THE DESIGN OF A PUMPING STATION FOR THE IRRIGATION OF FOUR HUNDRED ACRES IN AKKAR

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THE DESIGN OF A PUMPING STATION

FOR THE IRRIGATION

Four Hundred Acres

OF ~~ONE THOUSAND HECTARES~~ IN AKKAR

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Contents:-

INTRODUCTION

In the fertile plain of Akkar flows the river of El-Kabeer which has a minimum discharge of 2m-sec. Due to its very gentle slope and its relatively deep water level, its water is not used for irrigating any land because of the impracticability of diverting it by a crude gravity system: the only method extensively used in the country.

Thus every year a fortune is lost to the country as a result of the unexploitation of its water resources. this country, being primarily agricultural and with a limited water supply, can not neglect the development of all its cultivable and fertile land into irrigated farmlands.

From the foregoing wee see the necessity of an immediate solution to the problem. This an attempt to solve it by considering the technical and economical feasibility of irrigation by pumping.

From the technical point, the installation of pumping machinery on the river does offer serious difficulties which can not be overcome. On the contrary it seems that the hydrological and topographic conditions of the river and the land form an ideal place for the installation of a pump and the smoothness of its operation.

The proximity of the land from the river keeps distribution lines and canals down to a minimum. The lift from low water level to the highest point does not exceed 20 m, which is relatively low lift. As a result of the gentle slope of the river, the velocity of the water is very slow; thus making it possible to dispense with expensive structures for the protection of the pipe.

A pumping station, as any other irrigation scheme, being an investment of capital, should be an economically profitable project. To determine the economic feasibility of such a project is not so simple due to the many factors involved. Moreover, and besides the purely economical considerations, such a project has national social, and political values that can not be accurately measured in terms of money. So a study of all costs involved is made and the determination of the limit of economical pumping is attempted.

Due to the uniformity of conditions in all places on the river this design forms a typical and general solution that could be used anywhere with equal success. The irrigation of 1000 hectares seems to be the maximum capacity of one pumping station in this country. If more land is to be irrigated, the duplication of stations becomes necessary. This has the extra advantage of minimizing the length of the canals by making every station irrigate the land nearest to it. Such favorable conditions for irrigation by pumping exist in many places in Syria and Lebanon, especially on the Euphrates.

The lack of complete references on the different aspects of this problem makes it immpossible to produce a complete and satisfactory treatment of the subject with the necessary design and construction details.

My thanks are due to Prof. E. Romansky who was of a great help to me in ~~bringing out~~ developing this thesis.

C H A P. I.

--- Study of the Requirements -----

I:- WATER REQUIREMENTS: A steady and uninturuted flow of water enough to irrigate one thousand hectares of land during the arid summer months is to be pumped. The gross water requirement is equal to the net water requirement of the land plus all the coveyance losses.

THe factors affecting the net requirement are;

I: THe kind and diversity of crops. Deep rooted plantd,as frui ts,need more water than shallow rooted plants,as cereals. THe growing of variety of crops which have different requirements and periods of maximum use will result in a more uniform demand.

2: THe Preparation of the Land,its slope, the method of application of the water,and the skill of the irrigator.

3: The Time and frequency of Cultivation. Cultivation reduces the losses in the moisture due to evaporation.

4: THe length of time in which irrigation has been practised. Newly irrigated land needs more water for the first two years.

5: Climatic Factors: Precipitation, Temperature, Humidity and wind movement.

6 : Length of the growing season in which irrigation is to be practised.

7: Character of the soil and subsoil. Fertile and manured land requires less water.

8: THe value of the water and method of payment. A high cost charged on the amount consumed in a more economical use.

THe water requirement is measured by a continuous discharge big enough to irrigate the given area and uninterrupted. during the whole of the dry season.

In general the water requirement is expressed in one of two metods:- a-- THe discharge necessary for every hectare, expressed in liters per sec.-b-- THe height of water spread over the entire irrigated area during the period of irrigation.

In Syria and Lebanon we can fix the maximum water requirement as o.7 liters per sec. per hect. This takes into account all losses in conveying canals. In the Bekka the Anjar irrigation project provides a discharge of o.5 liters per sec. for every hectare. At Homs o.4 lit. per sec. per Hect. Was found to be enough.

Special crops as cotton, and rice, and bananas need 1.o lit. per sec. per Hec.

2:-Total HEAD;- At no discharge the head developed by the pump, the shuf-off head, is equal to the difference in elevation between the water level and the highest point at which water is to be discharged. When water begins to flow through the pump and p iping system, an extra pressure head should developed by the pump to overcome all losses and to keep water flowing.these resistance or frictiona l losses are controlled by the designer, and in most cases,it usual to keep them down to a minimum.

