PD-AAT-247

44836

ARAB REPUBLIC OF EGYPT

MINISTRY OF IRRIGATION

MECHANICAL AND ELECTRICAL DEPARTMENT

IRRIGATION PUMPING PROJECT

(AID LOAN 263-K-039)

SECOND QUARTERLY REPORT

VOLUME I

DECEMBER, 1978

Prepared by: LOUIS BERGER INTERNATIONAL, INC.
100 HALSTED STREET
EAST ORANGE, NEW JERSEY, USA

FORWARD

The Quarterly Report for the period September through November 1978 has been divided into two volumes ; the material contained herein is varied in its application and will undoubtedly be used by numerous unrelated organizational entities. The first volume to be used primarily by the Mechanical and Electrical Department in its planning, followup and training activities presents the results of the CONSULTANT's experimental research into the techniques of designing and selecting pumps, and provides specific recommendations for computer hardware for operation of the budget planning and variance analysis system described in Section 3 of the First Quarterly Report submitted in August 1978.

The second volume of this report, to be used by potential investors and fiduciary institutions, presents by profitability analysis of the proposed venture to manufacture low lift pumps in Egypt.

Both volumes are designed to bring the client and AID up to date concerning the status of all aspects of the Irrigation Pumping Project.

CONTENTS

VOLUME I

Section I

1.0 Introduction 1

1.2 Pumps in Egypt 2

1.3 New Departures in Pump Design 4

1.4 Standard Specifications 5

1.5 Guidelines 6

2.0 Classification of Pumps 7

2.1 Types of Pumps 7

2.2 Kinds of Impellers Used in Pumps 8

2.3 The Parts of a Pump 9

3.0 Selection of Pumps 9

3.1 Definition of Operating Factors 9

3.2 Characteristic Curves 10

3.3 Performance Factors 13

4.0 Elementary Design Principles 17

4.1 The Efficiency of Centrifugal Pumps 19

4.2 Pump Design Procedures 20

4.3 Pump Balancing 41

5.0 Construction of a Pump: The Component Parts 42

5.1 Impellers 43

5.2 Casing and Diffusers 45

5.3 Shafts 46

5.4 Stuffing Boxes and Seals 47

5.5 Bearings 48

6.0 Standard Specifications 50

6.1 Organizations Concerned with Standards 50

FIGURES

Figure 1: Classification of Pumps

2: Mixed Flow Impellers

3: Axial Flow Impeller

4: Radial Flow Impellers

5a: Typical End Suction Radial Vane Pump

5b: Typical Axial Flow Vertical Pump

6: Range of Impeller Types for Different Specific Speeds

7: Backward-curved Vaned Pump

Small Radial Vaned Pump

8: Typical Pump Performance Curves

9: Effect of Impeller Diameter on Performance

10: Characteristic Curves for Various Specific Speeds

11: Pump Power Losses

12: Standard Pump Efficiency Curves

13: Pump Design Curves

14: Pump Design Curves

15: Pump Design Curves

16: Pump Design Curves

17: Impeller Materials

Appendix NOMENCLATURE

Section II

2.0 The Computer Program for Planning and Followup 53

2.1 Status of the Data Collection and Programming 53

2.2 Recommendations for the Establishment of a Mini-Computer Center within the Ministry of Irrigation 54

Appendix Consultant's Computer Hardware Recommendations

Section III

3.0 Status of the Invitation for Bid for the Thirty-Seven Pumping Stations 55

I

THE RATIONAL SELECTION OF PUMPS FOR IRRIGATION SERVICES

I

THE RATIONAL SELECTION OF PUMPS FOR IRRIGATION SERVICES

1.0 INTRODUCTION

The usual method of selecting pumps for irrigation services, i.e. pumping water, is based on measuring the physical factors at the site and then selecting a specific kind of pump from the manufacturer's performance curves. These data are written up in the form of a specification and submitted for tendering.

Alternatively, very elaborate designs in great detail may be made. In either case, the existing range of pumps available and the regulations applied to the manufacture of this equipment in industrialized countries must be considered.

The range of pumps and drives available is very great; there are pumps designed to meet every conceivable set of conditions and pumps manufactured from a wide range of materials to cope with every kind of fluid and compound, with ranges of temperatures, pressures and viscosities. The cost of pumps varies from the relatively inexpensive simple single stage high speed centrifugal pump to the expensive low speed vertical pump, or high pressure boiler-feed pumps.

The engineer in the field of irrigation and water supply, as well as the specialist pumps engineer, must have a broad knowledge of basic pump design, of the components and materials of manufacture, the range of pumps on the market, and the standard specifications involved in pump manufacture.

A detailed set of specifications should be drawn up to meet the requirements of pumps for Egypt. These specifications should be cross referenced with internationally accepted standard specifications, such as the British Standard Specifications, German DIN, I.S.O., and the several American specifications institutes. Such specifications would provide an up to date specification for tendering purposes and for regulation of locally manufactured pumps.

1.2 PUMPS IN EGYPT

Pumps in Egypt can be classified in three categories. The first are small pumps driven by single cylinder diesel engines (or, more recently by electric motors), mounted on trolleys. These units are used to replace water wheels and "shadoof." A wide range of small pumps fulfills this need in farming communities at present. The pumps originate in many countries and some are manufactured locally, and standards of efficiency and quality vary greatly

The type of pump required for this class of operations is an end suction mixed flow low lift, high capacity pump. These pumps should be of a simple, yet robust design, requiring a minimum of maintenance, efficient and low priced. Such pumps can be manufactured in Egypt to supply local demand.

The second category of pumps are those pumps used to draw water from the Nile. The total number of pump stations exceeds 1000, while many more privately owned pumps are used along the Nile also.

These pumps can be divided into three kinds: vertical mixed flow pumps, vertically mounted centrifugal pumps and horizontal centrifugal pumps. Prior to the construction of the High Dam, water level fluctuations occurred that required the selection of pumps that would not be subjected to cavitation; consequently, most pumps were designed for negative suction head conditions, i.e., below the low water level mark. This kind of pump configuration required the construction of intake works, dry pump chambers and high level motor rooms. Concrete structures of this kind at the present time are both expensive and require considerable time to construct.

The vertical pumps appear to be mainly of the mixed flow configuration to cope with relatively low heads and large volumes of water,

usually in the order of 0.75 m^3/sec to 1.25 m^3/sec, while a few deliver up to 2.0 m^3/sec. The pumps are driven by electric motors; the older slower pumps are driven through reduction gears.

The vertically mounted centrifugal pumps are more commonly used. Mounted in dry sumps, these pumps though efficient, require long drive shafts which imposes speed limitations on the operation of the pumps. Motors had to be mounted above the high flood level of the Nile.

Horizontal centrifugal pumps are not widely used on dry land but are used primarily in floating pump stations, mounted on barges. These pump stations are used where great water level fluctuations occurred; they are now falling into disuse and are being replaced by permanent installations; as water level fluctuation is now very slight.

With stabilization of the Nile water levels within narrower limits, departures from old established concepts of pump and installation designs can now be considered. Under present day conditions the costly slow speed vertical centrifugal and axial flow pumps installed in costly buildings can be replaced with relatively lower cost high speed horizontal centrifugal pumps mounted on plinths on the bank or on platforms. Vertical mixed flow pumps can also be mounted on simple platforms.

The third category, the deep-well turbine pumps, are not as yet extensively used though a number are in use in the New Valley area of the Western Desert. These pumps have to cope with rather extreme conditions. The water tends to be corrosive, with high levels of carbon dioxide and hydrogen sulphide, and water temperature is 27°C to 50°C. These factors constitute a destructive situation for most metals. However, these problems seem to have been overcome by selecting suitable alloys of "stainless" steel for pump components and also for the well screens.

The existing investment in pumps and related equipment in Egypt, apart from the value of the agricultural production dependent on pumped water, is great. About 35% of the total irrigated area of Egypt is dependent upon pumped water, or 0.798 x 10^6 hectares. The maintenance costs for out-dated equipment -- equipment beyond its economic life span -- and the low efficiencies of the old pumps and drives add to the cost of operation through higher power requirements. Furthermore, expansion of agricultural land has overburdened the capacity of the older pumping stations which, even though operated longer hours, do not deliver sufficient water. Extended operation time interferes with proper maintenance, leading ultimately to mechanical failure.

All of the older pump stations will have to be replaced ultimately, irrespective of regional economic philosophy, with new more efficient and less costly pumps and equipment. To meet the requirements of these coming changes, new and up dated specifications and detailed knowledge of available equipment is required.

1.3 NEW DEPARTURES IN PUMP DESIGN

While pump design remains basically unchanged, improvements in motor design and of components have been made in recent years.

Although totally submerged motors have been used for a long time, the use of such motors coupled to a high capacity mixed flow or propeller type impeller, mounted simply in a drought tube, is a fairly recent development. Such pumps should be considered for use along the Nile for pumping irrigation water. Installation costs are low because building requirements are minimal as are maintenance costs.

Another recent development is a pump with the impeller fixed directly to a hydraulic motor which in turn is driven by a high pressure

pump powered by a diesel engine. An electric motor could be be used to power the pressurizing pump. The chief merit of this pump is its mobility for requirements such as intermittent operation, emergency drainage, or breakdowns at fixed pump stations. Such a pump could also be used in fixed locations where costly buildings for conventional pump stations would be avoided. However, little is known about the actual operating and maintenance costs of such installations at the present time. This kind of pump is being used in the North Sea oil fields.

Other new developments have taken place in the field of metallurgy, in new kinds of lubrication, and miniaturized electronic control gear. At present, pumping equipment can be housed in very simple structures or even left in the open, as at desert oil field installations. In this case, the pumps, motors and switchgear are integrally protected against dust and adverse atmospheric conditions.

1.4 STANDARD SPECIFICATIONS

Most of the western industrial countries have very comprehensive specifications covering most manufactured commodities and the materials used in their manufacture. Only in a few instances are such specifications statutorily obligatory, as for example, where life may be endangered (e.g. electrical household fittings). Such standards do not imply a maximum standard to which products and commodities are made, but a minimum standard of tolerance. Quality above these standards costs more in a competitive market. Such specifications also serve the purpose of eliminating very divergent or bizarre products. Specifications facilitate economy in spare parts inventories and interchangeability of parts.

The International Organization for Standardization (ISO) collates most standards specifications. Most countries have their own standards organizations, though the American Standards Association (ASA) has only recently been established. At present there are some 55 separate organizations providing specifications for pumps and assocaited equipment.

The British Standards Institute (BSI) standards are used throughout the Commonwealth, while Canada, Australia, India, Pakistan and many other nations use the standards as the basis for their own standards. The German DIN standards are also extensively used in Europe. French standards (AFNOR & DTU), Dutch (NEM), etc. are gradually giving way to the I.S.O. standards (See Appendix 2 for the names of the various organizations).

Engineers concerned with pumps and water supply should be familiar with these standards. Apart from technical ability, knowledge of standard specifications, and writing of specifications and tendering procedures is required of the engineer. Standard specifications are based on research carried out by private, quasi-governmental organizations, by manufacturers and in academic institutions. The standards set down minimum levels to which a commodity is manufactured, i.e, "best at least cost." Higher quality, or deviation from normal manufacturing procedures, greatly increases cost. Knowledge of manufacturing standards enables the buyer to state his requirements explicitly and protects him against paying high prices for low quality equipment.

Knowledge of the various funding or loan agencies or professional institutions' procedural requirements for tendering is essential. USAID has procedural rules for drawing up Invitations for Bid. The World Bank uses a book on contracting procedures compiled by the International Confederation of Consulting Engineers (FIDIC). This book is accepted as a basis for engineering contracts by all European countries and the United States. Though primarily concerned with civil works contracts, this book covers all general conditions of contracts.

1.5 GUIDELINES

A classification of pumps according to the method of energy input and the geometry of the fluid drive system will be followed by a simple and practical example of the principles of pump design, to

give the engineer not familiar with pump design some idea of the design procedure and to give mechanical engineers familiar with the theoretical principles, a "refresher" in pump design. The example is elaborated so as to draw attention to the salient features of pump design, and hence, selection of a pump for a specific set of conditions. Some basic features of engineering common to many machines are not considered here in detail.

Component parts, such as bearings, seals and lubricating systems, are patented and manufactured by specialists and the pump designer, or manufacturer, selects the most suitable components from what is available; thus, a lengthy discussion of the design and materials of components would be superfluous.

Finally, a brief discussion of standards is presented, and an appendix listing of the organizations regulating such standards.

2.0 CLASSIFICATION OF PUMPS

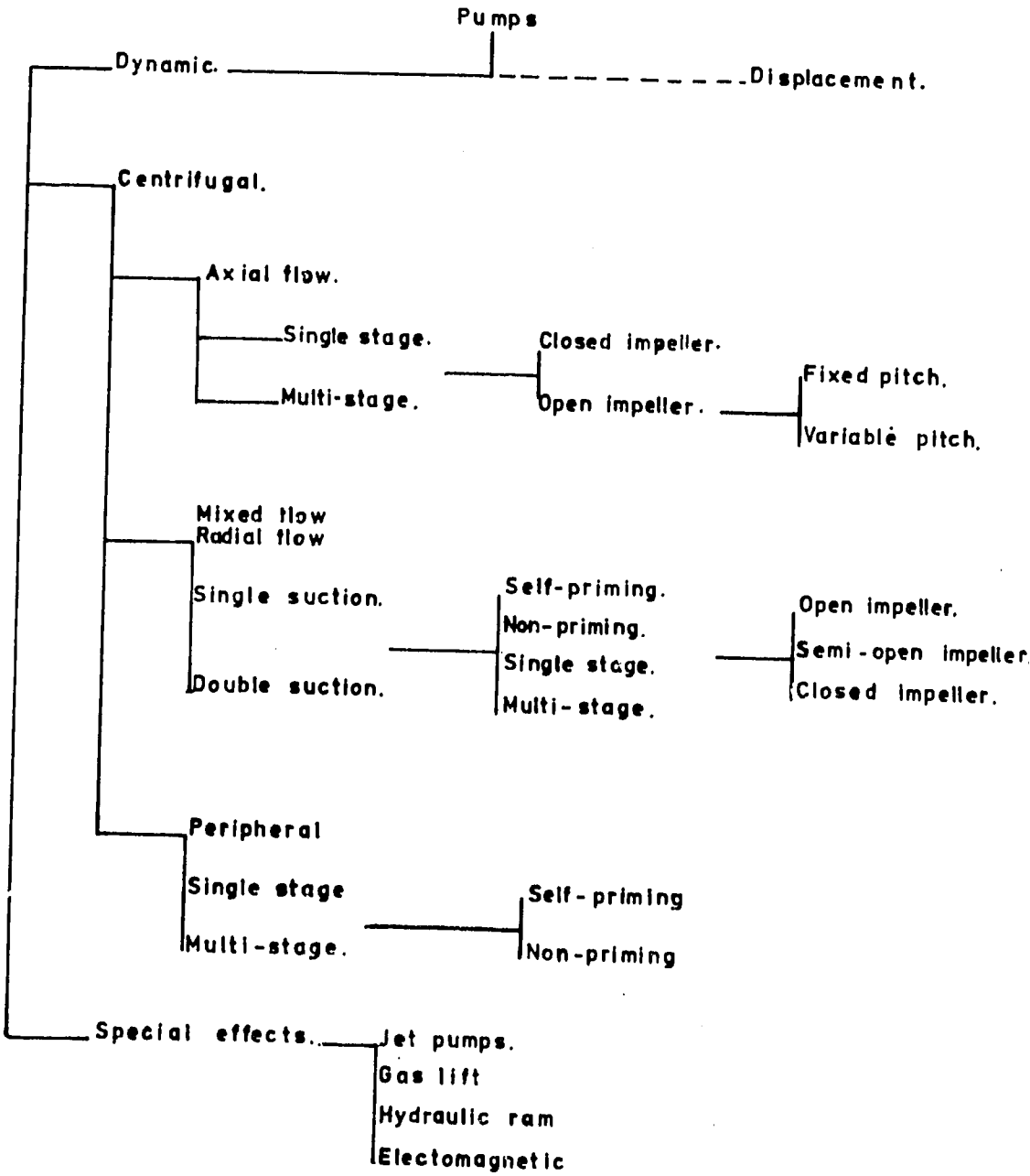
2.1 Types of Pumps

Pumps may be classified on the basis of the applications they serve, or their construction materials, by the fluids they handle, or the orientation of the pump. A most logical system of classification is the definition of a pump in terms of the principle whereby energy is applied to the fluid, the method of driving the fluid, and the geometry of the drive. This system is shown in Figure 1.

Pumps are grouped as dynamic types and displacement types. In our discussion we will consider the dynamic types, which are commonly used to deliver irrigation and drainage water in Egypt. Displacement pumps such as piston or plunger pumps, diaphragm and rotary pumps, are not commonly used in Egypt for irrigation purposes. Dynamically energized pumps are divided into centrifugal and

Figure 1.

Classification of Pumps.



"special effect" pumps; here again, we will consider only the centrifugal pumps.

2.2 Kinds of Impellers Used in Pumps

Centrifugal pumps are divided into the following categories depending on the specific duties the pump will be required to perform.

a) Axial flow or propeller pumps have either fixed or adjustable vanes (or blades) on the impeller. The adjustable blades may be either adjustable after dismantling or during operation -- fixed or variable pitch. This adjustment increases or decreases the capacity or total head and the power input at constant speeds. Such devices can be fitted to pumps where frequent water level fluctuations occur or to start up motors against zero loads. Variable pitch pumps are costly. Axial flow pumps have the highest specific speed of all the centrifugal pump types, ranging from about 110 (Ns) up to 300(Ns) , meaning high capacity at low total heads up to about 15 meters. Axial flow impellers can be fitted to vertical columns in horizontal elbow casings or in concrete volute casings for very large discharges.

   A typical axial flow impeller in the vertical column mounting is shown in Figure 3.

b) Mixed flow pumps have either an enclosed, helical or diagonal impeller or a semi-axial propeller-type impeller. The specific speed of this kind of impeller ranges from about 80 (Ns) up to 150(Ns) and such pumps can handle large volumes from low to medium heads (10-15 meters) in single stage, and up to 50 meters in a two stage vertical pump. An enclosed impeller in a multi-stage vertical unit can operate at heads up to 150 meters or more.

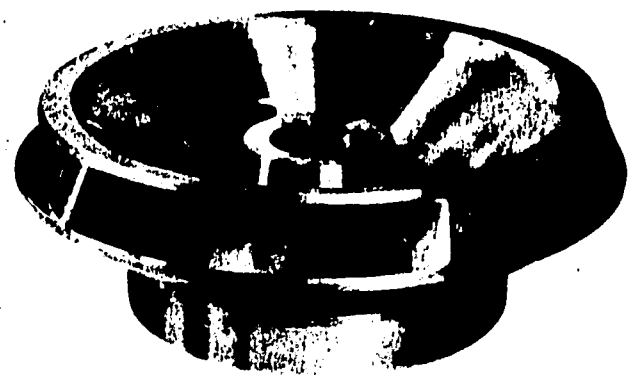
   Figure 2(a) shows a typical open type of impeller and Figure 2(b), an enclosed impeller of the mixed flow type.

Figure 2.

Mixed Flow Impellers.

a.

Open Mixed Flow Impeller.



b.

Closed Mixed Elow Impeller.

c/w

Eigure 3.

Axial Flow Impeller

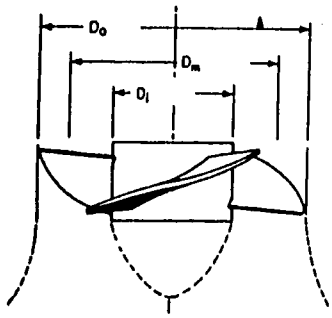
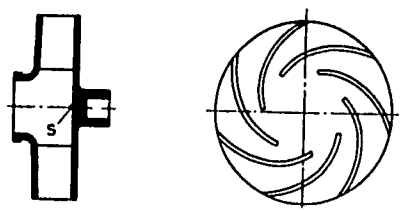
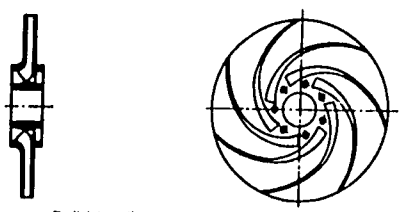


Figure 4.

Radial Flow Impellers.



Radial impeller with pure radial vanes.



. Radial impeller with vanes extending into the suction mouth

c) Radial flow pumps are what are commonly called "centrifugal" pumps. Radial flow impellers are graduated into high, medium and low pressure impellers, the specific speed ranges from about 25(Ns)to 40(Ns) , and 70 up to 100 (Ns), respectively. The delivery rate is relatively small with greater total head. Various forms of radial flow impellors are shown in Figure 4.

2.3 The Parts of a Pump

The nomenclature of both horizontal and vertical pumps have been established by consensus in the United States and in European countries and are shown in Figure 5(a) for horizontal pumps and in Figure 5(b) for vertical pumps.

3.0 SELECTION OF PUMPS

The most important operating characteristics of a pump are the capacity (Q); the head (H); the power (P); and the efficiency, (e). Variables which influence these are the speed (N) and the impeller diameter (D). Assuming that all other dimensions of the impeller and casing are fixed, the specific speed (N_s) is a parameter which classified impellers according to geometry and the operating characteristics. The value at these operating conditions, or maximum efficiency, is called the specific head of the impeller.

