. : ______________ Classification : ______________
Production date of pump to be tested : ______________________________

Items to be inspected

ITEMS	Manufacturer's Specification	Verification by the Testing Agency
A1 Type		
A2 Size, mm		
A3 Overall Dimensions, mm		
A1.1 Length		
A1.2 Width		
A1.3 Height		
A4 Weight, kg		
A5 Impeller		
A5.1 Type		
A5.2 Diameter, mm		
A5.3 Width, mm		
A5.4 No of. vanes		
A5.5 Material		
A6 Suction side		
A6.1 Type		
A6.2 Diameter, mm		
A6.3 Material		
A7 Discharge side		
A7.1 Type		
A7.2 Diameter, mm		
A7.3 Material		
A8 Casing		
A8.1 Type		
A8.2 Material		
A9 Stuffing box		
A10 Rotation		
A11 Rated maximum shaft speed, rpm		
A12 Rated maximum discharge, L/s		
A13 Rated maximum TH, m		
A14 Rated power, kW		

Annex B

Pressure Gauges Attachment

The pressure tappings are specified as follows:

B1 The suction and discharge side of the pump shall be connected to a straight pipe with a length of 4 times the diameter of each bore and one pressure tapping shall be provided at a distance twice the diameter from each flange surface of the pump. Its position shall be at right angle to the plane of the bend or of the curve of spiral of the pump. (see Fig.B.1)

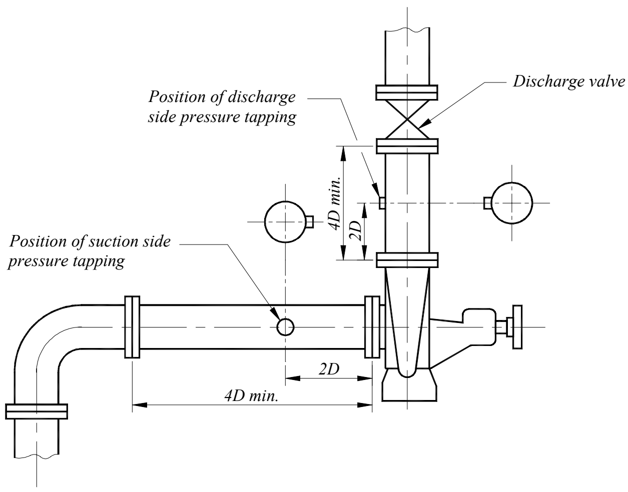
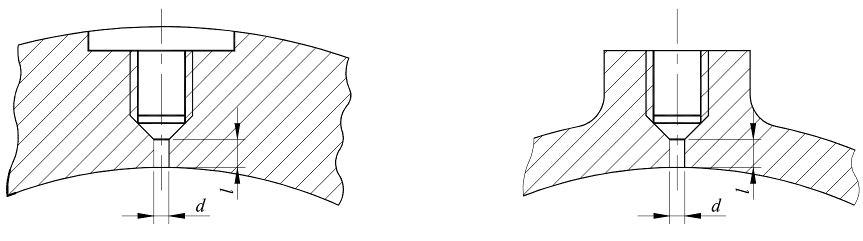


Figure B1 - Position of discharge side and suction side pressure tappings

B2 The diameter of pressure tapping shall be 2 to 6 mm or 1/10 of pipe inner diameter, whichever has the less value, and the bore shall be normal (perpendicular) to the inner wall of the pipe and shall have length of not less than twice of its diameter (see Fig.B.2). Inner wall of the pipe at this part shall be sufficiently smooth and inner rim of the bore shall be made free from any burrs.



a) Thick wall **b) Thin wall**

Figure B2 – Pressure tappings with thick or thin inner wall

Annex C

Different Methods of Discharge Measurement

C1 Container method

Measurement of discharge by container method is primarily suitable for the measurement of relatively small flow rate. The two ways of discharge measurement by means of a container are the weight and volume methods.

a) **Weight method.** This method is preferably used when a liquid's bubbles are hard to break. The container shall have a sufficient capacity to prevent the liquid from overflowing during measurement. The weight of the liquid in the container shall be obtained using a suitable scale at a definite time usually one minute. The discharge shall be computed using the formula:

$$Q = \frac{0.06\ W}{\rho\ t}$$

where:

Q is the discharge, m^3/h

W is the weight of liquid introduced into the container in t seconds, kg

t is the time required to introduce liquid of W, s

ρ is the weight per unit volume of liquid at the temperature during measurement, kg/L

b) **Volume method.** The container shall have sufficient capacity to prevent the liquid from overflowing during measurement, and it shall be sufficiently rigid to prevent deformation when it is filled with liquid. The liquid shall be obtained in a container of known volume for a definite time usually one minute. The discharge shall be computed using the formula:

$$Q = \frac{60V}{t}$$

where:

Q is the discharge, m^3/h

V is the volume of liquid introduced into container in t seconds, m^3

t is the time required to introduce liquid of V, s

C2 Using weir

For the measurement of flow by means of a weir (sharp crested triangular or rectangular weir) shall preferably be used. The flow shall be calculated according to the following equation:

a) for 90º triangular weir

$$Q = 0.0138\ H^{5/2}$$

where: Q is the discharge, L/s

H is the head, cm

b) for rectangular weir

$$Q = 0.0184\ l\ H^{3/4}$$

where: Q is the discharge, L/s

l is the length of crest, cm

H is the head over the crest, cm

Annex D

Performance Data Sheet

D1 Test Condition

D1.1 Condition of water source

a) Location : ____

b) Source of water : ____

c) Static suction lift/head : ____

d) Pumping water temperature, ºC : ____________________________________

D1.2 Ambient condition

a) Temperature

1. Dry bulb, ºC : ____

2. Wet bulb, ºC : ____

b) Relative humidity, % :____

c) Atmospheric pressure, mb : ____

D2 Performance Test

Shaft Speed rpm	Shaft Torque kg-m	Pump Input Power kW	Total Head m	Discharge L/s	Water Power kW	Pump Efficiency %

Annex E

Cavitation Test Data Sheet

E1 Test Condition

E1.1 Condition of water source

a) Location : ______________________________

b) Source of water : ______________________________

c) Static suction lift/head : ______________________________

d) Pumping water temperature, ºC : ______________________________

E1.2 Ambient condition

a) Temperature

i. Dry bulb, ºC : ______________________________

ii. Wet bulb, ºC : ______________________________

b) Relative humidity, % : ______________________________

c) Atmospheric pressure, mb : ______________________________

E-2 Performance Test

Shaft Speed rpm	Total Suction Lift or Head m	Net Positive Suction Head Available m	Total Head m	Discharge L/s

Annex F

Priming Test Data Sheet

Trials	Priming Time, min.
1	
2	
3	
Ave.	

Annex G

Measurements of Head and Formulas Used During Calculation and Testing

G.1 Total head, *TH*

$$TH = H_d + H_s$$

where:

$$H_d = \frac{P_d}{\gamma} + \frac{v_d^{\,2}}{2g} + z_d + h_f$$

$$H_s = \frac{P_s}{\gamma} + \frac{v_s^{\,2}}{2g} + z_s + h_f$$

where : TH is the total head, m

H_d is the total discharge head, m

H_s is the total suction head, m

$\frac{P_d}{\gamma}$ is the pressure gauge reading on the discharge pipe at gauge connection, in meters of H_2O

$\frac{P_s}{\gamma}$ is the vacuum gauge reading on the suction pipe at the point of gauge connection, in meters of H_2O

$\frac{v_d^{\,2}}{2g}$ is the velocity head at the point of gauge attachment on the discharge side, m

$\frac{v_s^{\,2}}{2g}$ is the velocity head at the point of gauge attachment on the suction side, m

Z_d is the elevation of the pressure gauge, m

Z_s is the elevation of the vacuum gauge, m

Note : Friction loss for the part between pressure tapping and the pump flanges shall be computed.

G.2 Water Power, *WP*, (kW)

$$WP = \frac{TH \text{ x } Q}{102}$$

where: TH is the total head, m

Q is the discharge, L/s

G.3 Input Power of the pump, IP_p, (kW)

$$IP_p = \frac{T_s \ x \ N}{974}$$

where: T_s is the input shaft torque, kg-m

N is the input shaft angular speed, rpm

G.4 Efficiencies

G.4.1 Pump Efficiency, η_p, (%)

$$\eta_p = \frac{WP}{IP_p} \text{ x } 100$$

where: WP is water power, kW

IP_p is input power of the pump, kW

G.4.2 Overall Efficiency (wire to water efficiency), η_o, (%)

$$\eta_o = \frac{WP}{IP_m} \ x \ 100$$

where : WP is water power, kW

IP_m is input power to the motor, kW