The total head against which the pump is working is then:-

I: Suction Head.-Hs-

2: Discharge or Static Head;-Hd-

3: Resistance Heads, which include:

a- Head necessary to create velocity in the suction,hi, pipe ,or velocity head;

b- Influx head or head necessary to overcome resistance due to the shape and condition of suction inlet, footvalve,etc.

$h2 = K1v^2$ -- For a

For a straight pipe projecting into a reservoir Ki=o.oI49

For an opening flush with side or reservoir ; Ki=0.oo73

For bell shaped inlet,Ki varies between o.ooI7 and o.ooI3

c-- Friction Head or head necessary to overcome resistance or friction in the suction and discharge pipes;

$$h3 = f \frac{l}{d} \frac{v^2}{2g} = K2v^2$$

d-- Pump head or head necessary to overcome resistance in the pump passages,valves,etc.-h4

e-- Velocity head or head necessary to create velocity in the discharge pipe.-hi^1

f-- friction head in the discharge pipe, to overcome friction due to;the size of the pipes, bends, valves,etc-$h3^1$

Thus it is evident that the actual working head-ha- has a value equal to:

$$Ha = Hs + Hd + (h1 + h2 + h3 + h4 + hI^{1} + h3^{1})$$

THe resistance head is to be overcome,and the designer has the possibility of making it as small as possible if the extra expenses incurred are more tha n balanced by the gain resulting from the increased efficiency of the pumping installation.

3:-THE SUCTION LIFT .The theoratical useful head -H- has been divided into suction lift-Hs- And discharge lift-Hd-- There are many considerations to be reckoned with in choosing the suction lift which affects the design and choice of the pump as well as the arrangement of thesuction pipes.

If a perfect va cum is established,inside a tube, atmospheric pressure on the water surface will cause the water to rise in the tube to a height depending on the atmospheric pressure. This height will vary from 34 ft. maximum at sea level to 23.7 ft. ma ximum at IO,000 ft. above sea level. Conditions of low a tmospheric pressure will reduce these heights about I.35ft. , which must be taken into account if the pump is to operate succesfully at all times.
The average height to which water will rise at any elevation above sea level can be determined by the formula:

$$\text{Log } F = I.53I - \frac{L}{64\ 000}$$

SOURCE ?

In which:--

F= Height of a column of water in a perfect vaccuum

L = Elevation of station above sea level in feet.

This calculated pressure head is to be modified by reducing from it :

I:-The effect of low barometric conditions.

2:- The water vapor pressure and pressure caused by other gases escaping fromm water or leaking through the suction pipes or pump. The water vapour pressure; depends on the temperature of the water to be pumped, which for ordinary range -32°---90°-F has little effect on the height to which it can rise. However, when the tempera ture of the water is increased, the height to which water can rise in a vaccuum is seriously reduced by the tension of the water vapour.

In addition to the losses in the suction pipe due to low barometric conditions and water vapour pressure, there are also losses caused by the velocity of flow in the suction pipe. thse losses are:

I:-Friction losses in suction pipe.

2:- Velocity Head.

3:- Influx head.

4:- Loss from bends.

5:- Pump friction.

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For thee smoothness of operation and the ease in starting the pump,it is advisable to use as low a suction lift as possible. Practical considerations may dictate the use a high suction lift. In our p roblem it is necessary to locate the pump above high water level;which is 5m. above low water level

4:-THE INTAKE: Th e main function of the intake is to protect the end ofthe conduit pipe from injury by material flowing in the stream,and also to admit the water into the suction p ipe of the pump free from coarse sand and gravel and in the best possible state of purity. Sand carried in pumped water causes an appreciable wear in the blades of the impeller, thus freedom from insures a long life to the pump as well as smoothness of operation. To achieve this end, the velocity of water into the intake is made as small as praticable; small enough to cause the deposition of sand and silt .It should not exceed I.5 ft. per sec. Screens are also installed to prevent the entrance of gravel,wooden pieces,and fish.

Selection of the proper location is important. An outlet for cleaning the intake must be provided. A concrete support for the suction pipe is necessary to relieve the weight of the pip e from the pump flanges and to keep steady and unaffected by the vibrations caused by the motor.

5:- ENERGY EXPANDED IN PUMPING WATER.

The theoratical amount of energy necessary to raise water to a higher level is:

$$E = W H \quad ; \quad \text{where}$$

W = Weight of water

H = Static head.

The total energgy expended is more than this by the amount needed to overcome resistances.

The power needed to run the pump is given by:

$$P = \frac{GwHa}{33\,000} \quad ; \quad \text{in which}$$

G = Volume of water , in gallons per min.

w = Weight per unit of water;in Lbs.

Ha = Total head against pump.

So in selecting a motor for a certain pump the power output of the motor should be equal to that given by the equation divided by the mechanical efficiecy of the pump.