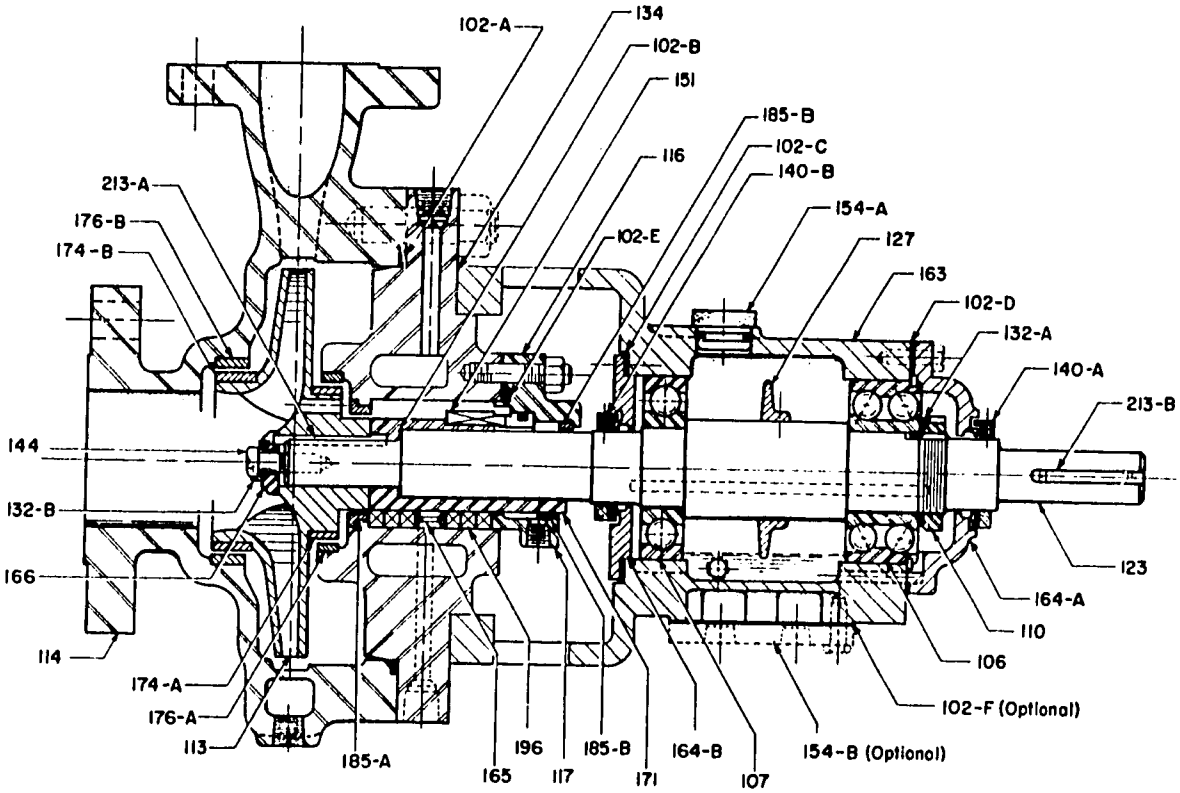
3.1 Definition of Operating Factors

a) Capacity: The pump capacity Q is the volume of fluid (water) per unit delivered by the pump, normally expressed in cubic meters per second (m^3/sec), or in another measure of flow rate.

b) Head: The pump head H represents the net work done on a unit weight of fluid passing from the inlet to the outlet and can be expressed as follows:

Figure 5a.

Typical End Suction Radial Vane Pump.



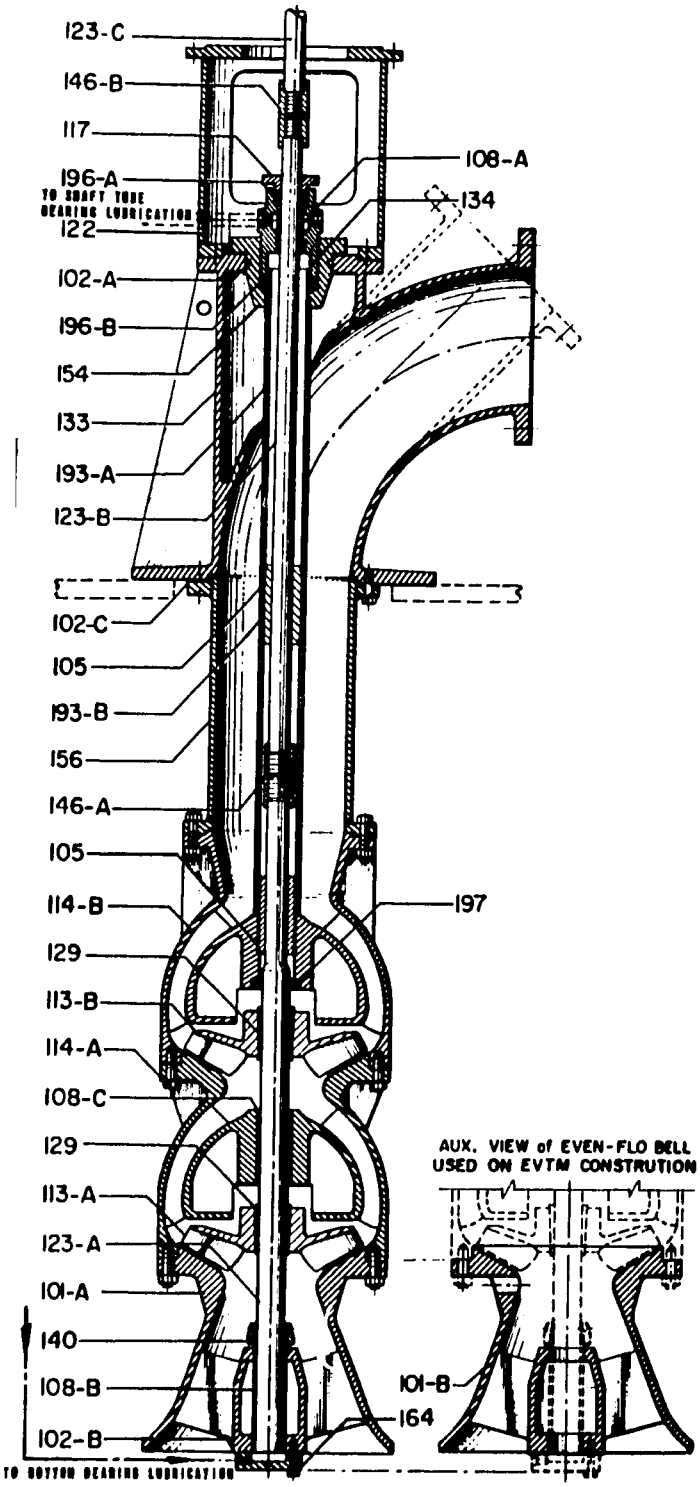
Note: When Mechanical Seal is furnished delete Part Numbers 117, 165, 185-B and 196.

PART NO.	DESCRIPTION	PART NO.	DESCRIPTION	PART NO.	DESCRIPTION
102-A	Gasket-Volute	123	Shaft	164-B	Radial Bearing Cover
102-B	Gasket-Sleeve	127	Oil Flinger	165	Lantern Ring
102-C	Gasket-Bearing Cover	132-A	Lockwasher-Bearing	166	Retainer-Impeller
102-D	Gasket-Bearing Cover	132-B	Lockwasher-Impeller	171	Shaft Sleeve
102-E	'O' Ring-Gland	134	Stuffing Box	174-A	Impeller Ring-Hub
102-F	Gasket-Jacket Cover	140-A	Deflector Disc	174-B	Impeller Ring-Eye
106	Thrust Bearing	140-B	Deflector Disc	176-A	Casing Ring-Hub
107	Radial Bearing	144	Impeller Capscrew	176-B	Casing Ring-Eye
110	Bearing Locknut	151	Mechanical Seal	185-A	Bushing-Throat
113	Impeller	154-A	Inspection Cover	185-B	Bushing-Gland
114	Volute	154-B	Water Jacket Cover	196	Packing
116	Gland-Mechanical Seal	163	Bearing Housing	213-A	Impeller Key
117	Gland	164-A	Thrust Bearing Cover	213-B	Shaft Extension Key

9a

Figure 5 b.

Typical Axfál Flow Vertical Pump.



PART NO.	DESCRIPTION
101-A	Suction Bell
101-B	Even Flo-Bell
102-A	"O" Ring
102-B	Gasket
102-C	Gasket
105	Tube Connector Bearing
108-A	Bushing
108-B	Bushing
108-C	Bushing
113-A	Impeller - 1st Stg.
113-B	Impeller
114-A	Bowl - Bottom
114-B	Bowl - Top
117	Gland
122	Driver Stand
123-A	Shaft - Pump
123-B	Shaft - Interm.
123-C	Shaft - Drive
129	Taper Sleeve
133	Discharge Head
134	Tube Tension Nut
140	Deflector
146-A	Shaft Coupling
146-B	Shaft Coupling
154	Tube Tension Plate
156	Column
164	Bearing Cover
193-A	Shaft Tube - Upper
193-B	Shaft Tube - Lower
196-A	Packing
196-B	Packing
197	Shaft Seal

Unnumbered parts in the illustrations are the same as corresponding parts shown with numbers.

$$H = \left\{ \frac{p}{\gamma} + \frac{v^2}{2g} + Z \right\}_{\text{discharge}} - \left\{ \frac{p}{\gamma} + \frac{v^2}{2g} + Z \right\}_{\text{inlet}}$$

Where $\frac{p}{\gamma}$ is the pressure head,

$\frac{v^2}{2g}$ is the velocity head, and

Z is the elevational or potential head

The difference represents the energy needed to move a unit weight of water through the pump and is the <u>total dynamic head</u>, usually expressed in meters.

c) <u>Power</u>: The power input is usually expressed in liquid (or water) horsepower:

$$P = \frac{Q\,H}{75{,}000}$$, if Q is expressed as litres /second

or $$\frac{Q\,H}{75}$$, if Q is expressed as m^3/sec.

d) <u>Efficiency</u>: The pump efficiency is the water horsepower P divided by the power input to the shaft; this value is usually called the <u>brake horsepower</u>.

$$\eta = \frac{P_w}{P_s}$$

3.2 Characteristic Curves

The curves or graphs supplied by manufacturers describing the performance of the various kinds of pumps made by them show performance over the ranges of capacity, total head, shaft power input,

pump efficiency and the net positive suction head (NPsH) of a particular pump. The shape of such a set of curves depends on the pump type, the impeller diameter and geometry, pump casing and the specific speed. Such influences as the internal tolerances, bearing factors, vicosity of the fluid, etc., are not taken into account in these curves unless specifically noted.

These curves form the basis for selecting a specific size of pump once the other factors are known. The capacity, head and speed required to drive the pump is used to calculate the specific speed for a particular pump:

$$N_s = \frac{N\sqrt{Q}}{H^{3/4}}$$

The diagram in Figure 6 may be used to estimate the impeller configuration and the maximum efficiency of such an impeller and pump. For example:

1) $Q = 0.05\ m^3/sec$, $H = 24.5\ m$; $N = 1460\ rpm$

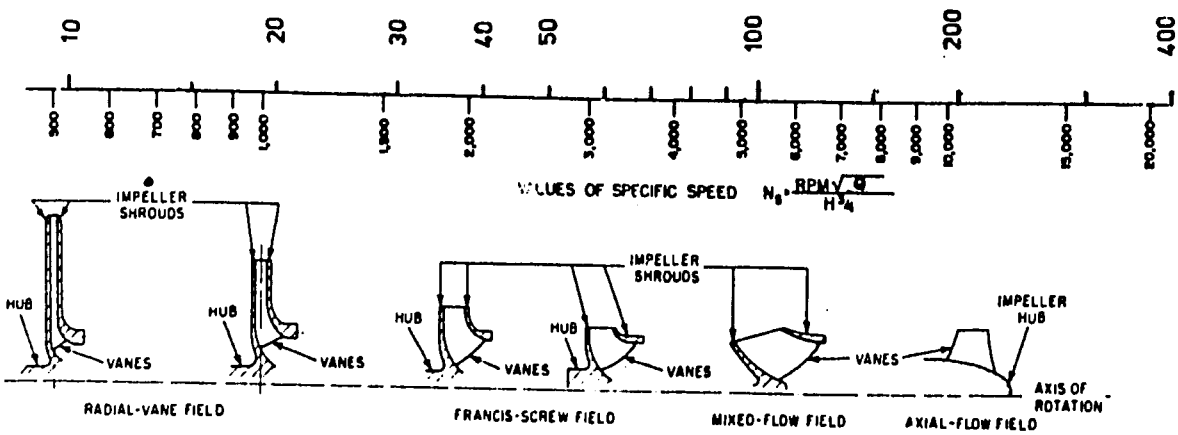
$$Ns = \frac{1460\sqrt{0.05}}{(24.5)^{.75}} = 29.65$$

From the diagram, the type of impeller that may be used for this duty would be something similar to the Francis screw type impeller.

Conditions Affecting Performance Curves

a) The ideal pump and ideal fluid: The ideal impeller would consist of a great number of vanes of infinitesimal thickness while the particles of an ideal fluid move exactly parallel to the vane surfaces without friction. The analysis of the power transmitted to an ideal fluid by such an impeller is determined by Euler's pump equation yielding curves that are linear:

Figure 6



Range of Impeller Types for Different Specific Speeds.

$$H_E = \frac{U_2 C_{u2}}{g} - \frac{U_1 C_{u1}}{g}$$

b) The real pump and real fluid: In real pumps, the vanes are of finite thickness, limited in number, and widely spaced. As can be shown experimentally, fluids do not flow parallel to the vanes, even at the point of highest efficiency and the conditions for Euler's principle are not fulfilled. The curves are in most cases irregular -- or curved. Analysis of such curves has provided a satisfactory way of predicting characteristics of real pumps with the required accuracy and the actual graphical representation of tests are used. These characteristic curves are supplied by manufacturers in their technical manuals.

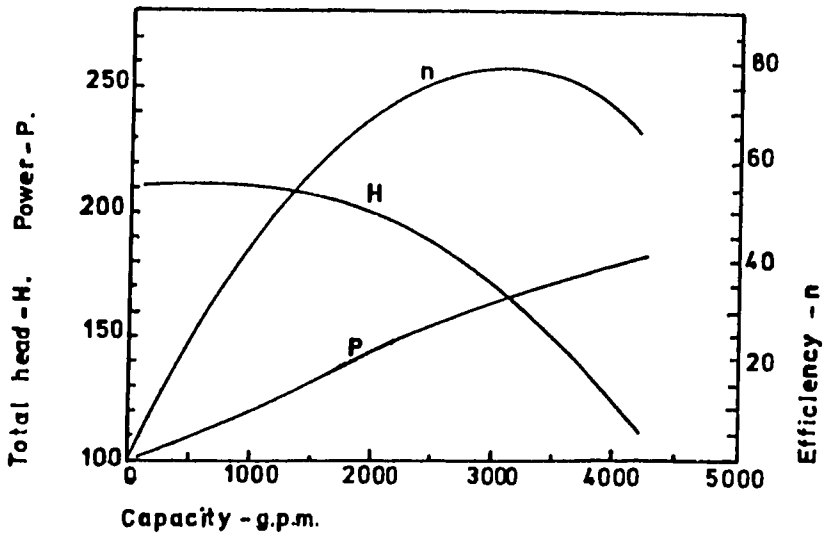
The normal values of a pump are usually given as the curves at the optimum point, but a pump may be operated at a point a little above or below the optimum point and this is called the rated or guarantee point. It is not advisable to operate a pump continuously at a point much below the maximum value; this is both uneconomical and will lead to severe damage of the installation.

The curvature of the vanes of a pump have a very specific effect on the performance, the purpose to which the pump will be put and the cost of such a pump.

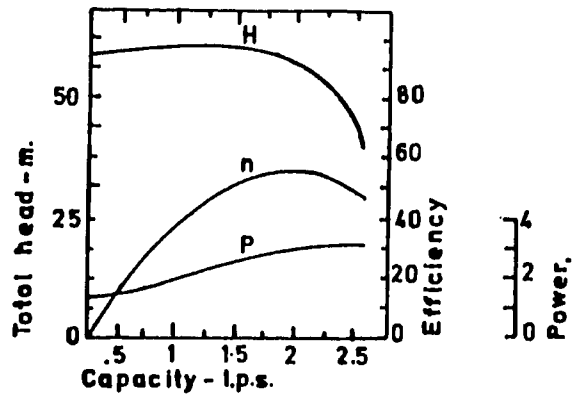
a) Backward curved vanes: The angle of the vane with the periphery of the impeller is less than 90° (discussed in the next section). Most modern pumps are designed with this form of vane. Typical characteristic curves of this type are shown in Figure 7. The maximum efficiency of pumps fitted with such impellers is some 80-85% in the best designs.

b) Radial vanes: The vane angle is 90°; this type of impeller is used in simple inexpensive pumps. Typical pumps of this kind are those used as a circulator cooling pump in motor car engines and fuel bowser pumps. The performance of such impellers

Figure 7



Backward-curved Vaned Pump.



Small Radial Vaned Pump.

is shown in Figure 7(b). The maximum efficiency of such pumps is about 50-55%.

c) Forward curved vanes: The vane angle is greater than 90°. Such pumps have been developed experimentally but are not in practical use.

3.3 Performance Factors

The performance of a pump can be compared to a geometrically similar pump by means of the laws of affinity using dimensional analysis. The three dimensionless parameters used in describing pump performance at the point of best efficiency are:

a) the unit speed: $\frac{D\omega}{\sqrt{gH}} = C_1$ or $\frac{Dn}{\sqrt{K}} = K_1$

b) the unit capacity: $\frac{Q}{D^2\sqrt{gH}} = C_2$ or $\frac{Q}{D\sqrt{H}} = K_2$

c) the unit power: $\frac{P}{D^2\rho(gH)^{3/2}} = C_3$ or $\frac{P}{D^2H^{3/2}} = K_3$

In the above equations, the factors ω (radians per unit time), ρ (density of the fluid) and g (gravity), are replaced by a value expressed in a unit of measurement, the value K. This value, K, being dimensional, can be used for any set of measures. Curves in Imperial, U.S. or metric measures can thus be compared.

a) Specific Speed

$$n_2 = K_1\sqrt{K_2}$$

$$= \frac{n\sqrt{Q}}{H^{3/4}}$$

Conversions of common units of measurement are given in Table 1.

TABLE 1. Specific Speed Conversion Factors

Metric $m^3/s.$	U.S. gpm	Imperial gpm
1	51.64	47.13
.021	1.1	1
.019	1.0	0.9

The specific speed is a useful parameter for classifying the geometry and the performance characteristics of an impeller. It should be noted that the capacity of multi-stage pumps or double suction pumps must be divided by the number of stages to calculate the specific head. This applies to the head value H. The total head is divided by the number of stages; the power factor is likewise divided by the number of stages.

b) Geometric Similarity: Defines conditions for a series of impellers operating at dynamically similar conditions, i.e., at identical specific speeds, the laws of affinity apply as follows:

$$\frac{Q_1}{Q_2} = \frac{n_1 \; D_1^3}{n_2 \; D_2^3}$$

$$\frac{H_1}{H_2} = \frac{n_1^2 \; D_1^2}{n_2^2 \; D_2^2}$$

$$\frac{P_1}{P_2} = \frac{n_1^3 \; D_1^5}{n_2^3 \; D_2^5}$$

It is assumed that the points are selected for any two sets of conditions in the non-cavitating operating range.

These laws are applied to the alteration of the size of impellers also. Commercial pump curves show a series of impeller diameters available for various operating conditions. The impeller is "turned" or cut in small increments until the required capacity is obtained. It is generally assumed that the head will remain proportional to (nD^3) provided all other factors of the pump remain unaltered, leading to the following proportionalities:

$$\frac{Q_1}{Q_2} = \frac{n_1 \; D_1}{n_2 \; D_2^{\,2}}$$

$$\frac{H_1}{H_2} = \frac{n_1^{\,2} \; D_1^{\,2}}{n_2^{\,2} \; D_2^{\,2}}$$

$$\frac{P_1}{P_2} = \frac{n_1^{\,3} \; D_1^{\,3}}{n_2^{\,3} \; D_2^{\,3}}$$

These proportionalities apply only to a given impeller. In actual practice, cutting an impeller to a smaller size according to the above equations seldom achieves the exact result and it varies from 10% to 20% of the true value. The illustration of various sized impellers in Figure 9 are of a range of impeller sizes having curves established by test measurements.

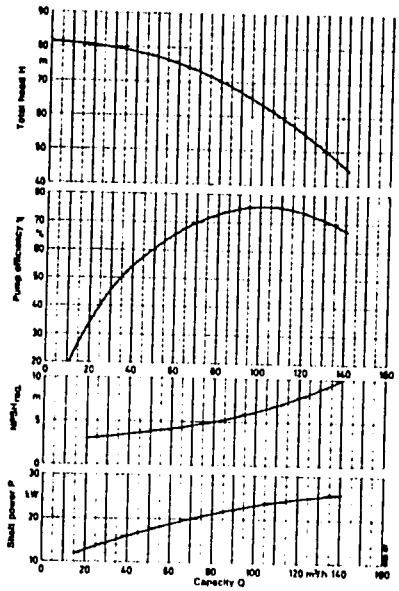
c) <u>Dimensionally similar pumps</u>: These can be compared by considering the characteristics of pumps of different specific speeds at some selected operating point, usually the point of best efficiency.

The selected value of the best efficiency can be transposed into factors at other comparative values:

$$q = \frac{Q}{Q_n} \quad ; \quad h = \frac{H}{H_n} \quad ; \quad p = \frac{P}{P_n} \quad ,$$

where the subscript n designates the value at the best efficiency

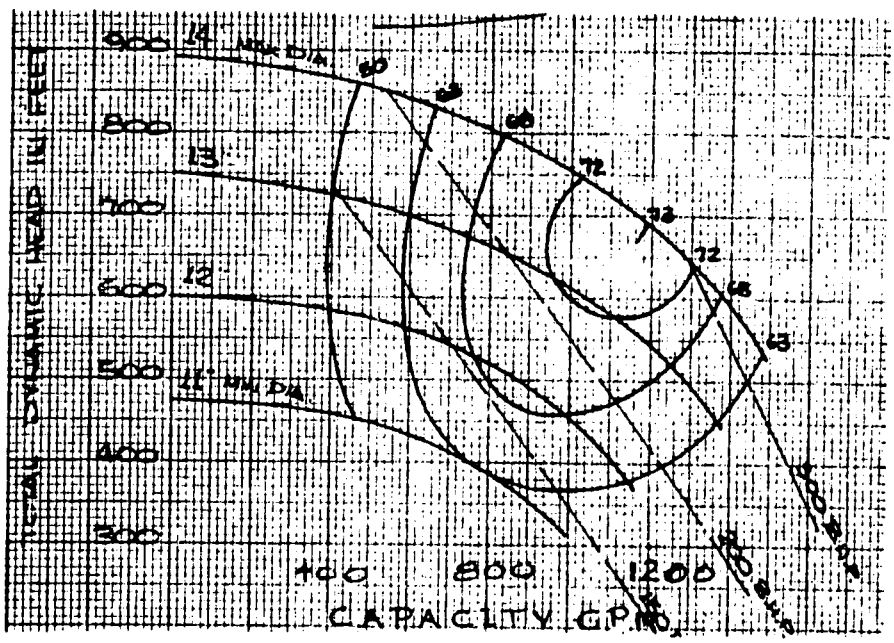
Figure 8.



Typical Pump Performance Curves.

Effect of Impeller Diameter on Performance.

Figure 9.



A series of dimensionless curves at different specific speeds have been plotted in Figures 10(a), 10(b), and 10(c). Such curves can be calculated for metric values and used to compare any pumps. Considering the curves in the illustration, curves 1 and 2 exhibit a rising head or unstable characteristics where the head increases with increased capacity over the lower part of the capacity range. This indicates that instability will occur at heads greater than the shut-off value. Curve 3 exhibits an almost constant head at low capacity and is called a flat characteristic. Curves 4 to 7 are typical steep or stable head characteristics in which the head always decreases with increasing capacity.

d) Efficiency of pumps is a product of three separate efficiency factors, namely:

$$\eta = \eta_m \cdot \eta_u \cdot \eta_h$$

η_m is the mechanical efficiency and depends upon bearings, stuffing boxes and all disc friction losses such as wearing rings, balancing discs;

η_u is the volumetric efficiency depending upon the leakage through the wearing rings, internal labyrinths, balancing devices, glands and bearing cooling

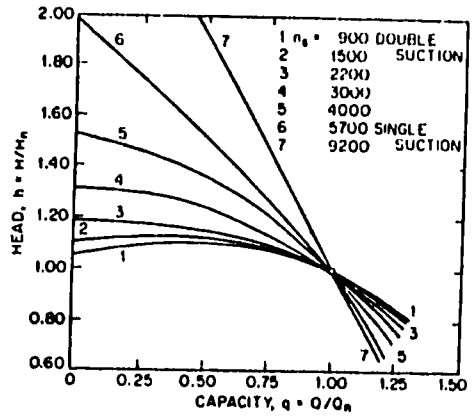
η_h is the hydraulic efficiency depending on the fluid friction losses through the internal flow passages, inlet and outlet, impeller, diffusion vanes and volute casing

The effect of these various efficiency losses are shown in Figure 11.

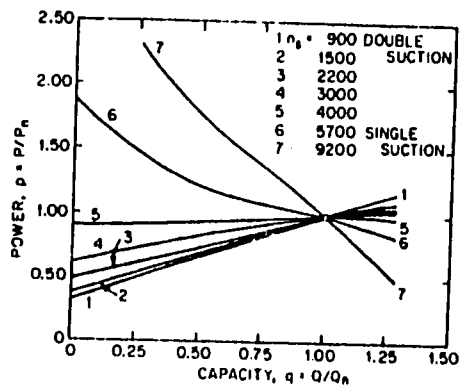
Various factors which affect the ultimate efficiency of pumps are the speed, and consequently, the specific speed, as well as the significant effects of internal clearances. Increasing the speed of the impeller at low speeds in small pumps improves the efficiency only slightly, while at very high speeds the increase is greater. However, increases in speed also increases the cost of the pump and the driver. The danger of cavitation increases with high speeds also.

Figure 10.

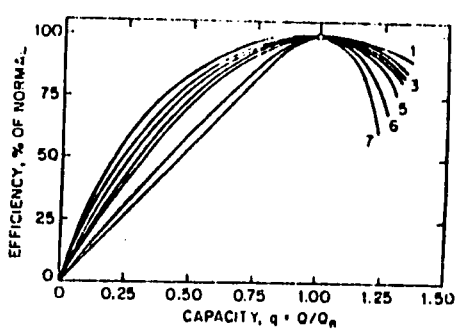
Characteristic Curves for Various Specific Speeds.



Head - Capacity Curves.



Power - Capacity Curves.

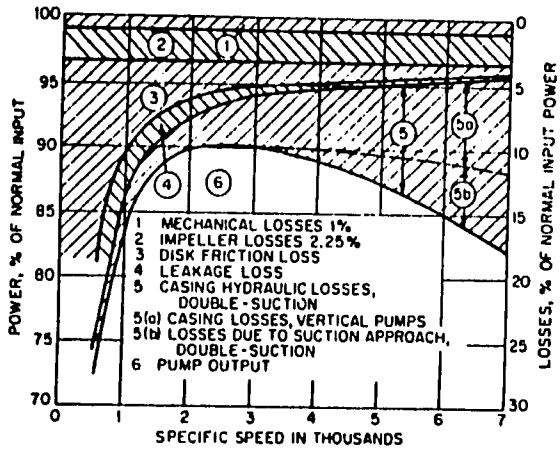


Efficiency - Capacity Curves.

(Note: U.S. measurements)

Figure 11.

Pump Power Losses.



Losses in a Typical Radial Flow Pump.

Normally, for a given head and capacity, a pump with the highest specific speed complying with the duties required will usually be the smallest and least expensive and lower in operating and maintenance costs.

The effects of internal clearances in a pump have a very significant influence on efficiency:

a) Wearing ring clearances, the design of the wearing rings and the abrasiveness of the fluid influence the rate of wearing; hence the replacement of the rings is necessary to prevent prolonged inefficiency. These rings are usually made of a fairly resistant metal to reduce such wear.

b) Vane tip clearance: impellers without an outer shroud, or open, or semi-open impellers, rely on close tip clearance to maintain a low leakage level across the vane tips, but as these tips wear, leakage increases and either the impeller is built up by welding and turning, or completely replaced. Sometimes an oversized casing wear ring may be fitted. Although impellers of this kind are not normally used on pumps with specific speeds of less than 120 N_S (or 6000 in U.S. units), semi-open impellers are successfully used at lower ranges, from 35 to 75 (Ns).

   On the contrary, reducing the tip clearance by a small amount is one way of improving both the efficiency and the head. Impellers are quite sensitive to small changes of clearance.

4.0 ELEMENTARY DESIGN PRINCIPLES

The engineer concerned with the selection of a pump to perform a specific task will not normally wish to to into the design theory of pumps, but from the foregoing, it should be clear that in the selection of pumps, many design principles should be known in order to select a pump for a particular set of conditions. Similarly, a broad knowledge of pump design will enable an engineer to evaluate

the pumps offered by various manufacturers and to select the right equipment for the specific situation.

Most practical pump designs are based on one-dimensional approximations, neglecting all secondary factors, treating the main flow through the pump on the basis of available flow areas and conduit wall directions. Inevitably, this leads to small errors and corrections must be made by introducing correction factors, such as the slip factor, for example. This approach to the design of pumps is necessary because the details of the time-motion of fluids are not well understood. The one-dimensional analysis procedure is commonly used and has proved successful in practice, and this approach will be used here to explain the design of pumps.

Although a great deal of research work has been done on pump design using two and three dimensional analysis, the mathematical analyses are very complex, as are the testing procedures used to study flow structure through a model. Thus, no comprehensive theory has emerged with which to design pumps using a complete hydro-dynamic design procedure. For this reason, relatively little change has taken place in the basic design of mechanisms such as pumps. The range of pumps on the market are generally of a highly efficient design, and improvements have been made in metallurgy, bearing design and lubrication chemistry in recent years.

In order to demonstrate the application of the one-dimensional analysis to the design of a simple centrifugal pump, an example will be carried through and various practical considerations discussed in the course of the analysis. This example was taken from the hydro-dynamics course studies of the Imperial College of Technology (1952). Design graphs included in the text were taken from various standard references and from professional institute publications that are not widely available to most engineers. Many of the data were given in Imperial measurements and the metric conversions are therefore shown on the diagrams. Retaining the Imperial or U.S. units is useful, as much of the commercial literature is still in the out-dated units.

4.1 The Efficiency of Centrifugal Pumps

Before proceeding with the principles of pump design, we shall examine the subject of pump efficiency.

Normally, the maximum efficiency of a pump is considered to be a measure of its quality. This notion is not altogether accurate; in the course of time, many pumps of various kinds, driven at different speeds for a great range of capacities and duties, have been tested and found to have greatly varying efficiencies. Hence, it was necessary to determine the reasons for the variability in efficiency -- from poor design to unfavorable operating conditions.

The method used for comparing the operating services of such pumps was the dimensionless factor, the specific speed, allowing a rational comparison of pumps.

A set of figures shown in Figure 12, were published in 1947 establishing the relationship between the efficiency of pumps and the specific speed for different discharges (Wislicenus, 1965). The curves were based on the statistical analysis of a great number of pumps tested. This set of curves forms the "hall-mark" of the pump designers and manufacturers and still forms a sound basis for comparing the efficiency of pumps of various capacities, heads and speeds.

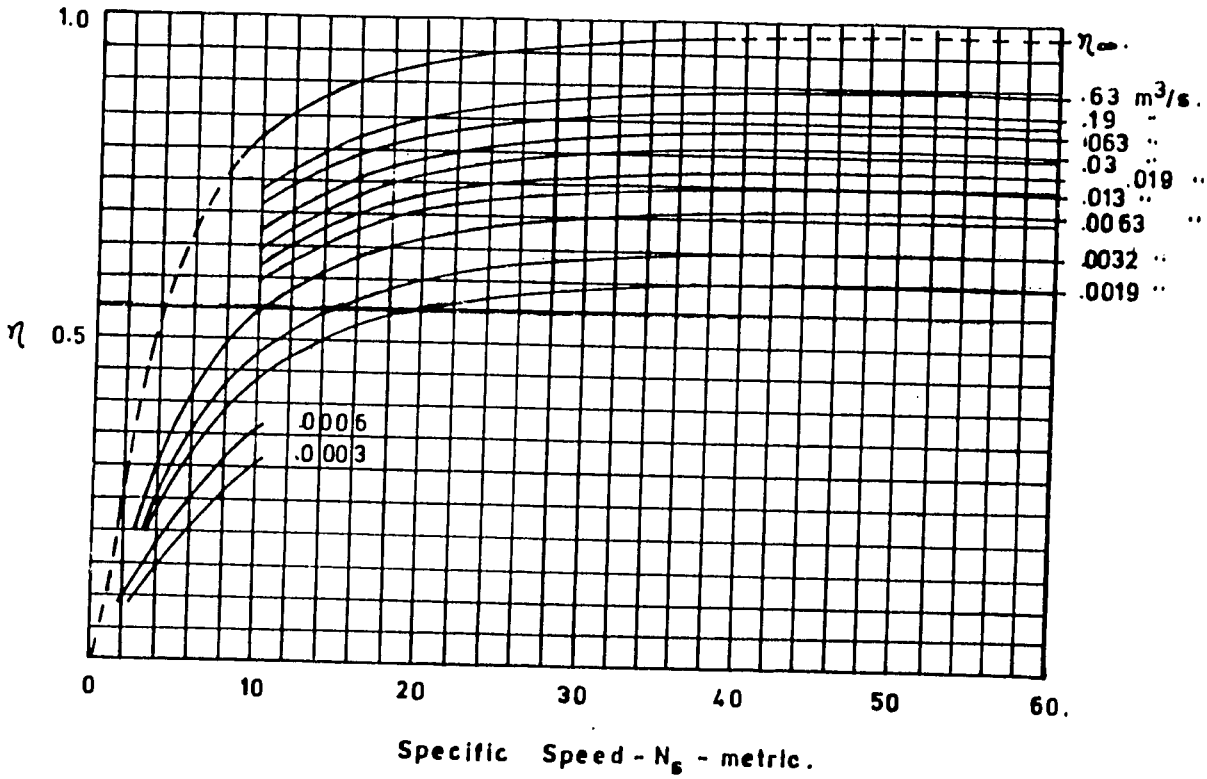
The use of the specific speed parameter for the prediciton of efficiency rests on the premise that geometrically similar pumps, operating at the same specific speed, have geometrically similar internal velocity characteristics. Consequently, the ratios of the flow velocities to the impeller peripheral speed should be the same. Scale factors preclude the relative losses being the same; flow friction and leakage losses increase proportionally with increases in capacity.

The graph in Figure 12 will be useful for the selection of pumps and for comparing pumps, using the equation to obtain the specific speed:

$$N_s = \frac{rpm \sqrt{Q}}{H^{.75}}$$

Figure 12.

Standard Pump Efficiency Curves.



In comparing pumps, the capacity and head should be known and the speed, either constant -- e.g., directly coupled to an electric motor -- or variable, through a variable speed drive or diesel engine. The estimated optimum efficiency can then be read off the graph. A pump approaching this efficiency can then be selected for the given data. A similar procedure is used for designing a pump: knowing the capacity and head, a speed is then selected and the dimensions of the impeller and volute casing are calculated by means of the procedure described in the next section.

4.2 Pump Design Procedures

The example chosen is a fairly common duty for a simple centrifugal pump, a horizontally mounted unit that could be used for pressurizing an irrigation system or a water supply system, and is representative of many pumps of its kind.

Step 1

a) Operating Conditions:

Head, H: 60 m
Capacity, Q: .075 m^3/sec. (75 l.p.s.)
Total suction head (NPsH): 12 m.

b) Operating speed and efficiency

The optimum operating speed will normally give the best efficiency; however, this may not be the most convenient speed. If electric motors are used and the use of a reduction gear is to be avoided, then the pump must be operated at a given speed of the electric motor, bearing in mind that the cost of an electric motor increases with a decrease in speed.

Consider 50 cycle 4 pole speed at 1470 rpm; the specific speed is:

$$N_s = \frac{1470\sqrt{.075}}{60^{.75}} = 18.67, \text{ say } 19$$

The efficiency, from Figure 12, is 0.78 (η = .78).

Try 50 cycle 2 pole speed at 2970 rpm:

$$N_s = \frac{2970\sqrt{.075}}{60^{.75}} = 37.73, \text{ say } 38$$

$$\eta = 0.845$$

We will use the higher, 2 pole, speed for the higher efficiency. Checking the <u>suction specific speed</u>:

$$S = \frac{2970\sqrt{.075}}{12^{.75}} = 126.15, \text{ say } 126$$

The suction specific speed is less than the limiting factor of s = 175.

<u>Step 2</u>: <u>Impeller Design</u>

Basically, the simplified design of an impeller consists of resolving the flow velocity at the entrance to the impeller (the eye) and the flow velocity at the outer edge of the impeller (at the periphery); that is, across the vanes, by vector analysis using the following assumptions.

Euler's equation is used to express the total head across the flow regime of the impeller:

$$H_{thr} = \frac{1}{g}\left(U_2\, C'_{u2} - U_1\, C'_{u1}\right)$$

The total head H, including losses and zero prerotation, is equal to:

$$H = \frac{\eta H}{g}\, U_2\, C_{u2}$$

For this equation, the hydraulic efficiency factor ηH, does not take into account disc friction, leakage or other mechanical losses, but rather, only fluid flow losses inside the pump. The difference in the static head between the inlet and outlet can be found by applying Bernoulli's equation for rotating impellers and subtracting this from the Euler equation:

$$H_{thr} = \frac{1}{g} \; (U_2 \; C'_{u2} - U_1 \; C'_{uo})$$

Subtracting, $\frac{(C_o)^2}{2g} - \frac{(C_2)^2}{2g}$, the dynamic head and the losses between I and II, the static head difference becomes:

$$h_2 - h_1 = \frac{1}{g} (U_2 C'_{u2} - U_1 C'_{uo}) - \frac{(C'_{o2})^2}{2g} + \frac{(C'_2)^2}{2g} - L_{o-2}$$

and resolving this into:

$$h_2 - h_1 = \frac{1}{2g} \; (U_2^2 - U_1^2) + \frac{(W'_o)^2}{2g} - \frac{(W'_2)^2}{2g} - L_{1-2}$$

this being Bernoulli's equation for impellers, using an efficiency factor η_I ,

$$h_2 - h_1 = \frac{\eta_I}{2g} [U_2^2 - (W_2)^2 + C_{mo}^2]$$

Considering the <u>efficiency factors</u>: the overall efficiency is the ratio of water power to shaft power,

$$\eta = \frac{P_W}{P_S}$$

water power being calculated by:

$$P_W = \frac{Q.H.\gamma}{75}$$

where the capacity Q is in m^3/s and the head H is in meters.

Also, the shaft power, P_S, can be resolved from the several hydraulic losses, into P_H :

$$\eta_H = \frac{H}{H_{th}} = \frac{P_W}{P_W + P_H}$$

and

$$\left(\frac{1}{\eta_v} - 1\right) (P_W + P_H)$$

and the volumetric efficiency is:

$$\eta_V = \frac{Q}{Q+Q_2}$$

where Q_L accounts for internal leakage losses.

Finally, the power inputs required to overcome impeller disc friction, P_{DF} , and losses in bearings and seals, all resolve into the overall mechanical losses in a pump:

$$\eta = \frac{1}{\frac{1}{\eta_H \cdot \eta_V} + \frac{P_{DF}}{Pw} + \frac{Pm}{Pw}}$$

The values of the efficiency factors η_H, η_V and Pm/Pw will be given later in the curves obtained from numerous actual tests (see Figure 16).

The derivations of these mathematical equations are interesting, but can be found in most references on pump design. They are basic data used by manufacturers in pump design, and therefore need not be elaborated further.

Another important factor we will consider is the phenomenon called "slip." This is a result of non-uniform velocity distribution across the impeller channels, or boundary-layer effects and flow separation. The precise prediction of <u>slip</u> is very difficult to measure in practice, and is a continuing problem in the design of impellers, and therefore of pumps as a whole. The "slip factor" is defined as:

$$\mu = \frac{C'_{u2}}{C_{u2}}$$

This is a function of the number of vanes, vane discharge angle and the impeller radius ratio. The slip factor is estimated by

means of empirical deduction. Two equations will be presented here, first, the Stodolo equation commonly used by pump designers in the United States:

$$\mu = 1 - \frac{\Pi \sin \beta_2}{Z}$$

and that of Pfleiderer, widely used in European design practice:

$$\mu = \frac{}{1 + a \left(\frac{1+\beta_2}{60}\right) \frac{r_2^2}{ZS}}$$

where, $S = \int_{r_I}^{r_2} r dx = \frac{1}{2} (r_2^2 - r_1^2)$

thus: $$\mu = \frac{1}{1+\frac{a}{Z} \left(1+\frac{\beta_2}{60}\right) \frac{2}{1 - \left(\frac{r_I^2}{r_2^2}\right)}}$$

The values for the coefficient a for various pump configurations are:

Volute:	a = 0.65 - 0.85
Vaned diffuser	a = 0.60
Vaneless diffuser	a = 0.85 - 1.0

First, the slip factor μ must be determined. From Step 1, we choose the specific speed, N_s, of 37.73 (say 38), and the suction specific speed of 126.15 (say 126). Referring to Figure 13(a), $C_{m2}/U_2 = 0.12$, and from 13(b), $\beta_2 = 23.5^o$. The number of vanes on an impeller ranges from 4 to 8 for N_s values up to 80. A greater number of vanes leads to casting problems. Z=7 will be used for this example.

Using Stodolo's equation,

$$\mu = \frac{1-\Pi \sin \beta_2}{7} = \frac{1-\Pi \sin 23.5}{7} = 0.82$$

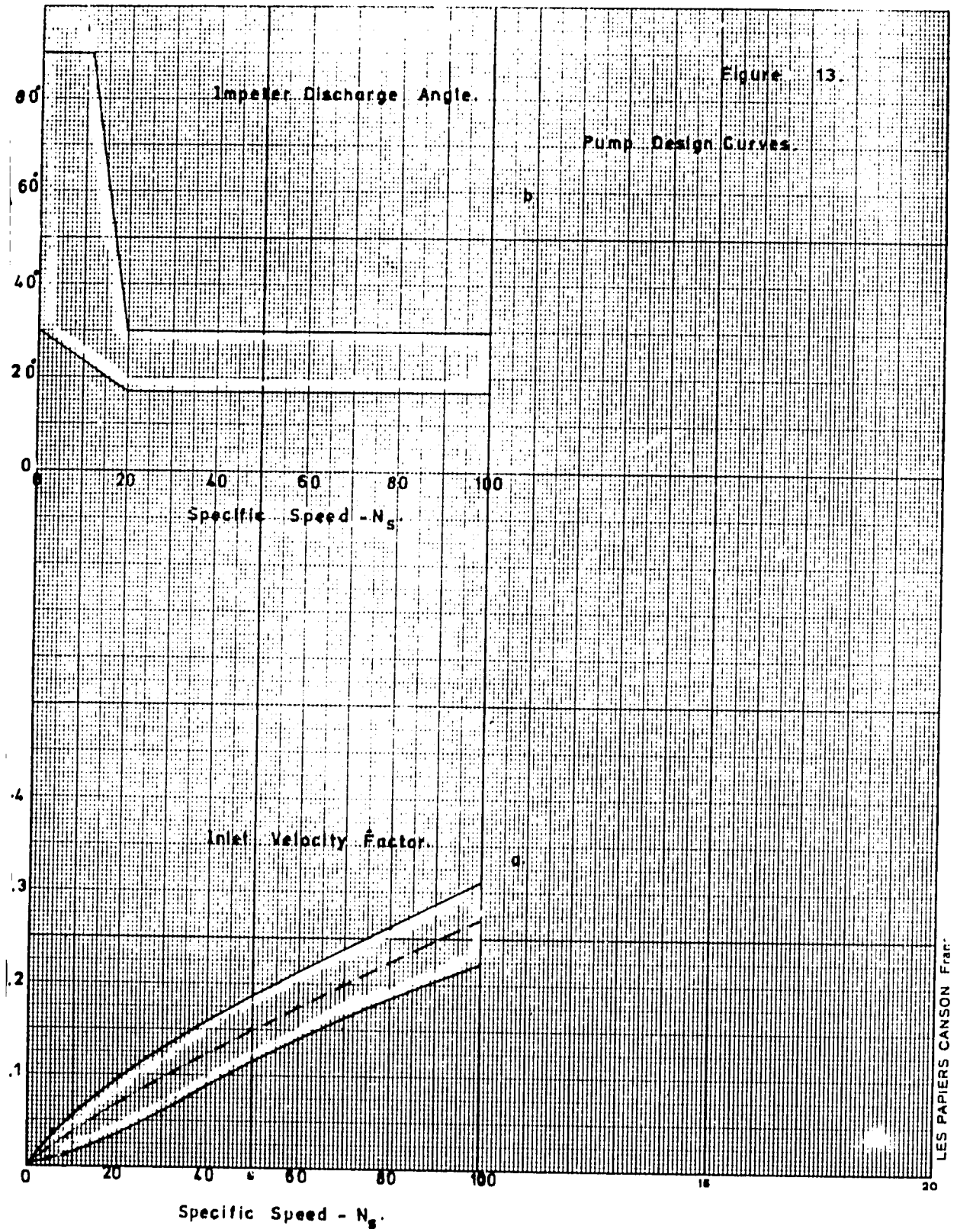

Impeller Discharge Angle.
Pump Design Curves.
b
80°
60°
40°
20°
0
0
20
40
60
80
100
Specific Speed - N_s.
Inlet Velocity Factor.
a
.4
.3
.2
.1
0
20
40
60
80
100
Specific Speed - N_s.
LES PAPIERS CANSON Fran

Figure 13.

and Pfleiderer's equation -

$$\mu = \frac{1}{1+\frac{a}{Z}\left(1+\frac{\beta 2}{60}\right)\frac{2}{1-(r_1{}^2/r_2{}^2}}$$

The value of the radius ratio $r_1{}^2/r_2{}^2$ is taken as a near constant value of 0.5, and the value of the coefficient "a," for a volute configuration, is 0.65, and where Z = 7:

$$\mu = \frac{1}{1+\frac{.65}{7}\left(1+\frac{23.5^{o}}{60}\right)\frac{2}{1-(5)^2}}$$

$$= \frac{1}{1+(0.0929)(1.392)(2.667)}$$

$$= 0.744$$

The lower value, 0.744, would give better performance characteristics.