6- POWER FOR PUMPING Nearly every kind of power has been used for pumping water for irrigation . The best kind of power is decidedly the cheapest available in the region and which is reliable and sure the give the required service all the time. A chea p electric supply should not be used if it is cut now and then and for long intervals.

Windmills are used for small pumping units, but they are out of the question for driving big pumps.

STEAM POWER:- Coal or oil may be used to generate steam in boilers to drive reciprocating engines or steam turbines. Their great cost makes their installation prohibitive, except in pumping stations irrigating la nds producing valuable crops.

ELECTRIC POWER :-A reliable and cheap source of electricity is a very good motive power for pumps. In many instances water falls in cana ls are used to generate electricity to raise a part of the water to a higher elevation. Electricity generated by water is the cheapest source of power.

In our case an existing supply of electricity is not found in Akkar. To produce an electric supply is beyond the scope of such a project. So , electric power for our pumps is not available.

DIESEL OR SEMI-DIESEL ENGINES:-These provide very cheap p ower bcause they consume low quality oils. Their first cost is also relatively low. Though they do not have the same speed as the pump they are opperating, is possible to couple them through gear or belt drive. The small loss in efficiency due to this form of coupling is not big enough to a ffect the over-all efficiency of the system. So a diesel engine seems to be the only possible satisfactory slution, under the present circumstances, to provide us with the necessary power.

Asmall dynamo may be withthe pump to generate electricityfor lighting the station and a few houses.

The semi-Diesels differ from the Diesels in that they have an uncooled portion of the combustion space;they are subject to lower pressure. They do not cost as much as Diesels;they run at lower pressures,have fewer working parts, but have lower efficiencies and are not so convenient to start.They are cheaper to operate than other engines and require about one third the lubricating oil of gasoline engines.

Commonly,Diesel engines require 0.0625 gal. of crude oil per horse-power per hour clculated,on the basis that the heat equivalent of one pound of crude oil is 18 500 B.T.U.

Although Diesels can use impure qualities of fuel,every precaution should be taken to eliminate foreign matter from it.

The minimum fuel reserve should be sufficient for 5 days supply, stored in underground reservoirs or oil tanks.

7:SSELECTION OF PUMPS :- Every pump has its own characteristics which will allow the pump to be used to give the highest efficiecy under a certain set of conditions.The capacity of the pump,the head against which it is going to work determines to a large extent the kind of pump to be used. In general,the basis of selection of pumping machinery should include:

I:- Reliability of service.

2:- Promptness in service.

3:- First cost of plant.

4:- Efficiency of plant.

5:- Cost of energy.

6:- Depreciation or life of pump.

7:- Maintenance costs.

8:- Cost of labour.

9:- Flexibility.

IO:- Priming requirements.

8:- TYPES OF PUMPS: The common types of pumps are:

I:- Displacement pumps in which pressure energy is given by a piston moving in a liquid cylinder and displacing its volume of the liquid.

2:- Impeller pumps in which pressure energy is given to the liquid by the rotation of an impeller and its centrifugal force. The centrifugal pump is the most used form of this type.The propeller pump is another form.

3:- Rotary pumps wherethe liquid is forced through the pump cylinder or casing by means of rotating drums without the help of centrifugal force.

4:- Air-Lift pumps which raise water by the boyancy of an aerated column of water in a submerged tube.

9:-COMPARITIVE STUDY OF PUMPS:

Displacement or reciprocating pumps have a nealy uniform efficiency over a large range, whereas centrifugal pumps are affected by any change in head or speed. This makes for a greater flexibility in the operation of reciprocating pumps. Repairs and renewals do not require expert labor. For common suction conditions, a properly packed pump requires neither a priming device nor a foot-valve. Reciprocating outfits cost more, occuppy more floor space, require heavier foundations, require more attendance, make more noise, req- air chambers on discharge line to avoid water hammer, and can not be driven by high speed motors or engines except by reduction gearing, withthe consequent loss in efficiency.

Centrifugal pumps have low first cost and operation, excellent dura bility, small weight, compactness, low cost for foundations, simplicity in design and operation, quick starting, high speed for direct connection to high speed drives, steady flow, starting torque rarely exceeds 30% of normal full load torque, freedom from shock, p ressure not excessive in case of sudden stopping, low rate of depreciation, operation in parllel for quantity and series for pressure boosting.

The centrifugal pump has the following disadvantages: necessity for priming, efficiency is lower than that that of a good reciprocating pump, direct connection to low-speed engines not possible, for high pressure pumping, rate of discharge can not be efficiently regulated for wide ranges in duty, will not operate with a slight leakage in the suction pipe, other types of pumps handle higher suction lifts more efficiently, the high speed requires accurate balance and frequent attendance to bearings, in case of a break in the line the pump may race and damage the motor.