The hydraulic efficiency η_H, from the curves in Figure 14, gives $1 - \eta_H = 0.145$, or 0.855. The head coefficient is then:

$$\psi = 2\mu\eta_H\left(1-\frac{C_{m2}}{U_2}\,\mathrm{Cot}\ \beta_2\right)$$

$$= 2 \times .744 \times 0.85(1-0.12\ \mathrm{Cot}\ 23.5)$$

$$= 2 \times .744 \times 0.615$$

$$= 0.916$$

Now, we can calculate the <u>peripheral speed of the impeller</u>:

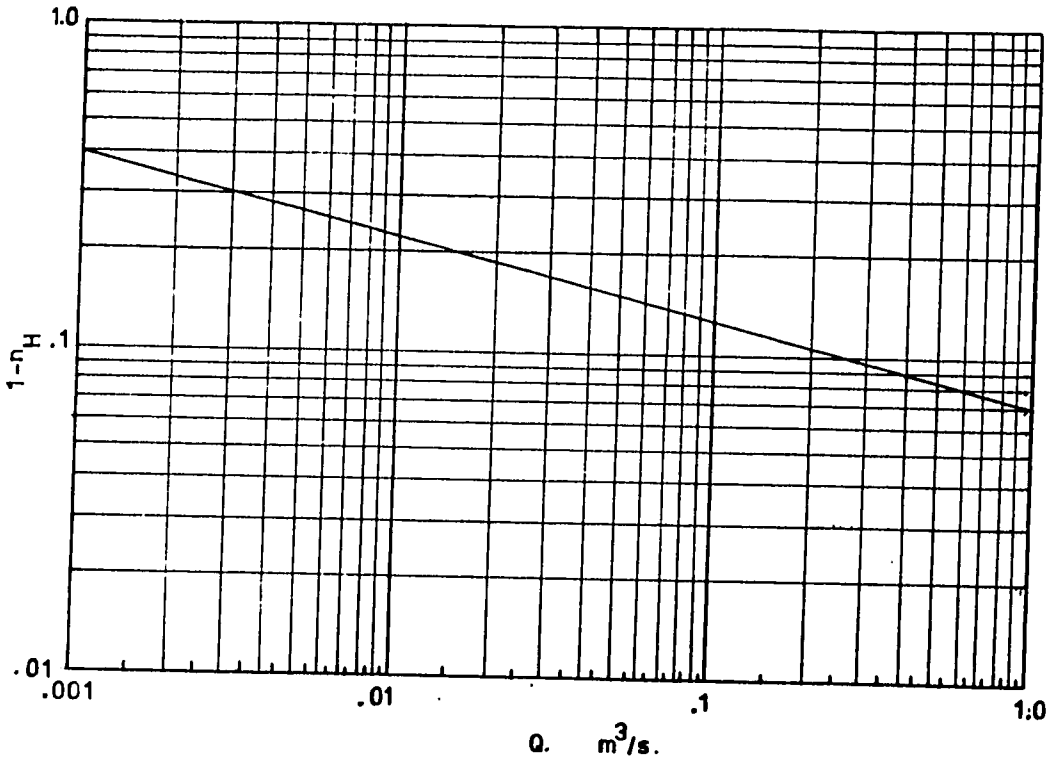
$$U_2 = \sqrt{\frac{2gH}{\psi}} = \sqrt{\frac{2x9.81m \times 60m}{0.916}} = 35.85\ m^3/sec.$$

and the meridional velocity:

$$C_{m2} = \frac{C_{m2}}{U_2} \cdot U_2 = 0.12 \times 35.85 = 4.30\ m/s$$

Figure 14.

Pump Design Curves.



Hydraulic Efficiency.

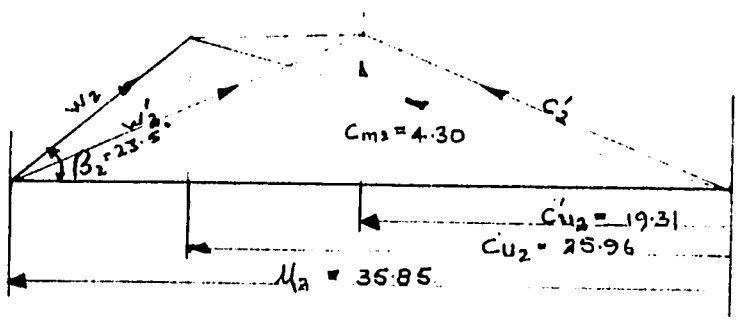
and the <u>absolute impeller discharge velocity</u>, without slip, is:

$$C_{U2} = U_2 - C_{m2} \cot \beta_2 = 35.85 - 4.30 \cot 23.5 = 25.96 \text{ m/s.}$$

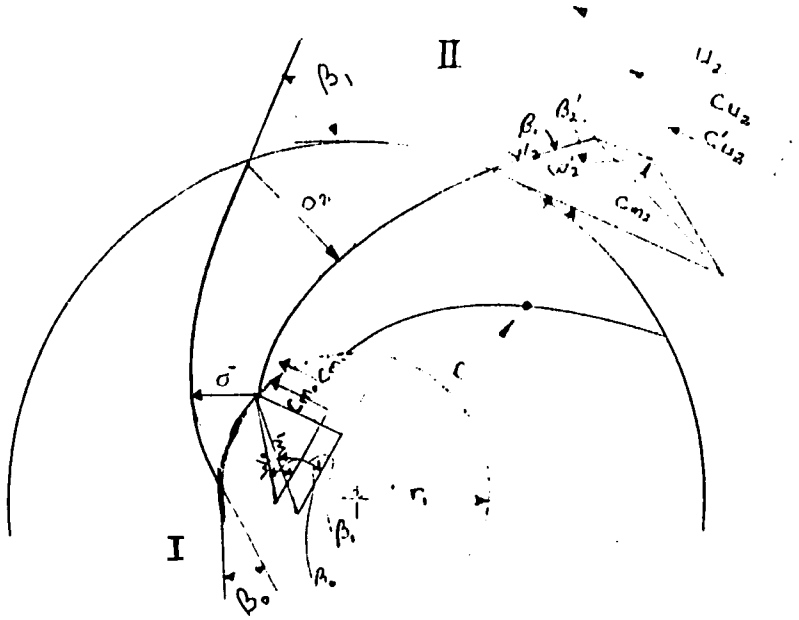
and, with the slip factor:

$$C'_{U2} = \mu C_{U2} = 0.744 \times 25.96 = 19.31 \text{ m/s}$$

By vector analysis or by drawing a vector diagram (or velocity diagram), the absulute flow angle d'_2, at which the flow leaves the impeller, can be obtained.



<u>Outlet Vector Diagram</u>



Impeller. Diagram showing location of the Inlet (I) and outlet (II) vector triangles.

The layout of the impeller vanes is shown in the above diagram. To prevent flow separation and inefficient operation, the vane angle is increased slightly from a_1 to a_2. The mean relative velocities at these two points are:

$$W_1 = \frac{Q}{Za_1} \quad \text{and} \quad W_2 = \frac{Q}{Za_2}$$

thus the ratio: $$\frac{W_2}{W_1} = \frac{a_1}{a_2}$$

From design experience, and to avoid flow separation, the area increase between a_1 and a_2 should not exceed a ratio of a_1/a_2 = 1.0 to 1.3.

The location of the vanes can be plotted by using the equation for a logarithmic spiral, $r = r_1 . e^{(\pi \cdot \Phi/180 \tan \beta_o)}$

Assuming that β_o and β_1 are equal; if not, a stepwise procedure varying the value of β_o can be used.

<u>Step 3</u> Dimensions of the impeller discharge and inlet

The impeller diameter is:

$$D_2 = \frac{60 \times U_2}{\Pi N}$$

$$= \frac{60 \times 35.85}{\Pi \times 2970} = 0.23 \text{ m (or 230 mm)}$$

the radius, $r_2 = D_2/2 = .230/2$

$$r_2 = 0.115 \text{ m, or 115 mm}$$

and the <u>impeller discharge width</u> 15

$$b_2 = \frac{Q}{2\Pi \cdot r_2 \cdot C_{m2}} = \frac{0.075}{2\Pi \cdot .115 \cdot 4.30}$$

$$= 0.0245 \text{ m, or 24.54 mm.}$$

Now the inlet diameter will be calculated. Since the NPsH conditions are not limiting, the flow angle to the impeller vanes β_o will be taken to be 17.0°. The flow angle β_o ranges from 10° to 25°. For the best efficiency the angle β_o can be a little larger than 17° but at low NPsH levels the angle should be smaller.

Using an axial inlet, where K is:

$$K = 1 - \left(\frac{D_H}{D_s}\right)^2 = 1 - \left(\frac{0}{D_s}\right)^2 = 1.0 \quad :$$

As the hub at the inlet to the impeller is small and will not interfere with the flow, $D_H = 0$, and the suction diameter will be:

$$D_s = 2.9 \left(\frac{Q}{K\ N \tan \beta_o}\right)^{1/3}$$

$$= 2.9 \left(\frac{0.075}{1.0 \times 2970 \tan 17^o}\right)^{.33}$$

and $D_s = 0.12633$ m , or 126.33 mm

The inlet radius is:

$$r_1 = r_2 = D_s/2$$

$$r_1 = .12633/2 = .06317 \text{ m}$$

The mean inlet radius,

$$r_{1m} = \left(\frac{r_1^2 + r_H^2}{2}\right)^{.5}$$

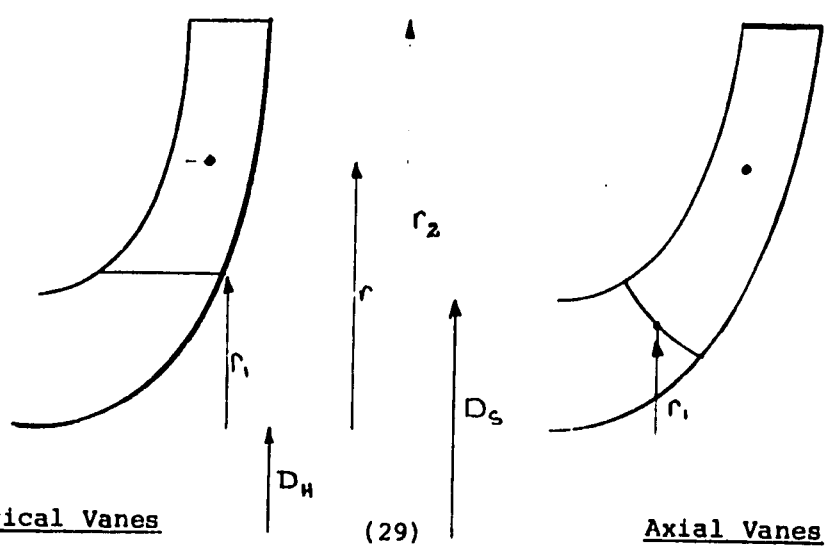
$$= \left(\frac{.6317^2 + 0^2}{2}\right) = 0.04467 \text{ m}$$

and the ratio, $\frac{r_1}{r_2} = 0.50$, previously assumed, we have:

$$\frac{r_{im}}{r_2} = \frac{.04467}{.115} = 0.388$$

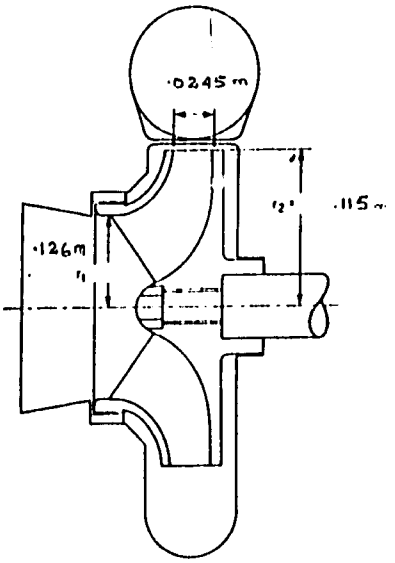
Thus, the ratio is less than 0.5, and the foregoing assumptions are correct.

The dimensions of the impeller are shown in the follwing illustrations which show the two kinds of impeller configurations, (a) cylindrical, (b) axial, and the dimensions of our design example.



Cylindrical Vanes

Axial Vanes



Dimensions of impeller and volute casing, showing a side view.

Step 4: <u>Inlet Vane Angles</u>

The flow angle β_o varies along the leading edge of the vanes, which protrude into the axial section of the inlet. If the meridional

velocity is uniform over the radius, the flow angle will be:

$$\tan \beta_o(r) = \tan \beta_o \frac{r_1}{r}$$

In order that the vanes do not become "blocked," the vane angle β_1 is made slightly larger than β_o, and then:

$$\tan \beta_1(r) = \frac{\tan \beta_o(r)}{1-(ZS/2\pi r \sin\beta_1(r)}$$

This equation is applicable to both cylindrical and axial type impellers. The inlet width b_1 can be determined for vanes with their leading edges parallel to the axis. Assuming constant and equal meridional velocity for both axial and radial sections of the inlet:

$$b_1 = \frac{K}{4} \cdot D_s \cdot \frac{D_s}{D_1}$$

where D_s/D_1 should be not less than 0.8, nor greater than 1.0 (for b_1 and D_1 see illustration above, where D_s = suction inlet diameter and D_1 = total inlet diameter). Note, that this factor is sometimes ignored in poor construction practice by connecting a smaller diameter suction pipe to the suction inlet of the pump.

The inlet vane thickness to be acceptable is a minimum of 5.0mm (.005 m) and $\beta_o = 170^o$, $r_1 = D_s/2 = .06317$ m, $Z = 7$. And, by interative trials for β_1, using the equation above:

$$\tan \beta_1(r) = \frac{\tan \beta_o(r)}{1-(\frac{ZS}{2\pi r_1 \sin \beta_1(r)}}$$

(i) try $\beta_1 = 20^o$:

$$= \frac{\tan 17}{1-(\frac{7 \times .005}{2\pi \cdot .06317 \cdot \sin 20}}$$

$$\beta_1 = 22.389^o$$

(ii) try $\beta_1 = 22^o$:

$$= \frac{\tan 17}{1-(\frac{7 \times .005}{2\pi \cdot .06317 \times \sin 22}}$$

$$= 21.794$$

It will be necessary to check the flow area between the vanes. This can be estimated by the following approximation. The inlet area between the vanes is:

$$A_1 = Za_1 \quad \Pi\, r_1^2 \sin \beta_{im}$$

$$= \Pi \cdot .06317^2 \sin 30.8$$

$$= 0.00642 \text{ m}^2$$

and the discharge area between the vanes is:

$$A_2 = Za_2 \quad b_2(2\Pi r_2 \sin \beta_2 - ZS_2)$$

$$A_2 = .0245\ (2\Pi \cdot .115 \sin 23.5^{\circ} - 7 \times .005)$$

$$= .0245\ (.28812 - .035)$$

$$= .00620 \text{ m}^2$$

(Note: $S_1 = S_2 = .005$ m)

The area ratio A_1 to A_2:

$$\frac{A_2}{A_1} = \frac{.0062}{.00642} = 0.966$$

This value is below the upper ratio limit of 1.3 and greater than 0.8.

<u>Step 5</u>: The design of the <u>volute casing</u>

The diffusing system most commonly found in pumps is the volute form; other forms are the double volute and a vane diffuser. In principle, the greater part of the dynamic energy ($C'/2g$) of the fluid from the impeller is changed into static energy in the diffusing system. Thus, the design of the diffusing system -- in our example the volute form -- begins with determination of the area of the "throat." The various parts and dimensions are shown in the following illustration.

The value 21.8 appears to be correct.

The mean inlet vane angle can be calculated by using the same equation, r_{im} = 0.04467 m, and the angle is obtained using the following equation:

$$\tan \beta_{im} = \frac{\tan \beta_o(r)}{1-[\frac{Z S_1}{\Pi} \times \frac{1}{r_{im} \sin \beta_1}]}$$

then, by iteration, the value of $\beta_{im} = 30.8^o$

Now, we can draw the impeller inlet vector diagram, after calculating the meridional velocity (note: $r_1 = r_s = D_s/2$)

$$C_{mo} = \frac{Q}{\Pi r_1^2}$$

$$= \frac{.075}{\Pi \cdot .06317^2} \quad (m/s)$$

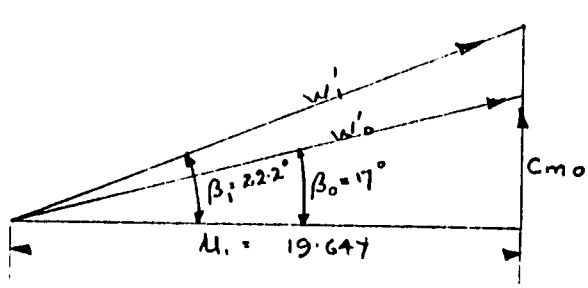
$$= 5.983 \text{ m/s}$$

The peripheral vane velocity at the eye is:

$$\mu = 2 \frac{\Pi \; r_1 \; N}{60}$$

$$= 2 \frac{\Pi \cdot .06317 \cdot 2970}{60}$$

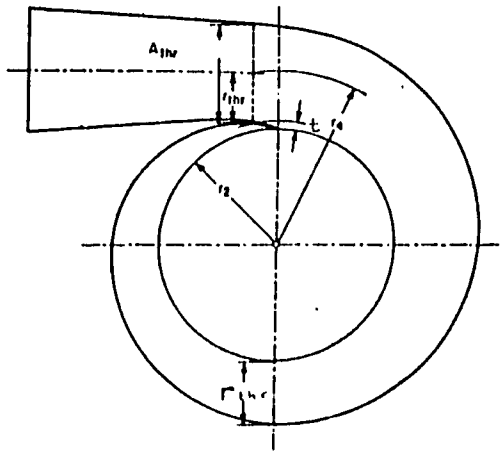
$$= 19.647 \text{ m/s}$$



Cmo = 5.983 m/s

Inlet Vector Diagram

Diagram showing the dimensioning of the volute casing



The throat area is calculated by the following equation:

$$A_{thr} = \frac{Q}{C_{thr}}$$

and the mean throat velocity, C_{thr}, is obtained by:

$$\frac{c_{thr}}{c'_{u2}} = \frac{r^2}{r_4} \quad C$$

where C - 1, for frictionless flow. Design and test experience has shown that C=1 can be used for large pumps and for smooth walled medium sized pumps; C=0.9 may be used for smaller sizes of pumps. The design values for the ratio c_{thr}/c'_{u2} to the specific speed can be estimated from Figure 15(a). An alternative method, or a check on the above procedure, is to use the ratio:

$$y = \frac{A}{A_{thr}} \quad \text{or } 1/y = A_{thr}/A_2$$

where $A_2 = Za_2$; the relation A_{thr}/A_2 to the specific speed is shown in Figure 15(b).

However, values below $N_s = 10$ should not be used and higher efficiency can be expected using values in the zone (as marked in the figure) midway between the upper and lower curves.

The radius r_4 in the previous equation can be estimated by:

$$r_4 = r_2 + t + r_{thr}$$

It must be noted that the clearance between the impeller and the throat "tongue" must not be too small, or large pressure pulsations can lead to impeller disintegration, while too large a clearance reduces the efficiency of the pump. From experience, a value of between 5% and 10% of the impeller radius gives a reasonable compromise. The value normally lies between 2.5 and 7.5 mm.

The intermediate volute radii can be obtained from:

$$\frac{c_v}{c'_{u2}} = \frac{r_2}{r_v} C$$

and then the volute areas can be estimated from:

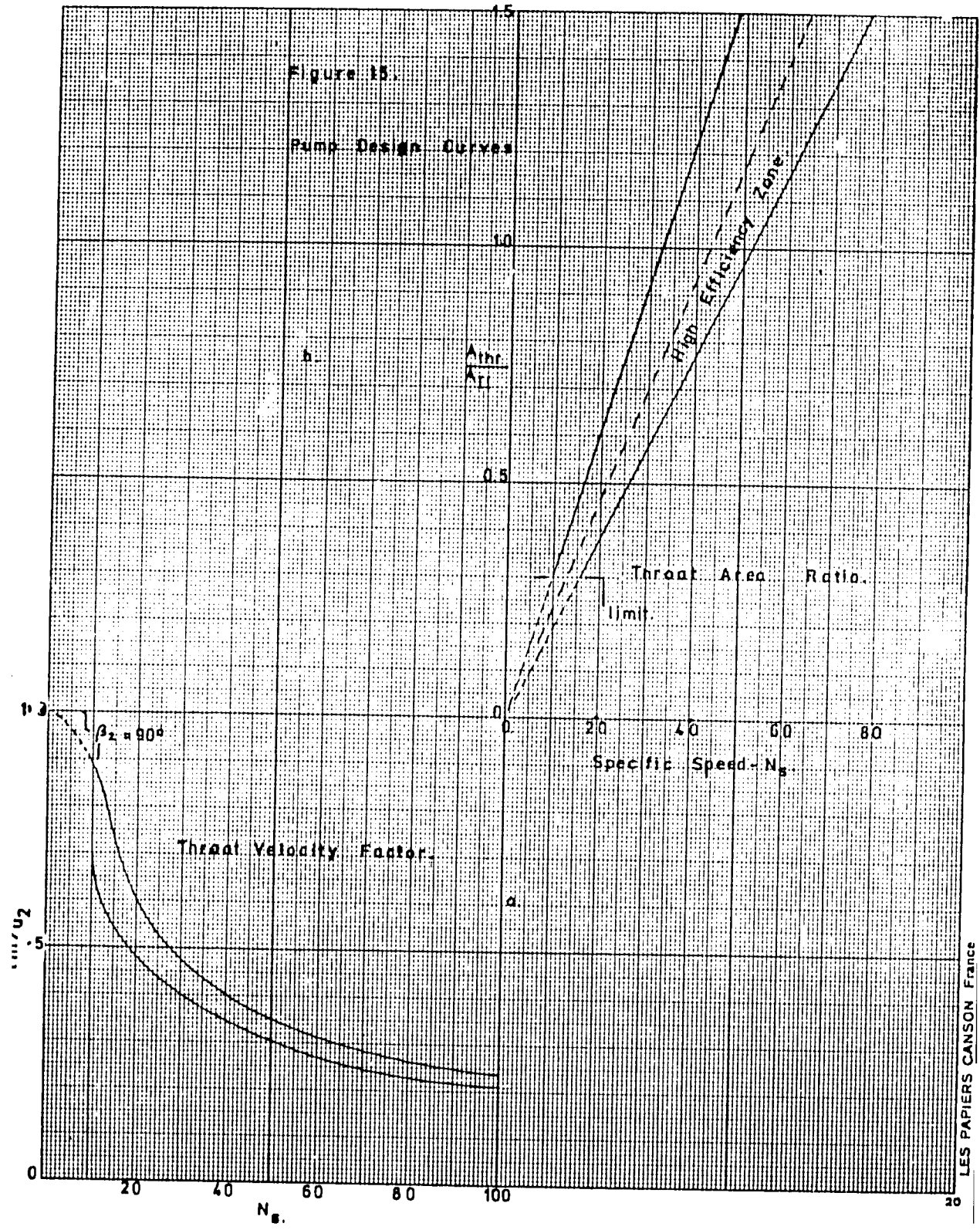

Pump Design Curves
b.
$\frac{A_{thr}}{A_{II}}$
Throat Area Ratio.
High Efficiency Zone
limit.
Specific Speed - N_s.
$\beta_2 = 90°$
Throat Velocity Factor.
a.
N_s.
1.5
1.0
0.5
0
20
40
60
80
100
1.0
.5
LES PAPIERS CANSON France

Figure 15.

$$A_v = \frac{Q}{c_v} \quad \frac{v}{360^o}$$

Alternatively:

$$A_v = A_{thr} \frac{v}{360}$$

The volute is followed by the diffuser outlet, and this outlet is normally conical in shape with a 5° to 10° flare. The diffuser can be circular in shape, trapezoidal or rectangular, and the width can be greater than the impeller width (b_2).

A vaned diffuser consists of a series of vanes set around the impeller and the fluid is collected in a volute or a circular casing and discharged out of the outlet pipe. The design is similar to that of the volute but there are a series of throat sections. The throat velocity c_{thr} is obtained by the following equation:

$$\frac{c_{thr}}{c'_{u2}} = \frac{r_2}{r_1} C$$

and the value of C=0.8. The ratio c_{thr}/c'_{u2} in Figure 15(a) can be used. The usual design practice is to use one more vane than that on the impeller and these vanes can be circular or straight. They may be parallel or diverge slightly.

We will now continue with the design example. Referring to Figure 15(a), the specific speed in our example is N_s = 38, and the ratio is

$$\frac{c_{thr}}{u_2} = 0.36$$

Then,

$$c_{thr} = \frac{c_{thr}}{u_2} \times u_2 = 0.36 \times 35.29$$

$$= 12.70 \text{ m/s}$$

The throat area A_{thr} is:

$$A_{thr} = \frac{0.075\ m^3/s}{12.7\ m/s}$$

$$= .00591\ m^2 \text{ (or, } 5905.51\ mm^2)$$

and using a circular cross section, the radius will be:

$$r_{thr} = \sqrt{\frac{.00591}{\pi}}$$

$$= .04336\ m \text{ (or } 43.36\ mm)$$

The "tongue" clearance is assumed to be 5%:

$$t = 0.05 \times 0.115$$
$$= .00578\ m \quad \text{(or } 5.75\ mm)$$

The the radius from the axis will be:

$$r_4 = .115 + .00575 + .04336$$
$$= .16411\ m \quad (164.11\ mm)$$

To check the throat velocity from the value of C used:

$$C = \frac{c_{thr}}{c'_{u2}} \times \frac{r_4}{r_2} = \frac{12.70}{19.02} \times \frac{.16411}{.115} = 0.953$$

and $$A_{thr} = .00591/.00620 = 0.953$$

This shows that the assumption that the value of C is approximately 1.0 was correct. 0.953 is within reasonable limits. If the value exceeds 1.0 or 0.9, an alternative value of c_{thr}/u_2 at the same N_s would have been used: within the design envelope, say a mid value of 0.39, and a third value, 0.42. However, a value of 0.36 proved adequate.

The dimensions of the volute casing can now be calculated by using either of the two equations given above. The dimensions can be

estimated by successive approximations. The first approximation can be made by using the equation:

$$A_v = A_{thr} \frac{\phi_v}{360}$$

(1) ϕ_v	(2) A_v (m^2)	(3) r_{thr} (m)	(4) $r_4(r_v)$ (r_2+t+r_{thr}) (m)
0	.000016	.002257	.12301
45	.00074	.0153	.13605
90	.00148	.0217	.14245
135	.00222	.0266	.14735
180	.00296	.0307	.15145
225	.00369	.0343	.15505
270	.00443	.0376	.15835
315	.00517	.0406	.16135
360	.00591	.0434	.16411

The values in columns (2) and (3) are obtained by dividing the values at 360° and proportionally dividing them for the other angles, viz.:

$$A_v = .00591 \times \frac{135}{360} = .00222 \quad , \text{ and}$$

$$r_{thr} = \sqrt{\frac{.00222}{\pi}} = .0266$$

$$r_4 = .115 + .00575 + .0266 = .14735$$

However, the values in the previous table can be refined by using the following equations, successively approximating the values required:

$$c_v = \frac{r_2}{r_v} \cdot C \cdot c_{u2} = \frac{.115}{r_v} \cdot .95 \cdot 19.02$$

$$= \frac{2.0779}{r_v}$$

and,

$$A_v = \frac{Q}{c_v} \cdot \frac{\phi_v}{360} = \frac{.075}{c_v} \cdot \frac{\phi_v}{360}$$

$$= .00021 \frac{\phi_v}{c_u}$$

ϕ_v	r_v^*	c_v	A_v	r_{thr}	r_v
0	.1230	16.894	.000012	.0062	.12695
45	.13605	15.273	.000614	.0139	.13465
90	.14245	14.587	.001285	.02022	.14097
135	.14735	14.102	.001994	.0252	.14595
180	.15145	13.720	.00273	.0295	.15025
225	.15505	13.401	.00349	.0334	.15415
270	.15835	13.122	.00429	.0369	.15765
315	.16135	12.878	.00509	.0403	.16105
360	.16411	12.662	.00591	.0434	.16411

The volute casing can now be drawn, as shown in the previous illustration.

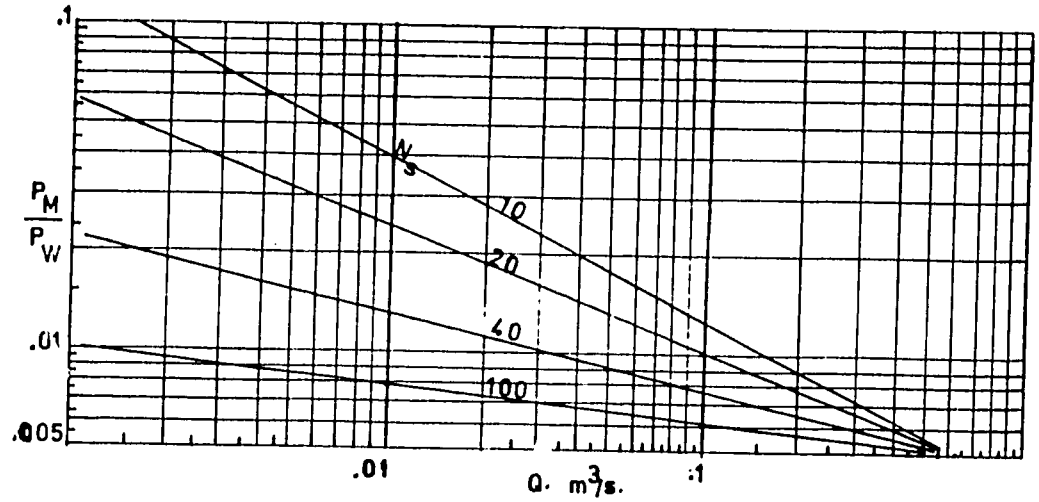
Step 6: Estimating the Efficiency of the Designed Pump

The derivation of the various efficiency factors was discussed above, and we can now apply the reasoning given to our design example.

The hydraulic efficiency was estimated at $\eta_H = 0.85$. From the curve in Figure 14, where $1-\eta_H = 0.145$ and $\eta_H = 1-.145 = 0.855$, the volumetric efficiency can be estimated from the curves in Figure 16(b):

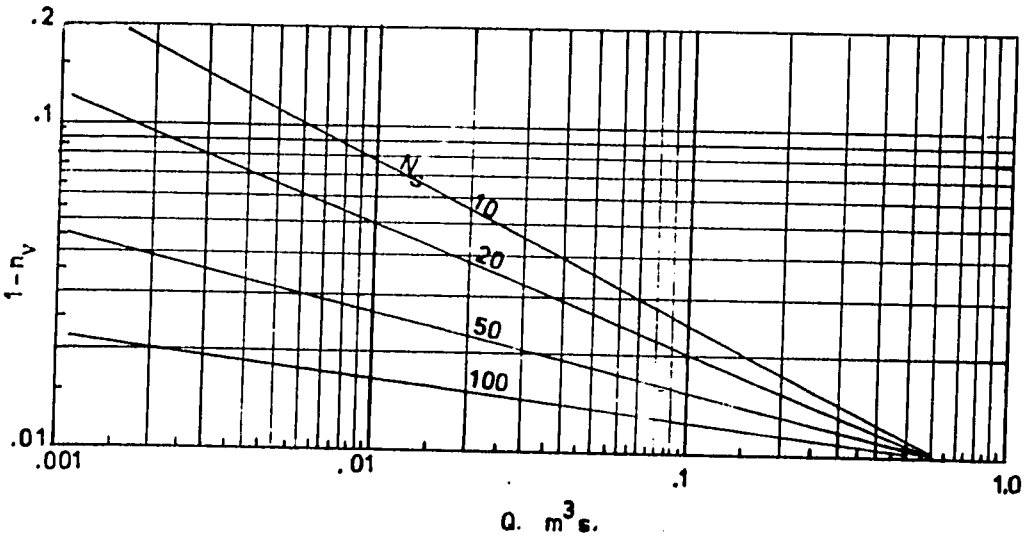
Figure 16.

Pump Design Curves.



a.

Mechanical Losses.



b.

Volumetric Efficiency.

$$Q = 0.075\ m^3/s; \quad N_s = 38.0, \quad \text{and}$$

$$1-\eta_H = 0.019$$
$$\eta_H = 1-.019$$
$$= 0.98$$

The ratio of mechanical losses to water power will be from Figure 16(a):

$$\frac{P_m}{P_W} = 0.0095$$

The ratio of disc friction to water power can be derived from an empirical equation relating disc friction to maximum efficiency; however, this relationship should not be used for specific speeds less than 10.0 or exceeding 50. Above $N_s = 50$, $P_{DF}/P_W = 0.02$

$$\frac{P_{DF}}{P_W} = \frac{11.2}{(N_s)^{1.67}} = \frac{11.2}{(38)^{1.67}} = 0.026$$

(Note: the equation based on experimental work by Schultz-Grunow:

$$\frac{P_{DF}}{P_W} = \frac{52.0}{(N_s)(\phi)^{2.5}} \quad \frac{D + se}{D}$$

This equation gives values up to 50% above the previous equation. However, the previous equation is applicable to water at normal temperatures; for fluids with different viscosities, this equation must be corrected by $(\nu/\nu_{water})^{0.2}$)

The efficiency, then, of our pump will be:

$$\eta = \frac{1}{\frac{1}{\eta_H+\eta_V} + \frac{P_{DF}}{P_W} + \frac{P_m}{P_W}}$$

$$= \frac{1}{\frac{1}{.855x.98} + .026 + .0095} = 0.815$$

This efficiency value is close to the estimated value of 0.845, taken from Figure 12.

The power input to the pump will be:

$$Ps = \frac{Q \ H \ \gamma}{75 \times \eta}$$

$$= \frac{.075 \times 60 \times 1000}{75 \times .815}$$

$$= 73.62 \text{ h.p.}$$

The example of pump design is thus concluded.

Although this is basically a design for a very simple pump, the procedure demonstrated is that used for simple, or more complicated, pumping units. Such a pump would be constructed as a prototype, tested, modified until the desired characteristics are obtained, and then the resulting model put into production.

The theoretical application of fluid mechanics is still approximate, even with computer techniques. Many problems are still difficult to solve.

4.3 Pump Balancing

The balancing of hydraulic loads has not been included in this design sample. However, axial loads, in particular, can be balanced in a number of ways:

a) Mechanically, by the complete absorption of the thrust by a thrust bearing, viz., a roller bearing, this being the most efficient method though not necessarily the most economical, as complicated bearing configurations may be required;

b) By using internal hydraulic design procedures such as the back-to-back arrangement of the impellers through which, in a multi-stage pump, some thrust will be taken up by the bearings; or, by throttling action using balance holes and sealing rings at the discharge end, which method is commonly

used in modern pumps and is the least costly.

Many combinations of orifices and discs can be used to counteract axial loads according to the duty required. Experience indicates the design preference and tests establish the exact dimensions of such devices.

5.0 CONSTRUCTION OF A PUMP: THE COMPONENT PARTS

The nomenclature of the component parts of a pump have been given in Figure 5(a) and 5(b). The various parts of the pump have been described in the order of the design example in Section 4.0. Some of these parts will be discussed below in cases where these parts have a particular bearing on the selection of a pump. While all aspects of these components cannot be examined here, the information given should help to make an objective assessment of the design or the specific requirements for which the pump is intended.

The components of a pump, such as the bearings, seals and stuffing box, packing, and in many instances the housing for these components are manufactured by specialist manufacturers in their respective fields. Pump designers rarely design these components, but rather select those components suitable to the requirements of their designs. In many cases these components are patented and however desirable it may be to manufacture them it is more economical to simply buy them. Ball and roller bearings are a case in point: it can be said that a pump is built around the bearings. Bearings of a certain kind and loading duty are selected from the manufacturers' catalogs to suit as closely as possible the anticipated requirements for the shaft size, the bearing supports, lubrication coating, etc. and then final pump design, being built around them. Very rarely are component parts specifically manufactured unless they are needed in very large numbers or for extraordinarily specially designed expensive equipment

In consequence, a pump designer or engineer selecting pumps should be aware of the components available on the market, and the standard specifications covering these components. The engineer in Egypt who understands the specialization of these components will see that local manufacture of pumps is altogether practical provided that certain components are imported until the demand and capability for a large volume output make such specialized manufactures economical. The specifications of the components to be imported must be thoroughly studied.

5.1 IMPELLERS

Impellers are classified into four kinds according to the vane configuration:

a) Straight vane
b) Francis or screwed vane
c) Mixed flow
d) Axial flow, or propeller impellers

Each kind of impeller configuration performs in a specific set of conditions in combination with a specific speed, as shown in Figure 6.

The straight vaned impeller has vane surfaces parallel to the axis of rotation, or single-curvature vanes. The vane surfaces of the Francis type are of a double curvature configuration. The mixed flow impeller combines both radial and axial curvature. The true axial flow impeller has flow strictly parallel to the axis of rotation.

Depending on the entry of fluid to the impeller, there can be either single or double entry types. The greater number of impellers are of the single entry type. For smaller pumps in particular, single entry impellers are less costly to manufacture. The shaft or hub does not impede flow into the impeller and where the water contains solids or suspended matter such as sewage these are preferred.

The double-suction impeller on the other hand is preferred because it is axially balanced and the pump can be operated with less net suction head and with greater suction area. Further, this kind of impeller in a horizontal split casing design is commonly used. These pumps are used for clear water operation, as in water works, and offer superior maintenance facility iwth accessible bearing supports.

The next factor in impeller configuration is the throud or sidewall. The shroud can be entirely absent, as in the open impeller, or semi-open, where a back wall is provided, or totally closed. Open impellers are used in small, inexpensive pumps of limited capacity or for handling suspended matter. Semi-open impellers are fitted with a back wall or a side plate and are used for similar purposes as the open impeller. The closed impeller is used for many applications. However, open and semi-open impellers are used in large vertical pumps of the mixed and axial flow types, but for most high pressure, or high heads, and for clear fluids, totally closed impellers are preferred.

The wear ring, with the impeller and casing have an inegral function on the efficiency of the pump (see Figure 5(a) for location of the wear ring). The wear ring provides a controlled amount of leakage to the place between the impeller and the casing. As these surfaces get worn, efficiency is reduced, and provision is made for replacing the rings. In small pumps both rings are replaced by wearing surfaces or only a casing ring; when worn, the impeller is replaced or built up by welding. In the larger pumps very elaborate wearing rings are used, some with re-entrant double rings, etc. Where water contains abrasive material such as sand, annular rings or dams are provided so that the dams can be flushed out. The wearing rings are fixed in position by means of grub screws, or recessed joints, or threaded to the parts. On smaller pumps the rings are press fitted into position. The clearances between the respective rings is in the order of 0.25 mm

up to 0.75 mm, with tolerances of 0.05 mm to 0.125 mm, depending on the leakage joint diameter. As the leakage joint has a specific bearing on efficiency the clearings should be maintainted at the dimension specified by the manufacturer.

The materials used for casting impellers depends largely on the service that is required, as is shown in Figure 17.

For lower Ns and shut-off heads, cast iron is used, or bronze, or ductile iron; for both semi-open and closed impellers. Axial flow and propeller impellers may be made of ductile iron, as it is easier to machine. Stainless steel or chrome steel may be used where cavitation occurs because of fluctuating suction heads.

The metals normally used for wearing rings are usually dissimilar metals, such as one kind of bronze with another, cast iron and bronze, steel and bronze, monel metal with bronze, etc. This procedure prevents cathodic corrosion and in some cases, metal flow -- or "galling," the buildup of small raised "galls" on the surface of the wear rings.

5.2 Casing and Diffusers

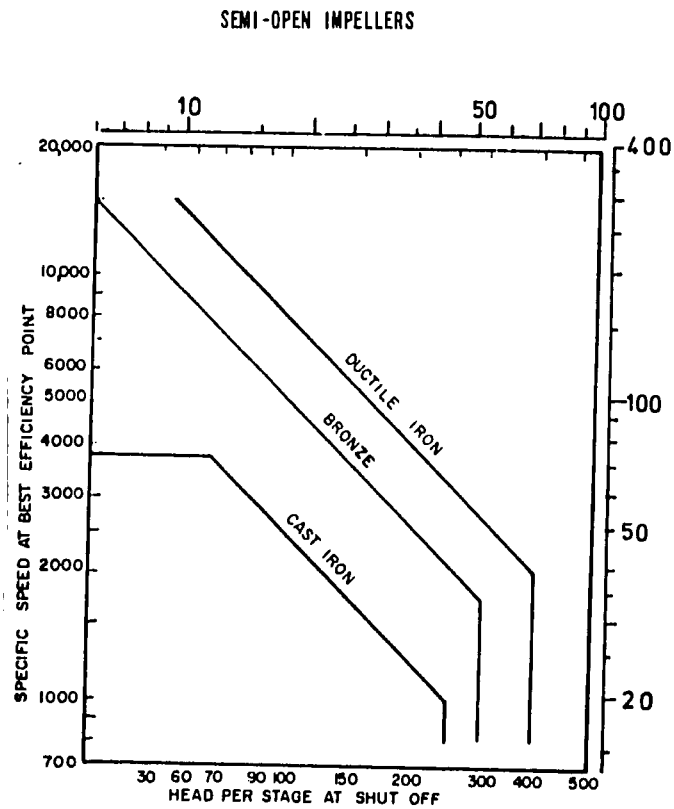
A volute casing of a pump collects the fluid discharged by the impeller and converts the velocity energy into pressure energy, by progressively increasing the initial area through 360° and flaring out into the discharge nozzle, or outlet. The diffuser vanes and concentric casing serve the same purpose as the volute.

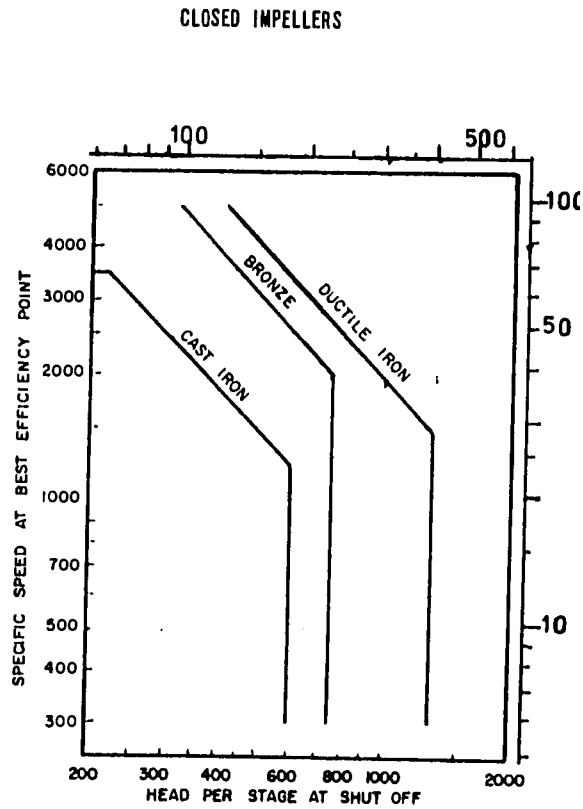
With vertical axial flow and propeller pumps, volute casings are not used; the impeller is placed in a tubular casing with diffuser vanes, though in high capacity low head pumps the vanes may be omitted. Horizontal axial flow pumps have a simple type of volute outlet.

The double volute pump is designed to counteract radial thrust forces that can occur at extreme operational points, at shut-off

Figure 17.

Impeller Materials.





NOTE: (a.) Substitutions for Bronze.
Above these limitations substitute either 11/13 Chrome or Stainless Steel.

(b.) Substitutions for Cast Iron or Ductile Iron.
Above these limitations substitute either Steel, 11/13 Chrome, or Stainless Steel.

and extremely low flows. Continuous operation at very low flows can cause broken shafts and impellers unless heavier shafts are provided. Radial reaction, where partial capacities may occur, can be overcome by using double volute casing.

Other casing configurations are briefly considered here:

a) Axially or horizontally split casing: the upper section is removable to expose the impeller and the shaft, and the shaft is suspended between bearings on the outboard. This type of pump is easily dismantled for maintenance.

b) End suction pump: Single stage (or some special irrigation pumps with two stages) are the most commonly used pumps for overhead irrigation and process pumping and are made in sizes up to 250 mm for high head and capacity, in radial flow forms, though large sized mixed and axial flow pumps for high capacity low head conditions are also made.

c) Twin suction, bottom inlet pumps are in a class of their own, used in waterworks duty, and embodying many advantages of all pumps in (a) and (b) above.

d) Vertical shaft, end suction, double volute pumps: Made in large sizes for high capacity and intermediate head service.

5.3 Shafts

The pump shaft serves the basic purpose of transmitting the torque required to start and operate the impeller and to support the impeller and other rotating parts. Thus, the shaft must be sufficiently rigid so that the deflection is less than the minimum clearances between the rotating and stationary parts of the pump. The loads that the shaft carry are: (a) the torque, (b) weights of the parts, and (c) the radial and axial hydraulic loads.

In the design of the shaft, the maximum allowable deflection, load location, the span and the critical speed of the resulting design must all be taken into account. The functional design of shafts for pumps follows normal design of rotating shafts, and the principles of shaft design can be found in standard references.

The pump shaft is designed either as a flexible or rigid shaft. A rigid shaft operates at a speed lower than its first critical speed, while a flexible shaft operates above its first critical speed. Normally, pump shafts are designed to operate at pre-selected speeds, related to the electric motor speed. The shafts on pumps operating at 1800 rpm or lower are designed as rigid shafts, while at 3000 rpm or higher, the shaft is of the flexible design.

The deflection of pump shafts is kept within limits to maintain wearing ring clearances. Usually, deflections are limited to tolerances of 0.125 mm to 0.15 mm.

Shafts are rarely of equal diameter along their length, in order to accomodate the various parts on the shaft; this varying diameter provides a measure of safety against overloading.

Shaft sleeves are commonly used to protect the shaft against corrosion at the stuffing box. These sleeves are removable and are fixed to the shaft by various means -- threaded and screwed or by use of locknuts. The sleeve is made of a non-corrosive metal: stainless steel, hard bronze, or chrome steel. In some cases ceramic coated sleeves are used. Hard chrome steel gives the best service.

5.4 Stuffing Boxes and Seals

The stuffing box is to prevent leakage from the pump where the shaft emerges from the casing. The stuffing box consists of an

annular cylindrical recess filled with packing material around the shaft. The box is sealed by means of a latern ring, with packing on either side and sealing fluid. Water is fed in, at the pressure of the pump, to the latern ring recess. In some cases, a liquid different to the pumped liquid is used to seal the pump.

The packing used in the stuffing box is made of either prelubricated (with graphite and oil) braided asbestos, or is metalic packing consisting of oil or grease impregnated metal foil. Babbit foil is used for water under normal conditions; copper for oils and high temperature water, and aluminium for oil and water at high temperatures and pressure.

Other kinds of mechanical seals are used, ranging from patented spring load seals to neoprene rubber and teflon. New ceramic materials are highly resistant to wear and corrosion and may be used for extreme conditions. Seals of these kinds may well be used for pumps in Egypt. They would reduce the cost of maintenance, but should be readily available from local suppliers for purposes of efficient maintenance. The manufacture of such seals would depend upon the volume to be commercially produced, and as the conditions for an economic volume may not occur in Egypt for some time, they will remain expensive for the foreseeable future.

5.5 Bearings

The bearings in a pump serve the purpose of supporting the shaft and of maintaining the shaft in the correct alignment. Two kinds of roller and ball bearings are commonly used, line bearings are used to provide radial positioning and thrust bearings to give axial positioning. There are also sleeve bearings, and though these have been largely replaced by ball bearings, they are still used for special, high pressure applications. Though less expensive, sleeve bearings are used not only on small inexpensive light

duty pumps but also on very large heavy-duty pumps with large shaft diameters for which roller bearings are not made. They are also used in vertical pumps where the bearings are run in the fluid pumped.

The location of the "inboard" bearing is closer to the coupling and the "outboard" bearing, furthest from the coupling. Usually, bearings in horizontal pumps are mounted in pedestals, but on smaller pumps a pair of bearings are enclosed in a "capsule" (e.g., the DIN 24-255 series) which allows for easy servicing.

Ball or roller bearings, referred to as anti-friction bearings, not only support the shaft but also provide radial and axial load support. They consist of bearing rings or discs, and the rolling element can be spherical, cylindrical, tapered or barrel-shaped. They are normally mounted in a cage to prevent contact between the adjacent rolling elements. Depending on the direction of the loading, a distinction is made between radial bearings, axial thrust bearings and radial <u>deep grooved</u> bearings for both axial and radial loads. The type of bearing is quite easily distinguished: in <u>radial</u> bearings, the rolling elements run <u>between</u> the <u>races</u> or <u>rings</u>, while in <u>axial</u> bearings they run between <u>discs</u>. Bearings are available in single and double rows of rolling elements, depending on the magnitude and direction of the load. The loading capacity and life of rolling bearings are standardized.

According to the design, the fluid to be pumped, the loading or duty, and speed, a specific lubrication will be chosen. In vertical or wet-pit pumps pumping water, water will be chosen. Oil refinery pumps are, by choice, oil lubricated, while marine pumps are grease lubricated. On the other hand, pumps operated at high speed -- above 4000-5000 rpm -- are oil-lubricated. For most roller bearing services, at low to medium speed, grease lubrication is preferred. Ease of maintenance and economy are important in the choice of grease, in both vertical and horizontal

pumps. At present, manufacturers supplying bearings also provide recommendations for the lubrication of their bearings. Many bearings are supplied "lubricated for life," and the filling will last for the effective operating life of the bearing. Of course, the life of a bearing is limited by the design life and the maintenance it receives. Maintenance free components may well be more economical in the long term than those that require constant attention, or "oiling."

Sleeve bearings will not be discussed, since these bearings would not normally be selected for horizontal pumps. With the exception of the shaft tension bearing, and depending on whether an open or closed shaft is selected, water lubrication is used in the first instance (open) and oil for the other (closed), though grease may be used in specific cases where oil contamination of water would be undesireable. Synthetic rubber or various kind of non-corrosive metal bearings are used for open line shafts and normal bearing metals for oil or grease lubrication.

6.0 STANDARD SPECIFICATIONS

Earlier in this discussion, it was stated that a sound knowledge of specifications concerend with the equipment and materials is essential both for the design of pumps, and for the selection of pumps to be purchased to operate under conditions in Egypt. Space does not permit a complete list of the relevant specifications, or codes of practice (C.P.'s), but a listing of the various organizations and their addresses are included in Appendix 2.

6.1 Organizations Concerned with Standards

In most of the manufacturing and exporting countries, organizations have been formed by manufacturers, professional institutions and in most cases, by governments, to regulate the standards of materials

and components, methods of manufacture, construction, etc., and these are known as codes of practice and standard specifications. The code of practice generally indicates the procedures used in the production -- or construction -- of the item under consideration, while the standard specifications regulate the dimensions, materials used and tests to establish compliance with the standard.

The various organizations concerned with such documentation, are as follows:

a) The International Standards Organization (ISO), centered in Switzerland. This body issues standards covering most of the factors concerned with pump materials, components and testing.

b) The American standards are covered by no less than 51 organizations that contribute in varying degrees to standards for pump manufacture and materials. The Hydraulic Institute provides mainly a code of practice, as well as standards. The American Society for Testing Materials (ASTM) regulates the standards concerned with materials. The other organizations are concerned with every range of manufacture and the specific application of pumps in industry.

c) The British Standards Institute (BSI) issues specifications on pump acceptance tests and manufacture, as well as many other aspects covering materials and components, finishes and tolerances. The British Pump Manufacturers Association and the Institute of Mechanical Engineers regulate the standards of manufacture and also contribute to research and applied research.

d) In Europe the German DIN, VDE (Association of Electrical Engineers) and VDI (Association of Engineers) lead in the field of compiling the most comprehensive standards on most manufacturing procedures, including pumps and hydraulic machinery. Other European standards for pumps are issued by France (AFNOR), Italy (UNI), Netherlands (NEM). The ECC countries collectively regulate pump manufacture and development for the European Commission of Pump Manufacturing Associations.

e) Finally, there are other standards organizations in other European countries -- Spain, Denmark, Sweden, etc. -- not listed here, as well as the Japanese Standards Association. Most countries' standards are mutually recognized by other countries.

APPENDIX I

NOMENCLATURE

APPENDIX I

NOMENCLATURE

A = sum of areas between vanes, m^2

D = diameter, m

H = total head, m

L = flow friction loss, m

N = rotative speed, rpm

NPSH = net positive suction head,

Ns = specific speed, rpm $\frac{\sqrt{m^3/sec}}{m.75}$

P = power

Q = capacity, m^3/sec

S = suction specific speed, rpm $\frac{\sqrt{m^3/sec}}{m.75}$.

T = torque, kg.m

sp gr = specific gravity

a = area between two vanes, m^2

b = width, m

c = absolute velocity, m/sec

e = sum of widths of shrouds at outer impeller diameter, m

g = gravity constant, 9.8066 m/s^2

h = static head, m

m = length along streamline, starting from inlet, m

n = distance from shroud to point on orthogonal, m

p = pressure, kg/m^2

r = radius, m

s = vane thickness, m

t = clearance between impeller and volute tongue, m

u = peripheral velocity, m/s

w = relative velocity, m/s

y = elevation, m

z = number of vanes

α = angle between c u

β = angle between w u

γ = density, kg/m^2

γ = angle between streamline direction and axis of rotation, deg.

η = efficiency

θ = angular distance from radial line rotating with impeller, rad

μ = slip factor

ν = kinematic viscosity, m^2/s

ρ = radius of curvature in m

ϕ = central angle, deg.

η = head coefficient

ω = angular velocity, s^{-1}

Subscripts

DF = disc friction

H = hydraulic

H = hub

I = impeller

L = leakage

M = mechanical

S = suction

S = shaft

V = volumetric

V = volute

W = water

a = at shroud

av = average

b = at hub

m = meridional

m = mean

p = at pressure side of vane

r = refers to arbitrary radius

s = at suction side of vane (shaft)

th = theoretical

thr = at throat of volute or diffuser

u = denotes peripheral component

w = water

θ = denotes circumferential component

I = beginning of confined vane channel

II = end of confined vane channel

APPENDIX II

ORGANIZATIONS ISSUING STANDARD SPECIFICATIONS

1. UNITED STATES

ANSI

American National Standards Institute
1430 Broadway, New Yor, N.Y. 10018

ASTM

American Society for Testing and Materials
1916 Race Street, Philadelphia, PA 19103

API

American Petroleum Institute
2101 L. Street N.W., Washington, D.C. 20037

AFBMA

Anti-Friction Bearing Manufacturers Association
60 E. 42nd Street, New York, N.Y. 10017

HI

Hydraulic Institute
Cleveland, Ohio

(These are only five of the 51 organizations concerned with standards in the U.S. A full list is included giving the names but not the addresses.)

2. UNITED KINGDOM

BSI

British Standards Institute
Maylands Avenue
Hemel Hempstead, Herts. HP2 4SQ, England

BPMA

British Pump Manufacturers Association
37 Castle Street
Guildford, Surrey GU1 3UQ, England

3. GERMANY

DIN

Deutscher Normenausschuss
Beuth-Vertrieb GmbH
Friesenplatz 16
Koln, Germany

VDI

V.D.I.-Verlag
Muncher. Verlag R. Oldenbourg 1937
Germany

VDE

V.D.E.-Verlag
Bismarck-Strasse 33
Berlin-Charlottenburg
Germany

The addresses of the following organizations can be obtained from the commercial consuls of the respective countries.

FRANCE

AFNOR: Association Francaise de Normalisation

DTU: Documents Techniques Unifies; Group de Coordination des Textes Techniques

ITALY

UI: Unificazione Italiana

NETHERLANDS

NEN: Netherlands Normalisatic Instituut

AUSTRALIA

ANSI: Australian National Standards Institution (n.b.: Australia also uses BSI documentation)

INTERNATIONAL

ISO: International Organization for Standardization (1, rue de Varembe, 1211 Geneva 20, Switzerland)

(NOTE: Many other countries have organizations regulating standards, but they use mainly standards of other countries; e.g., Spain uses DIN and BSI.)

REFERENCES

Bennett, T.P., and Worster, R.C. 1961. Friction on rotating discs and the effect on net radial flow and externally applied whirl. British Hydromechanical Research Assoc. RR 691.

Fisher, K., and Thoma, D. 1932. Investigations of the flow conditions in a centrifugal pump. Trans. A.S.M.E. Vol. 54.

Pantrell, K. 1950. Versuche uber Scheibenreiburg. Forsh. Gebiet Ingen. Vol. 16, No. 4.

Pfleiderer, G. 1961. Die Kneischpompen Springer Verlag. OHG, Berlin.

Stepanoff, A.J. 1967. Centrifugal and axial flow pumps. 2nd ed. John Wiley & Sons Inc. New York.

Stodola, A. 1945. Steam and gas turbines. Peter Smith Publishers. Gloucester, Mass.

Toyokura, T. 1971. Studies on the characteristics of axial flow pumps. Bull. Japan Soc. Mech. Eng. Vol. 4, No. 14.

_____. 1975. Centrifugal pump lexicon. K.S.B.

_____. 1961. Pump handbook. 2nd ed. K.S.B.

Wislicenus, G.F. 1970. Fluid mechanics of türbo machinery. McGraw-Hill Book Co. New York.

_____, Watson, R.M., Karanik, I.J. 1939. Cavitation characteristics of centrifugal pumps described by similarity considerations. Trans. A.S.M.E. Vol. 16.

Worster, R.C. 1960. The interaction of impeller and volute in determining the performance of a centrifugal pump. British Hydromechanic Research Assn. RR 679.

II

THE COMPUTER PROGRAM FOR PLANNING AND FOLLOWUP

2.0 The Computer Program for Planning and Followup

2.1 Status of the Data Collection and Programming Project

Pump station operating cost data for 1977 described in Section 3 of the First Quarterly Report has been collected for most of the stations and the over seven thousand entries have been key punched. The first run of the program is scheduled for January 15, 1979 during which the program will be checked for accuracy and debugged, if necessary.

All reports described in the First Quarterly Report will be bound in hard cover for quick reference by the Ministry and AID. The variance analysis will be completed by the end of January, following which the Ministry will be able to identify for corrective management by exception those pumping stations within the system that are operating inefficiently. To keep the program running on a continuing basis, it is recommended that the Mechanical and Electrical Department start collecting 1978 data for future input according to the formats shown in Section 3 of the First Quarterly Report. The current program is set for running on equipment belonging to Ain Shams University Computer Center but can be adapted to any hardward available in Cairo.

2.2 Recommendations for the Establishment of a Mini-Computer Center within the Ministry of Irrigation

While it would be satisfactory to continue using external hardware facilities for the computerized planning and followup system developed by the CONSULTANT, the use of external facilities does not provide the immediate accessibility of information and program scheduling that would be afforded by the establishment of a mini-computer center within the Mechanical

and Electrical Department. In the judgment of the CONSULTANT, such a facility is warranted in light of the need for quick retrieval of information and to avoid processing delays caused by the requirement for advance scheduling when using external hardware.

During the reporting period, the CONSULTANT has examined various available alternatives for mini hardware systems and has made a recommended selection based upon the following criteria:

- Complete suitability to planning and followup software developed by the CONSULTANT;
- Growth capacity for future programs such as payroll, stores inventory, etc.;
- Support facilities in Egypt offered by the vendor on related products, maintenance, software, etc.;
- Availability of customer training provided by vendor for Department personnel as a comprehensive component of the sales agreement.

From our analysis of available alternatives, we recommend that the Mechanical and Electrical Department give serious consideration to the purchase of a Burroughs Series B-80. This machine, which can be made available within two to four months, very adequately meets all of the criteria cited above. The CIF price of the above machine is LE 23,000 including programming and operator training of selected Mechanical and Electrical Department personnel. A complete description of this model provided by the authorized dealer in Egypt is presented at Appendix II-1.

APPENDIX II-1

CONSULTANT'S COMPUTER RECOMMENDATION

شركة الادارة الحديثة والاستشارات
(شركة ذات مسئولية محدودة)
٢٥ شارع السد العالى (فيفى سابقاً) - الدقى - ج.م.ع.
تليفون ٨١٠٢٥٣/٨١٨٢٣٢ - ص.ب ٢٠١٥ - تلغرافياً : كونسيدارا

Burroughs

MODERN MANAGEMENT METHODS
(Limited Liability Partnership)
25, EL SAD EL AALI STREET (EX FINY) - DOKKI, A. R. E.
TEL. 810253-818232 - P.O.Box 2015 - CABLE : CONSIDARA

Cairo, 2 / I / 1979

Eng. Abdel Mohsen Azmi
First Undersecretary and President
Mechanical and Electrical Department
Ministry of Irrigation
Cairo - Egypt

Dear Sir,

According to your request and our conversation with your consultant Louis Berger Intl., and as exclusive distributors for Egypt of

" Burroughs Corporation "
Detroit, Michigan U.S.A.

we are pleased to submit this proposal for equipment and services to fulfill the information processing needs of your department as outlined in the consultant's first quarterly report.

The desire to implement a Management information System as defined in the above mentioned report and details specified therein have enabled us to complete a study of your processing requirements. The successful conclusion of this study would not have been possible without the excellent cooperation of Mr. Steven Shepley and Dr. Farag Foda.

We appreciate this opportunity to recommend the Burroughs B80 Mini Computer to achieve the results you desire. Yhe B80 system represents a positive solution to your processing requirement.

The preliminary information and expression of confidence set forth in this recommendation of Burroughs products and/or services are submitted for your consideration and guidance only in the hope that we may be favoured with your order. Since this proposal is preliminary only, the order, when issued, shall constitute the only legally binding commitment of the parties.

The approval of our proposal now, will enable us to begin an orderly and early installation of the proposed system, so that you may begin to receive the benefits we know will accrue to you.

Yours Faithfully,

Peter Despotopoulos
Marketing Manager

Enclosures

TABLE OF CONTENTS

I - CRITERIA FOR SELECTION OF A SYSTEM

II - INTRODUCTION TO BURROUGHS CORPORATION

III - B 80 SYSTEM SUMMARY

IV - APPLICATION SUMMARY

V - INVESTMENT SUMMARY

VI - CUSTOMER SUPPORT

VII - IMPLEMENTATION PROCEDURES

1 CRITERIA FOR SELECTION OF A SYSTEM

Selecting a system to provide a solution for your information processing requirements should be determined through the satisfaction of the following criteria :-

Does the system provide a better return on investment than your present system?

Does the system provide a practical solution for the present problem ?

Does the system provide growth capabilities in hardware and program products to keep pace with your requirements?

Does the vendor offer total support - providing equipment, program products, and on-going system maintenance?

Are customer training courses and documentation available to assist you with the implementation of the new system ?

Our analysis of your stated objectives indicates that the Series B80 and more specifically the proposed configurations, meet these criterias in a most efficient way.

11 . INTRODUCTION TO BURROUGHS CORPORATION

A. BURROUGHS CORPORATION

When you choose to install a Burroughs B80 System, you get more than just a fourth generation computer. More importantly, you get the Company behind the computer. Burroughs is a world-wide company with over 90 years experience in the office equipment computer/field. A billion dollar company with over 50,000 employees helping business such as yours solve problems, and provide more meaningful management information . Leadership is a tradition with Burroughs .

Among some of the Burroughs accomplishments are :-

- The first desk computer E 101 - 1954
- The world's first solid state computer ever delivered. This system served as the ground - based guidance computer which guided all launched vehicles in Mercury and Gemini man -in-space programs.
- The first multiprocessing, multiprogramming computer system the B5000- 1961. This first, accomplished by integrating hardware and software at the design level, and development of the Master Control Program (MCP)
- The Leader in the commercial/mini-computer field with over 130,000 units sold world - wide. L/TC Series- released in 1968.

11 . INTRODUCTION TO BURROUGHS CORPORATION (Con't)

B . WHICH MACHINE IS RIGHT FOR YOUR JOB ?

Burroughs provides a complete line of computer equipment, from the mini-computer to the large scale data processing system, and therefore , is able to offer your company many alternatives to the solution of your data processing needs . As your requirements grow, Burroughs offers you many avenues for expansion, both within the B80 System, the B800 and B1800 small, medium scale systems.

C. WHAT DO PRESENT BURROUGHS USERS THINK OF OUR COMPUTERS?

A recent survey conducted by International Data Corporation shows Burroughs with an 89% customer loyality. This high customer loyality is the result of the basic research and development philosophy of Burroughs. In developing new systems, software specialists are crosstrained in equipment design and equipment specialists are crosstrained in software, together as a team, they produce a total system. The B 80 is designed as a total system with both hardware and software blending together to produce a most efficient and productive computer for the user.

111 . B80 SYSTEM SUMMARY

The Burroughs B 80 System is a very small, but powerful and fully featured general purpose computer system combining the advantages of large data processing systems with the simplicity and ease of use of an accounting mini- computer.

ACCOUNTING MINI-COMPUTER SIMPLICITY
Simple to Operate
Operator Controlled Processing
Direct Data Entry Console
Hard Copy Audit Control

LARGER SYSTEM ADVANTAGES
Master Control Program
Multiprogramming Capability
Fast, Efficient Data Input Devices
High Speed Processor
Random Access Disk Storage
High- Speed Printers
Data Communications Capability

Let's examine the B80 system features and their importance to you.

A . BURROUGHS COMPUTER MANAGEMENT SYSTEM

The B 80 System utilize Burroughs exclusive Computer Management System (CMS)- a comprehensive software concept specifically designed to integrate into the new family of B80, B800, andB1800 systems.

Truly effective use of high speed, modular hardware is enabled by the very complete Computer Management System offered with the B80.The various modules of CMS bring real simplicity of use to this system. Every aspect of data processing is simplified and enhanced by CMS.

The Master Control Program (MCP) - is actually a program that runs the B80 and the application program for the user. It eliminates the necessity of a user having to learn and understand the intricacies of hardware design. In addition, the MCP provides simple English language communication between the operator and the system.

Micro-programmed Interpreter . These newly created interpreters providethe maximum in efficiency and flexibility. They give the user the best possible system today and, the capability of continued enhancement in the future.

System Utilities - A full range of utilities, copy, sort, dump, etc.. are available with Computer Management System. Once again , the needs of the users for simplicity of operation have been correctly understood and designed into system.

Data Control System - The Data Control System (DCS) is a comprehensive , user oriented software system designed to provide interactive audit entry input,reporting, inquiry, file maintenance , and interactive conversational prompting capabilities. In addition this system provides a high degree of uniformity in operating procedures between different programs thereby adding to the simplicity of the system..

High Level Language Capability - A variety of high level language compilers are offered for on-site program creation :

- Common Business Oriented Language (COBOL)
- Report Program Generator (RPG)
- Network Definition Language (NDL)
- Message Processing Language (MPL II)

MASTER CONTROL PROGRAM (MCP)

Burroughs advanced Master Control Program (MCP) is a comprehensive operating system for the B80 .
It is designed to simplify the operation and control of the system and to increase productivity, by automatically handling many functions which would ordinarily be handled by an operator or a programmer. The principle features of the MCP are :

- Operator System Communication
- Multiprogramming
- Integrated Virtual Memory
- Dynamic resource allocation
- Input/ Out-put Control

OPERATOR SYSTEM COMMUNICATION

The key to ease of operation and installation of the B 80 is the communication provided by the MCP between the system and the operator.
Messages printed or displayed at the console by the MCP are in simple, clear statements .
They indicate that jobs have started or ended, that data is missing that an error exists, or on request, will display the status of the jobs in the mix. The operator communicates to the system by typing input messages.
The result of this two-way communication between the system and the operator is a printed or displayed message of all major activities that have occured, in plain English Language.

DYNAMIC MULTIPROGRAMMING

Dynamic multiprogramming makes use of all available resources. When executing a single program the processor remains idle until a peripheral provides the computer with data or a program segment. While this transfer of data or code is taking place, the processor ideally should be used for executing other programs, thus improving total system efficiency. This dynamic reassignment of an otherwise idle processor is called dynamic multiprogramming and is a basic capability provided automatically by the MPC.

INTEGRATED VIRTUAL MEMORY

Virtual memory refers to the concent whereby a program is broken into segments and only those segments which are required for the execution of that program are in main memory. At the time of completion the computer determins logical segment points and builds a directory for each program. Typically a program will be broken into input/output functions constant data, variable data, and executable logic code. Breaking the programs into segments enables the B 80 to provide a cost effective solution to processing requirements. This is vitrual memory concept. Obviously this sames the user the cost of additional memory. It also enables the B 80 to process a mix of programs which may be larger than the main memory, optimize memory utilization by accepting new programs or by permitting large portions of active programs to remain resident in main memory. Integrated virtual memory on the Burroughs B 80 system results in lower cost and greater system efficiency for the user.

DYNAMIC RESOURCE ALLOCATION

A major function of the MCP is to control the B 80 and maximize system productivity by allocating resources to meet job requirements. The MCP maintains an inventory of all the resources available on the B 80 . If a change occurs, the MCP will recognize the change and utilize the resources as needed . The MCP keeps track of :-

- What programs are running and the program segments of each program
- Memory assignments and available space.
- Peripheral assignments and available units.
- Disk files and available space.
- Program priority

By handling these resources automatically, the MCP provides the user with maximun system efficiency and throughput.

INPUT / OUTPUT CONTROL

The MCP handles all physical input/output operations and controls the operation of the input/output hardware. User programs have only to be concerned with logical I/O operations, such as opening, or closing, files and reading from, or writing to, a file. When a user program wishes to perform a logical I/O it communicates its request to the MCP. The MCP translates the request into the series of operations necessary to perform the desired action at the hardware level. The MCP automatically locates the files, transfers data to and from a physical device, and monitors for read/write errors. When the I/O is completed, the MCP returns control to the user program with an indication to the user program whether the I/O was successful or unsuccessful. If unsuccessful, the MCP also indicates to the user program the reason for failure.

In summary, the MCP handles physical I/O by :-

- Locating files
- Data transfer
- Error monitoring
- Buffer management
- Automatic label recognition
- Automatic retry on detection of an error

Because the MCP handles all of these functions automatically, they do not have to be imbedded into user programs. As a result, application programs are far simpler to write.

MICROPROGRAMMED INTERPRETERS

The variable micrologic design of the processor provides flexibility by providing multiple virtual machines within a single host B 80 system. A high level language such as COBOL runs very efficiently on the B 80 because of an interpreter, designed specifically for this language. In a data communications environment, two high - level languages, Network definition language (NDL) and Message Processing Language II (MPL II), are very efficient on the B 80 because of interpreters designed specifically for them. This open - end design structure means that other languages may be implemented efficiently on the B80 as new interpreters are developed. It also means that customers are

protected against obsolescence because they realize improvements in the throughput, without changing hardware, by taking advantage of improvements made to interpreters.

SYSTEM UTILITIES

To provide system initialization and program development aids, and to relieve the user from developing complex system software, Burroughs is providing a series of utility programs.

Each of the utilities provided has been specifically designed to furnish optimum performance on B 80 systems, through ease of operation and documentation provided with it.

DATA CONTROL SYSTEM

Data control system (DCS) inlcudes data handling capabilities designed to provide :

- Interactive entry and prompting.
- Generalized file build and maintenance.
- Basic input reporting and inquiry capability.

This system greatly enchances the total power of B 80 systems.

The input portion of DCS is transaction oriented and specifically designed for ease of use by keyboard operators. It allows for the acceptance of media from off-line Audit Entry Systems. The use of off - line Audit Entry machines not only provides error free input but also allows considerable growth in the systems input requirements.

Generalized file maintenance refers to that portion of DCS which allows the operator to build and maitain files. The user simply indicates to the system what file is to be created or changed the records to be affected, and what fields are to be entered. File creation and maintenance using DCS will greatly reduce the programming effort required for new programs by eliminating the need of writing initial installation and maintenance routines in the user program.

DCS also provides a basic input reporting and inquiry capability without the requirement of writing a separate program. It is designed so that information may be retrieved and displayed without requiring detailed technical knowledge of formatting, effort required to develop and maintain inquiry or input report programs.

HIGH LEVEL LANGUAGES

The use of multiple high level languages on the B 80 system provides for a great deal of design flexibility. The efficient use of more than one language is made possible by the variable micrologic design of the B 80 processor and the MCP providing multiple virtual machines within a single central B 80 system.

COMMON BUSINESS ORIENTED LANGUAGE (COBOL)

COBOL is a high level user oriented language and is available to the B 80 user for development of application programs. It is designed to meet ANSI " 74 specifications.

The Common Business Oriented Language (COBOL) is one of the most widely used business data processing languages in the industry. The advantages of COBOL are derived from its similarity to ordinary English.

A programmer writting in COBOL, is able to state problem solutions in an English like language that is largely self documenting. This lowers the real cost of programming, program maintenance, and personnel training as well as providing responsive results to the ever changing business needs .

COBOL programs are segmented during compilation to take advantage of the virtual memory concepts of the B 80 systems. This allows the programmer to write programs greater in size than the physical memory size.

THE REPORT PROGRAM GENERATOR (RPG)

The Report Program Generator (RPG) is a problem-oriented language whose broad applicability makes it valuable, in almost any installation, for the development of off-line batch programs.

RPG is a simple, easy to use programming language and is an industry standard. The standard programming forms are self-documenting and require very few comments. These self-guiding forms increase the efficiency of the programming staff and both decrease the cost of program implementation and minimize the effect of any personnel changes.

RPG programs are also segmented during compilation to take advantage of the virtual memory concepts of the B 80 system. This allows the programmer to write programs without considering the computer's physical memory size as a limiting factor.

NETWORK DEFINITION LANGUAGE (NDL)

The Network Definition Language (NDL) is a high-level language

which permits a user to describe a data communications environment in simple parameters. The parameters that define the characteristics of the lines, data sets, terminals, etc... are input to the NDL compiler which converts these source statements into generated tables and code required for a customized network control program.

The code output from the compiler will be brought into the B80 system memory from disk and be executed by the NDL Interpreter.

This will cause the system to perform the line disciplines, buffer management, message queuing, character translation automatic retries etc.. associated with running the specified communications network.

The CMS Network Definition Language can provide significant cost saving benefits to the user implementing a data communications network. For example:

- Application programmers do not have to concern themselves with complex data communications and network techniques.
- Application program products are not affected by network, line or terminal changes.

Data communications networks are dynamic, NDL provides an easy and economical way to implement additional lines, new terminal types etc, as user requirements change.

Various line disciplines may be programmed in NDL and NDL stored as reusable library routines called request sets. Standard NDL request sets will be made available from Burroughs Program Products Library.For users who wish to employ other line procedures, NDL presents an ideal tool to develop such line disciplines in a high level language.

Message Processing Language II (MPL II)

The Message Processing Language II is a high level language designed for the development of Message Control System (MCS) programs or for the development of logic and decision making application programs and provides an added level of control over messages.

The MCS may exercise complete control over the message queues, performing such functions as message validation and message routing. Recording of all processed messages on secondary storage for audit purposes and the temporary tanking in disk files of messages addressed to terminals which are temporarily out of service,are

other functions which may be performed by the MCS.

Burroughs Computer Management System and its individual elements bring significant improvements to data processing activities never before attainable, nor affordable in a small computer system.

B. B 80 HARDWARE CHARACTIRISTICS

I. Hardware Interrupt

The B 80 processor utilizes a hardware input/output interrupt feature. Each peripheral has its own buffered controller which interrupts the system if a data movement operation is to be performed. The processor handles the activity immediately under complete control of the operating system.

The processor devotes more time to the execution of your work, handles data transfers immediately, results in greater throughput.

2. Look Ahead Techniques

While one microinstruction is being executed, the next microinstruction if fetched from memory, decoded, and made ready for execution. This overlap process provides significantly improved system performance.

3. Data Entry

Data entry may be direct data entry through the B 80 System's console or "Audit Entry" data entry via magnetic tape cassette or diskette mediums, and/or"Interactive" data entry devices.

This provides the flexibility to answer current processing needs and the capability to respond to future demands.

4. Data Storage

Data may be created and retained for subsequent use on magnetic tape cassettes, industry compatible mini-disks, Burroughs Super Mini-Disks, and/or Burroughs removable disk cartridge.

These mediums provide fast access on our B 80 System plus the capability to interchange data between systems.

5. Reporting Capability

The B 80 System combines powerful input capabilities and

.../...

productive processing with output capabilities to meet your requirements. Console matrix printers provide output options of 60 characters per second or 180 characters per second. Up to two line printers may be selected for greater output potential with speeds to 250 lines per minute.

6. Data Communications

The B 80 System can support local terminal devices, a remote network, or can function as a terminal system in a large network. Network Definition Language (NDL) and Message Processing Language (MPL II) compilers provide for easy network generation and interface to the applications program to ensure timely and efficient implementation of a communication environment.

C. B80 SYSTEM - COMPATIBLE WITH THE FUTURE

The B 80 System has been designed to assure compatibility with the future. Systems features such as Master Control Program, variable Micrologic, etc.., combine with hardware modularity to provide you the responsiveness to meet the challenge of the future.

Let's briefly review the components of the B80 Series.

PROCESSOR AND DISK STORAGE

Read/write memory to 128 KB
Burroughs Super Mini-Disk to 6 million bytes
Burroughs Removable Cartridge Disk to 27,6 million bytes.
Burroughs fixed disk to 37 MB

INPUT / OUPUT

B 80 Direct Data Entry Console.
System Display.
Console Printer with speeds up to 180 characters per second.
Line Printers- Two - with speeds up to 250 lines per minute.
Magnetic Tape Cassette.
Industry Compatible Mini Disk, Burroughs Super Mini- Disk.
Multiple terminals for Inquiry/Input.

DATA COMMUNICATIONS

Versatile Data Communications Capabilities.
Host or terminal Capability.

The capability of growth is further secured by the total code compatibility of the B 80 with the larger B800 and B1800 CMS processors.

The System can be reconfigured to a medium system configuration. The transition is smooth as no reprogramming effort is required for the running applications.

The high level of responsiveness offered by the Burroughs B 80 System is the key to your continued productivity and effective usage. You will benefit from the management information and control capability you want and need, in a constantly changing business environment.

VI CUSTOMER SUPPORT

A. EDUCATION AND TRAINING

The proper education of your staff is vital to the successful installation of your system. The Burroughs education plan has been designed to train your personnel involved in every phase of the installation. Courses are available to management executives, installation managers, system analysts,programmers, and operators.

The schedule of courses recommended for you and your staff are detailed in Implementation Procedures, Section VII.

B. FIELD ENGINEERING SUPPORT AND SYSTEM SUPPORT.

While Burroughs manufactures and markets the very finest of hardware,we also recognize the importance of maintenance support. Burroughs maintains a highly competent field engineering force, to provide you with excellent service.

To keep your B80 System at the peak of operating efficiency, Field Engineers will perform periodic Preventive Maintenance. To assure you of continued system availability, they will render emergency service if required.

In addition, confidence test routines resident in the B80 System's memory may be executed by you to check the major functional components of your system.Additional diagnotic routines provide your operator the capability to perform full confidence testing.

C. MARKETING SUPPORT

Burroughs representatives are trained specialists, experienced in the isntallation of Business Management Systems. They will counsel your installation Manager in the proper implementation of your system and coordinate the resources Burroughs Corporation has to offer.

D. TECHNICAL SUPPORT

A competent technical staff is available to assist in

.../..

the proper implementation of your system and to respond to your system questions.

Your Burroughs marketing representative will assist and coordinate this resource for you.

E. COMPUTER FORMS.

Your Burroughs marketing representative and the System support representatives will make sure that your requirements for computer forms are satisfied by interfacing with your company and your forms supplier.

V INVESTMENT SUMMARY

Proposed Configuration

One Burroughs B 80 System
Including :- 80 KB Processor (1 MHZ)
180 CPS Console printer
Numeric, Alphanumeric keyboards
Burroughs Super Minidisk dual drive of an on - line capacity of 2MB. (both disks removable)

Price :- L.EG. 22,789 C.I.F

System Software:-Annual rent L.EG. 300 .-

Method of payment:
50% at the time of signature of contract.
50% upon receipt of the shipping documents

Delivery 3 - 4 months from date of signature of contract.

Maintenance A free of charge preventive and on call maintenance, including parts, is offered for 6 months after installation. Upon expiration of above period, annual Maintenance Agreement will be signed allowing the same benefits, against payment of a fee according to our price list effective at the time of signature of the agreement.

IV APPLICATION SUMMARY

The basic application will be the information Management systems as outlined in your report to the Ministry of Irrigation.

The implementation of such an IMS is considerably facilitated by the Powerful software of the B 80 CMS.

The following procedures will be used :

INPUT : Data will be keyed into the computer through the incorporated numeric and alphanumeric keyboards. The accuracy will be checked by the system according to the controls that will be established.

Processing :- Processing - programs will be used on request to produce the data is be output and stored for further use.

Output:- The outputs will be printed on the serial printer in the required number of copies and the proper formats.

The capabilities of the B 80 System in its present configuration and the possibilities of expansion will, we believe, permit the customer to consider the extension of the benefits of computerization to other fields of his activities.

Applications such as Payroll, Inventory Management System etc.., can easily be implemented by using the System Software and the programming facilities of the B 80 .
Possible requirements of hardware expansion, if any, will be determined by the result of the analysis of each additional application.

VII IMPLEMENTATION PROCEDURES

A. DEFINITIONS OF RESPONSIBILITIES

As a result of Burroughs Corporation experience gained in installing many data processing systems, we believe that an understanding as to the general responsibilites of your company and MMM/Burroughs is invaluable to the mutual success of your installation of the B80 System.

Specifically, unless otherwise agreed. It is the responsibility of MMM/Burroughs to provide your company with:

I. Equipment under MMM/Burroughs agreement for purchase or lease at established purchase (or rental) charges. This includes related Systems Software for controlling application programs.

2. Maintenance - under MMM/Burroughs Maintenance Agreement, at current rates, to keep your equipment at the peak of operating efficiency.

3. Education

   - System analysis and other application courses as appropriate.
   - Professional courses for management
   - Computer language courses.

4. Utility and Compiler programs - under program products license or software and support agreement at established program prices.

5. Programming assistance - under an agreement for Burroughs system engineering service at established charges.

6. Provide technical guidance in the physical installation and planning of your B 80 System installation.

7. Provide continued support for the program products installed.

8. Provide information as to new developments in Burroughs system techniques and equipment which may apply to your operation.

<u>It is the responsibility of your company to</u> :

I. Determine the economic justification for the proposed

.../...

use of Burroughs equipment or validate any data concerning economic justification prepared by MMM/ Burroughs.

2. Validate application plans proposed by MMM/Burroughs including equipment configurations, systems design, procedures and forms.

3. Incorporate in the application design sufficient check points, balances, and controls neccessary to satisfy accuracy, restart and audit requirements.

4. Select the programming to be used and/or determine the utility of any available pre-written programs.

5. Establish any protective measures that may be appropriate to safeguard the privacy of data or meet security requirements.

6. Write and test the necessary programs, or modifications to programs obtained from Burroughs or other sources.

7. Establish adequate back-up plans based on alternate procedures and/or partial on-site duplication of critical machines and/or off-site reciprocal arrangements for equipment with appropriate specifications.

8. Provide personnel, supervision, and management sufficien to obtain the desired results.

B. EDUCATION PLAN

Proper education of your staff is vital to the successful installation of any system. The Burroughs education plan has been designed to train your personnel involved in every phase of your installation.

The B80 Systems Customer Education Program will provide the necessary education for :

I- The executive who has management responsibility for implementing, staffing, financing, and evaluating the system.

2- The installation manager who is responsible for installin the system and overseeing its operation.

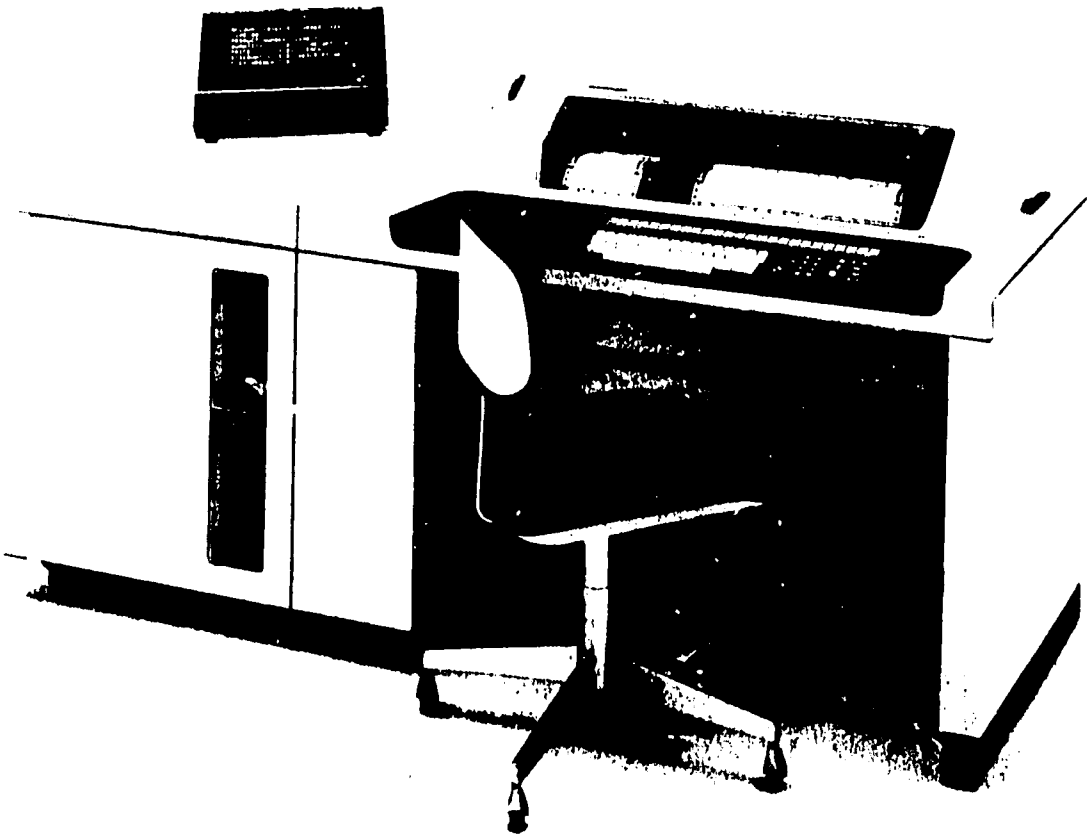
3- The persons who will operate the system.

4 - The programmer, should you select to have someone on your staff capable of programming.

Course	Attendees	Duration
I. Introduction to Computers	Department Management, Computer personnel	5 days
2. B 80 Hardware & System software appreciation	Computer Personnel	I week
3. Hands-on Workshop	Computer Personnel	5 days
4. Operators Basic Training & hands-on	Operators	I week
5. Cobol &RPG Programming languages	Computer Manager & Programmers	3 weeks

Burroughs Small
Computer Systems

Burroughs B 80-24/124 System



The B 80-24/124 System is pictured with optional mini disk.

The B80-24 is a small but fully featured general purpose computer system. It combines the most advanced concepts of both hardware and system software into one system. Among the salient hardware features of the B80-24 are:

- A highly efficient main processor.
- SELF-SCAN® System Display.
- A 180-character-per-second matrix printer.
- Burroughs super mini disk subsystem.
- Burroughs cartridge disk subsystem.
- Burroughs fixed disk subsystem.
- Full data communications capability.

These features combined with Burroughs Computer Management System (CMS) and/or Burroughs Accounting Computer System (ACSYS) system software, provide a cost-effective approach to data processing requirements—today and in the future.

Processor

The B80-24 central processor features the most advanced design in Large Scale Integrated Circuitry (LSIC), including NANO memory, micro stack, I/O logic, and system registers. This design allows the processor to be packaged with minimum space requirements, yet offering the processing power of larger computer systems.

Major processor characteristics include:

- Clock speed of 1 MHz.
- Memory access time of 500 nanoseconds per 1 byte.
- "Look Ahead" and "Overlap" of the fetch and execute of microinstructions. These allow more than one function to occur during a processor cycle. The processor operates under control of microinstructions stored in memory. Portions of processor logic continuously fetch and decode microinstructions into control signals which cause processor functions. Buffers in the decode logic enable an overlapping of these functions. These allow more than one function in a single processor cycle and contribute significantly to enhanced throughput.
- One microinstruction can have the capability of multiple character transfers. Data movement and processor efficiency are greatly enhanced by this feature.
- Through Hardware I/O interrupt, the processor takes only the time to service an I/O port when it is actually needed. This capability reduces processor overhead because scanning of the I/O ports is not needed.
- The B80-24 processor has up to eight I/O channels, each with its own unique address.
- Data movement occurs along an 8-bit wide data path.
- Main memory is Metallic Oxide Semiconductor (MOS) with a cycle time of one microsecond for one byte. The system has 4KB Read Only Memory (ROM) which contains:
  - Routines for loading interpreters from cassette or disk.
  - Basic customer confidence routines.
- 60KB read/write memory is basic, expandable to 124KB in 16KB increments.

On-board diagnostics

- On-board diagnostics are designed to contribute to optimum performance of B80 systems. This series of Maintenance Test Routines (MTR) assists in analyzing faults in the system and detecting degraded performance of a component before a fault occurs. They perform tests on the entire system, including peripherals, with the results printed in simple, easy-to-read statements on a journal. These on-board diagnostics facilitate faster repairs and assist in reducing unscheduled maintenance.

Keyboard

The keyboard provides a proven concept in design for ease of use and productivity. The following keyboard features are standard:

- Keyboard buffering permits keyboard entry at an operator's pace even when the printer and processor are in use.
- Standard alphanumeric typewriter.
- Ten-key numeric data input keyboard.
- Four operation control keys duplicated on both the alphanumeric and ten-key keyboard for operator convenience.
- Programmatic indicator lights for operator guidance.
- Twenty-four Program Select keys to simplify operator use of the system.

Printer and Forms Handler

The inbuilt line printer and forms handler are designed for flexibility and throughput. Characteristics include:

- 180-character-per-second serial matrix printer.
- Printer positioning at 450 characters-per second.
- 25.6-inch wide forms handler.
- Separate print journal for operator communication with the Master Control Program.
- Second pinfeed for normal typewriter mode or automatic line printer mode.
- Third pinfeed (optional) to permit greater flexibility in forms handling.

Disk Storage Subsystems:

The B80-24 may be configured with a variety of disk storage devices. These include:

- Up to 4 million bytes of Burroughs super mini-disk—or
- Up to 18.4 million bytes of Burroughs disk cartridge—or
- 18.8 million bytes of Burroughs fixed disk and one million bytes of inbuilt Burroughs super mini-disk.

Also available on the B80-24 are configurations with the following disk drives.

Burroughs Cartridge Disk Subsystems

- 4.6 million bytes/145ms average access time.
- 4.6 million bytes/80ms average access time.
- 9.2 million bytes/100ms average access time.

Burroughs Super Mini-disk Subsystems

- 1 million bytes/266ms average access single drive.

- 2 million bytes/266ms average access dual drive.
  A second inbuilt Burroughs super mini-disk may be added to the fixed disk configuration.

Input/Output Capabilities

- Industry-compatible Mini-Disk drive of 243 thousand bytes per single drive is optional.
- SELF-SCAN® System Display.
- Line Printer (optional).
- Combination system printer and inbuilt line printer.
- Terminal systems (optional).

Data Communications Characteristics

- Data Communications Channels—up to two
- Mode of Operation—half duplex.
- Interface—a choice of:
  - Asynchronous data set, BPS.
  - Synchronous data set, BPS.
  - Burroughs Data Link Control.
  - Two-wire Direct Connect up to 1,000 feet.
  - Burroughs Direct Interface (BDI) up to 15,000 feet.
- Buffers
  - Transmit Buffer(s).
  - Receive Buffer(s).

Burroughs Computer Management System (CMS)

Burroughs Computer Management System (CMS) is a totally integrated software system designed to provide identical procedures and results for Burroughs advanced interpretive computers.

CMS includes:

- Master Control Program (MCP).
- Data Control System (DCS).
- CMS REPORTER.
- On-Board High-Level Language Compilers.
- Microprogrammed Interpreters.
- Business Management Systems (BMS).
- Utility Programs.

Master Control Program (MCP)

The B80 MCP is a comprehensive operating system designed to simplify operation and control of the system. It increases productivity by automatically directing many functions which would ordinarily be handled by an operator or a programmer. Principal MCP features include:

- Operator Communication—The MCP provides a two-way communication between the operator and the system. MCP messages are simple, easy-to-understand statements.
- Multiprogramming—More than one job may be executed concurrently. The MCP controls automatic multiprogramming by assuring efficient use of the processor on one job while I/O is occurring for other jobs.
- Virtual Memory—The B80 MCP provides for a complete virtual memory system. This enables the B80 to run programs which are larger than the available memory size. This same concept enables the MCP to maximize memory utilization in a multiprogramming environment.
- Dynamic Resource Allocation—The MCP maintains an inventory of the resources available on the system and maximizes productivity by allocating these resources to meet job requirements. Among these resources are:
  - Programs that are running and the segments of each program.
  - Memory availability.
  - Peripheral assignments and additions.
  - Disk storage space.
  - Program priority.

  Any changes in resources are recognized automatically by the MCP so that optimum system efficiency and throughput can be achieved. This capability makes possible the utilization of additional resources without reprogramming.
- Input/Output Control—The MCP handles all physical I/O operations and also controls the operation of I/O hardware. These activities include:
  - Locating files.
  - Data transfer.
  - Buffer management.
  - Automatic label recognition.
  - Error monitoring.
  - Automatic retry on error detection.

  Because these functions are handled automatically by the MCP, they do not have to be included in user programs. Therefore, application programs are simpler to write.

Data Control System (DCS)

Data Control System (DCS) is an application development aid designed to provide the following data handling capabilities:

- Interactive data entry.
- File creation.
- File maintenance.
- Inquiry.

CMS REPORTER

CMS REPORTER provides an interactive method of specifying repetitive or one-time reports.

- A questionnaire technique simplifies report definition.
- Data to be reported may be selected based on:
  - Record type.
  - Ranges of records.
  - Conditions.
  - Run time supplied data

  Formatting, computed values, statistical and summary information may be specified in defining the report.

High-Level Languages and Compilers

- Network Definition Language (NDL) compiler simplifies the implementation of data communications networks.
- Message Processing Language II (MPL II) compiler generates programs to process, edit, collect, verify, route and audit messages.
- On-board COBOL compiler.
- On-board Report Program Generator (RPG) compiler.

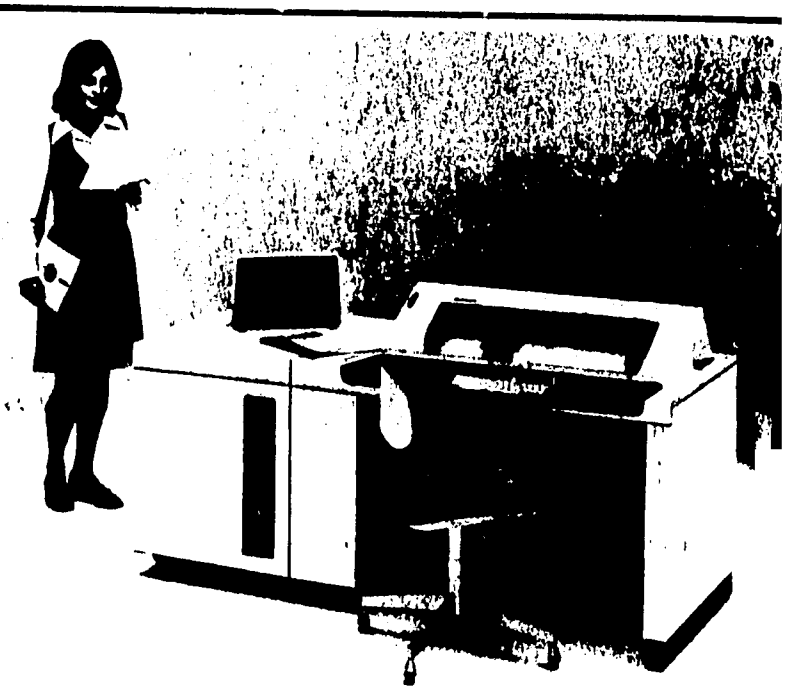
Microprogrammed Interpreters
Microprogrammed interpreters provide multiple virtual machines within a single host system. This open-end design concept means that other languages may be implemented efficiently on the B80 as new interpreters are developed. It also means that the user is protected against obsolescence because improvements in throughput can be realized without changing hardware.

Business Management Systems (BMS)
Burroughs Library of Program Products includes Business Management Systems and specialized application program products. They permit newly installed systems to become productive almost immediately. Burroughs program products have been fully proven in thousands of customer installations. They offer substantial savings, compared with developing and maintaining your own programs.

Utility Programs
Sort, merge, file load, file dump and file copy are just a few of the many Burroughs Utility Programs that can assist the user in obtaining greater system flexibility at an effective cost-to-result ratio.

Burroughs Accounting Computer System (ACSYS)
One of the many features of the Burroughs Accounting Computer System Software is to permit the use of existing Series L/TC magnetic tape cassette programs on B 80 disk systems, utilizing the disk to emulate cassettes. Series L/TC magnetic tape cassette programs may be executed without program modification on the B 80 System, providing enhanced throughput not previously possible with cassette programs.

- ACSYS Software supports the following disk subsystems:
  - Burroughs Super Mini-Disk.
  - Burroughs Cartridge Disk.



Physical Characteristics
Height: 37.00"—93.98 cm
Weight: 600 Pounds—272.16 kg
Depth: 29.00"—73.66 cm
Width: 70.30"—178.6 cm

Electrical Specifications
120 Volt 60 Hz
NEMA-type 5-20P Power Line Connector

93

Burroughs

Computer
Management
System

System
Software
Specifications

MCP

Master Control Program for the B 80 Computer System

STYLE NUMBER

CM80. MCP

CAPABILITY

Burroughs advanced Master Control Program (MCP) is a comprehensive operating system for B 80 Systems. It functions in complete integration with B 80 logic to:

- simplify system operation and control
- provide automatic multiprogramming
- centralize input/output control and data communications control
- permit the use of high-level, user-oriented programming languages, and
- accommodate future growth without reprogramming

MCP reduces programming and operating costs alike, while increasing both the system's productivity and responsiveness to the user's needs.

EASE OF OPERATION

- MCP manages all computer resources for system efficiency:
  - Controls memory space
  - Assigns peripheral units as needed
  - Facilitates random access disk file storage of programs and data
  - Manages program library
  - Retrieves jobs for processing
- Improves computer staff efficiency by simplifying system operation.
- Communicates with the operator in abbreviated English phrases.

SIMPLIFIED SYSTEM CONTROL

- Provides operator/system communication via console printer.
- Notifies operator of missing data, errors, start and end of jobs, and special conditions.
- Provides status of all active jobs upon request.

More Results Through Automatic Multiprogramming

- Runs segments of multiple programs concurrently:
  - Automatically allocates memory areas
  - Initiates I/O operations
  - Provides automatic error handling procedures
- Accepts programs in any sequence.
- Executes programs according to priorities.
- Keeps all hardware/software components functioning at capacity for maximum task throughput.

Centralized Input/Output Control for Total System Efficiency

- Obtains input data automatically.
- Transfers output data to peripherals.
- Multiprograms data communications and on-site work automatically.
- Works with Processor I/O control logic to optimize concurrent use of channels.

Programming Flexibility With User-Oriented Languages

- Accepts source programs in COBOL, RPG, NDL and MPL II.
- Guides compilation of programs.

- Assists in the use of utility functions (sort, merge, edit) and media conversion aids.
- Automates many tedious and costly programming operations such as:
  - Memory allocation
  - Loading routines
  - File opening and closing
  - Input/Output procedures
  - Console file handling
  - Indexed file handling
  - Program library calls
  - Error handling
  - Other computer "housekeeping"
- Saves time and money:
  - Programmers can concentrate on problem solutions
  - Less training time for programmers
  - More time for constructive programming

Growth Without Re-Programming

- The MCP lets you add memory, peripheral devices, data communications and terminal systems as you need them.
- Automatically recognizes system configuration.
- Permits confident, long-range planning.

SYSTEM REQUIREMENTS

Central Processor: B 80

Memory:

Peripherals: appropriate disk subsystem operator console

PRODUCT IDENTIFICATION

Program ID	Description	Code Form	Support Category
CM80 MCP	Operating System	Object Code	A*

*Support Category A indicates a "Supported Licensed Program" as defined in the Program Products License.

Burroughs
Computer
Management
System

System
Software
Specifications

UTL
Utilities and Intrinsics for the B 80 Computer System

STYLE NUMBER

CM80 UTL

CAPABILITY

To provide system initialization and debugging aids, and to relieve the user from developing complex system software (e.g. Sorts), Burroughs has provided a series of utility programs and micro-coded routines. The functions provided are as follows:

- Initialization
- Debugging utilities
- Sort utilities
- File maintenance utilities
- Load utilities
- Dump utilities
- List utilities
- Copy utilities
- Media conversion utilities
- Miscellaneous utilities

OPERATING EFFICIENCY

Each of the utilities provided has been specifically designed to furnish optimum performance on the B 80 Systems through ease of operation and documentation provided with it.

SYSTEM REQUIREMENTS

Central Processor: B 80

Memory:

Peripherals: appropriate disk subsystem
operator console
printer, if required by the utility

System Software: Computer Management System (CMS)
Master Control Program (MCP)
MPL II Interpreter

PRODUCT IDENTIFICATION

Program ID	Description	Code Form	Support Category
ADD	Adds files from magnetic tape cassette to disk, if not already present on disk	Object Code	A*
CLSTR	Cold start performs initial loading of system software on to disk. Optionally disks may be initialized and/or copied.	Object Code	A

96

Program ID	Description	Code Form	Support Category
COPY	Magnetic tape cassette/disk file copy with options of specifying portions of a file and/or file-parameter changes.	Object Code	A
DUMP	Writes files from disk to magnetic tape cassette.	Object Code	A
EDIT	Source file creation and maintenance.	Object Code	A
FS	Indexed file squash with index-table adjustment.	Object Code	A
KA	Prints an analysis of disk-space utilization.	Object Code	A
LIST	Magnetic tape cassette/disk file print with option of hexadecimal and/or alpha print-out and/or specifying portions of a file.	Object Code	A
LOAD	Writes files from magnetic tape cassette to disk, removing old files of the same name.	Object Code	A
LR	Lists disk-file parameters for selected files.	Object Code	A
MERGE	Combines up to 16 files.	Object Code	A
MODIFY	Changes parameters relating to file(s), as referenced by a specified program.	Object Code	A
PD	Ascertains presence (or absence) of file(s) on disk or magnetic tape cassette.	Object Code	A
RM	Removes file(s) from disk.	Object Code	A
SORT	Sorts a data file on specified key(s), maintaining key-tables as necessary.	Object Code	A
UNLOAD	Performs the function of DUMP, followed by an automatic RM, of specified file(s).	Object Code	A

*Support Category A indicates a "Supported Licensed Program" as defined in the Program Products License.

Burroughs
Computer
Management
System

System
Software
Specifications

COBOL

COBOL Compiler for the B 80 Computer System

STYLE NUMBER

CM80 COB

CAPABILITY

Burroughs COBOL Compiler converts source programs written in COmmon Business Oriented Language (COBOL) into object programs for execution by B 80 Systems. COBOL is an English-like language used for stating logic procedures to be followed by the computer in processing general business applications. This high-level language compiler offers a number of advantages over assembler languages and programming codes. These advantages include simpler, faster programming, easier program documentation and modification, and compatibility with larger data processing systems for major savings in future system conversion costs.

Burroughs COBOL includes capabilities called for by the American National Standards Institute plus extensions added by Burroughs to derive full benefits from the operating system and new hardware capabilities and to further reduce programming time and cost. Burroughs COBOL compiler generates compact object programs which save memory space and which the B 80 Systems can execute efficiently.

Simpler, Faster Programming

Its English-like structure makes COBOL an ideal language for business application programming. If a problem-solving procedure can be defined in English, it can be stated in COBOL for the computer.

A single COBOL statement may represent a number of computer instructions. This helps keep COBOL programs concise and comparatively simple in structure. It shortens program writing time and testing time; yet, it permits a high degree of sophistication when necessary. In addition, Burroughs COBOL incorporates program aids that help maintain clear logic trails even in large, complex programs.

Freedom from memory size limitation through simple program segmentation is another important consideration. The Burroughs B 80 Computer regards COBOL programs as collections of logical segments which it can operate upon individually or in groups. This means COBOL programs can be written without considering the computer's memory size as a limiting factor.

Easier Documentation and Maintenance

Burroughs COBOL's easy-to-read syntax and standardized format make programs self-documenting. Any problem-solving steps taken in structuring a program can be identified exactly. Since COBOL programs can be modified or expanded by other COBOL programmers, personnel changes have a minimal effect on program maintenance.

Compatibility With Large Systems

Burroughs B 80 COBOL provides a direct, inexpensive bridge to other Burroughs data processing systems. The ability to move existing programs to another system with virtually none of the re-programming effort or cost usually associated with conversion,

offers long-range protection for your programming investment and means that you can plan future projects with confidence.

Efficient Operation

Burroughs COBOL language and Burroughs COBOL compiler create application object programs which operate in unison with the B 80 Master Control Program (MCP). This integration of application programs with system software results in rapid compilation, compact code structure and efficient execution. The B 80 operating system automates many detailed operations related to input/output requests, error handling, file handling, and memory allocation. These operations would otherwise be programmer responsibilities.

SYSTEM REQUIREMENTS

Central Processor: B 80

Memory:

Peripherals: appropriate disk subsystem
operator console
card reader or alternate input method
line printer or alternate output method

System Software: Computer Management System (CMS)
Master Control Program (MCP)
MPL II Interpreter for Compiling
COBOL/RPG Interpreter for Execution

PRODUCT IDENTIFICATION

Program ID	Description	Code Form	Support Category
CM80 COB	Compiler	Object Code	A*

*Support Category A indicates a "Supported Licensed Program" as defined in the Program Products License.

Burroughs
Computer
Management
System

System
Software
Specifications

RPG

Report Program Generator Compiler for the B 80 Computer System

STYLE NUMBER

CM 80 RPG

CAPABILITY

Burroughs Report Program Generator (RPG) Compiler converts source programs written in the RPG language into object programs for execution on B 80 Systems.

Burroughs RPG is a problem-oriented language whose broad applicability makes it valuable in almost any data processing installation. Its simplicity helps minimize programming time, while a number of extensions (incorporated into Burroughs RPG) increase the effectiveness of this language as a convenient, low-cost programming tool.

Burroughs RPG Compiler produces compact object programs which B 80 Systems can efficiently execute.

GENERAL FEATURES

Programming Simplicity

- Burroughs RPG is a simple, easy-to-use programming language. The standard programming forms are self-documenting and require memorizing of very few conventions. These forms increase the efficiency of programmers, and decrease both the cost of program implementation and the effect of any personnel changes. RPG programs are segmented automatically during compilation, which means that programmers can generally write without considering the computer's memory size as a limiting factor.

Operating Efficiency

- Compiled RPG programs operate under supervision of the Master Control Program (MCP).

Compatibility

- Burroughs B 80 RPG is similar to most other RPG versions. Minimal conversion efforts are required for implementing existing RPG programs on a Burroughs B 80 System.

SYSTEM REQUIREMENTS

Central Processor: B 80

Peripherals: Burroughs Super Mini-Disk or Cartridge Disk

System Software: Master Control Program (MCP)
MPL II Interpreter for compiling
COBOL/RPG Interpreter for execution

PRODUCT IDENTIFICATION

Program ID	Description	Media	Support Category
CM 80 RPG	Compiler	Object Code	A*

Support Category A indicates a "Supported Licensed Program" as defined in the Program Products License.

100

STYLE NUMBER

CM 80 NDL

CAPABILITY

Burroughs B 80 System Network Definition Language (NDL) Compiler converts source statements written in NDL into generated tables and code required for a custom data communications environment. These tables and the code produced are for use in a B 80 System. When utilized in the system performs the line disciplines, message queueing, automatic retries, and character translation. Through the NDL-generated program and the B 80 System, users can deal with communications devices in the same manner as with more conventional peripheral devices such as tapes and printers.

GENERAL FEATURES

Programming Simplicity

The Network Definition Language (NDL) is a programming tool that enables programmers to define a Data Communications environment that is designed to fit its organizational requirements and vary that environment easily and quickly. This relieves users of programming in a low-level language and of having to limit the system to a set of commonly-used pre-programmed routines.

- Application programmers do not have to be trained on terminal devices or line discipline routines.
- Application programs are not affected due to line or terminal changes.

SYSTEM REQUIREMENTS

Central Processor: B 80

Peripherals: Burroughs Super Mini-Disk or Cartridge Disk

System Software: Master Control Program (MCP)
MPL II Interpreter for compiling
NDL Interpreter for execution

PRODUCT IDENTIFICATION

Program ID	Description	Media	Support Category
CM 80 NDL	Compiler	Object Code	A*

**Support Category A indicates a "Supported Licensed Program" as defined in the Program Products License.*

Burroughs
Computer
Management
System

System
Software
Specifications

MPL II

Message Processing Language Compiler for the B 80 Computer System

STYLE NUMBER

CM 80 MPL

CAPABILITY

The Message Processing Language (MPL II) is a compiler language used to solve logic and data communications message control problems. It is a procedure-oriented language with extensive subscripting, substringing, and data concentration abilities. Data declarations include arrays and substructures in bit or character formats. Data space may be allocated as permanent, local to procedures (shared space), dynamic (size calculated at run time), and virtual.

Data communications constructs of MPL II may interact with the user's NDL-generated program.

Burroughs MPL Compiler converts source programs written in the Message Processing Language into compact object programs for execution on B 80 Systems.

GENERAL FEATURES

Programming Simplicity

MPL II is a high-level programming tool that expedites the implementation of logic and decision-making applications on the B 80. The programmer does not have to be concerned with the physical technicalities of the computer. Instead, he uses MPL II to express the problem solution.

Operating Efficiency

Compiled MPL II programs operate under supervision of the Master Control Program (MCP). A MPL program or its program segments can be multi-programmed with other language programs to allow efficient use of all system resources.

The B 80 System accommodates a user-to-data communications interface. Through this interface, if the user desires, he may maintain rigid control over the system and handle system decisions such as file security, file control, second-level handling, pre-processing and post-processing of messages.

Growth Without Re-Programming

MPL II programs prepared for a basic B 80 System will operate without change on larger Burroughs systems. No re-programming, or even re-compilation, is required, yet the programs will benefit fully from the larger system's higher speed and more powerful resources.

SYSTEM REQUIREMENTS

Central Processor: B 80

Peripherals: Burroughs Super Mini-Disk or cartridge disk

System Software: Master Control Program (MCP)
MPL II Interpreter

PRODUCT IDENTIFICATION

Program ID	Description	Media	Support Category
CM 80 MPL	Compiler	Object Code	A*

**Support Category A indicates a "Supported Licensed Program" as defined in the Program Products License.*

107

III

STATUS OF THE INVITATION FOR BID FOR THE THIRTY-SEVEN PUMPING STATIONS

3.0 Status of the Invitation for Bid for the Thirty-seven Pumping Stations

As reported previously, the CONSULTANT completed the Invitation for Bid on July 15, 1978. During the next three months, disagreements between the Client and USAID concerning various aspects of the legal provisions of the document prevented its issue. During the 4th week of October these disagreements were resolved and the tender was announced locally. IFB documents went on sale at the Ministry of Irrigation on November 17th, 1978. Because of delays in announcing the tender in the Commerce Business Daily, IFB documents did not go on sale in the U.S.A. until December 23, 1978. For this reason, USAID requested and the Ministry of Irrigation agreed that the pre-bid conference originally scheduled for December 23, 1978 be postponed until January 8, 1978. This change in the conference date was announced locally during the last two weeks of December.

On December 21, 1978 the CONSULTANT's home office was notified by the Egyptian Embassy that the twenty copies forwarded by the Ministry had been sold out and that there were requests for additional copies. This information was passed on to USAID Cairo which subsequently requested that there be a second pre-bid conference on January 29th and that interested tenderers receiving late copies of the IFB be given an extension of the submission date to March 29, 1979. The Ministry agreed to this additional request and agreed to send 30 more copies of the IFB to its Embassy in Washington on January 6, 1979.

To date, 60 IFB documents for the pumping and electrical equipment have been sold by the Ministry and 20 copies by the A.R.E. Embassy in Washington, D.C. The supplier and

manufacturer response to this tender appears high and discussions between the CONSULTANT and prospective suppliers/manufacturers have revealed that many tenders will include offers of technologically advanced equipment which require minimal civil works. If such offers are within specifications and fall within the lowest price ranges, there is a good possibility that the Ministry will be able to award the tender to manufacturers with the best technological designs whose civil works requirements are minimal in cost and erection time. If this possibility occurs, the time lost through resolution of the disagreements between the Client and USAID could be more than compensated for.