Rotary pumps are the most compact, without valves, mainly used for pumping small quanties against large heads.

Air-lift pumps have the following advantages :simplicity, borehole may not be straight or vertical,sa nd is not detrimental to the pla nt,hot liquids ca n be used as easily.

Disadvantages: low efficiency,deep borehole.

IO:-CHOICE OF THE TYPE OF PUMP:- For our problem,where we need to raise a big amount of wa ter against a low head,the centrifugal pump seems to be the adapted to such a case.Besides the other adva ntages of the centrifugal pump,it is the most efficient pump in such conditions as those imposed by our problem. Centrifuga l pumps also have the extra advantage of allowing a great freedom in the setting of the suction and discharge pipes and the location of the station.

The different kinds of centrifugal pumps will be discussed in the chapter a bout the design of the pump.

C H A P T E R II

THE DESIGN OF THE PUMP AND PUMPING STATION

I :- A single stage of a centrifugal pump is to designed which is capable of maintaining a discharge of 0.6 L/sec./hec.for IOOO hectares. two similar full capacity pumps a re to be installed, each working on a n average of I2 hrs. a day, since the life of all the crops depends on the pumped water, it very important that nothing should happen that will cut the discharge.In of any major break in the the pump or motor,the other pump is operated contin- uously.The other alternative of installing one full capacity pump only and providing a reservoir storing water enough to irrigate the land during repairs taking several days was investigated. The tremendous capacity of such a reservoir makes very expensive. It is cheaper to install a nother pump and motor than to build a reservoir big enough to hold 2 da ys supply.

2:-CAPACITY OF THE PUMP:-

0.6 I OOO = 600L/sec. = 0.6 M^3/SEC.

= 2I.2 $ft.^3$/sec.

= I272 cu. ft./sec.

= 9500 G.p.m.

3:- SUCTION PIPE:-

v. is usually taken to be not more than 8 ft./sec.

Due to the difficulty of securing large pip es in this country, v. is taken a s 10 ft./sec.

$$A = \frac{21.2}{10} = 2.12 \text{ sq. Ft.}$$

So, D ---------------= 1.66 ft. = 20 In.

Ma ximum suction lift at v. = 10 ft./sec.

Computation?

LOSSES

Friction head	= 0.62 ft.
Velocity head	= 1.72 "
Influx head	= 1.49 "
Loss from bends	= 0.20 "
Pump friction(estimated)	= 5.00 "
Loss from temperature	= 0.83 "
Total loss	= 9.86 ft.
Net p ossible lift	= 22.65 FT;

The suction lift should be kept as small as possible. In our problem the pump is installed at the elevation of high water level to prevent the pump from being submerged.

Use Hs -------------------- = 18 ft. ?

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Recommendations for the installation of the Suction Pipe:-

The pipe should be a s short as possible and must always incline upwards to the pump. It must never form a pocket where air can accumulate. The run of the suction pipe should be free from sharp bends.

Since the pipe is under a pressure less than atmospheric,the air should be withdrawn. Two satisfactory methods are:-

I:-Fit an air-vent pipe ,connecting the air pocket in the suction pipe with the vaccuum side of a condenser,or a vaccuum pump which is always running.

2:- Fit an independent air pump for removing the air.

The end of the suction pipe should be as far below the water level as possible,in order to avoid vortices ca rrying air into the sytem.

The bottom of the pipe should be at least I I/2 diameters above the river bed so as not to carry silt.

The stra iner or grid should have an area in its holes equal, at least, to four times the pipe area.

Footvalves and strainer should be so arranged that they can be easily removed for cleaning.

4:- THE DISCHARGE PIPE:--

Use v. = I2 ft. /sec.

$$A = \frac{21.2}{12} = 1.76 \text{ sq. ft.}$$

So , D ----------- = I.5 ft. = I8 in.

The pipe should be as short and direct as possible. Sharp bends should be avoided where possible. When the branches on the pump are smaller in bore than the pipes,taper pipes should be fitted so tha t no loss due to sudden contraction or expansian occurs. These taper pipes should have an angle of expansian of 8° to IO° .

Delivery sluice valves should always be of the full bore type. Care should be taken that all valve handwheels in the plant open with the same direction of rotation.

5:- TOTAL HEAD:-

Suction head (Hs)	---------------------------------	= I8 Ft.
Static head (Hd)	--------------------------------	= 48"
Velocity head = $v^2/2g$ = 0.0I555 x IO^2	---------	= I.55 ft.
Influx head (h2) = 0.0I49 x IO^2	----------	= I.50 "
Friction head = f 1/d $v^2/2g$	-------------------	= 6.20 "
Pump friction (estimated)	--------------------	= 6.00 "
Loss from bends and valves	---------------------	= 2.00 "
TOTAL HEAD	--------------------------	= 83.25 ft.

6:- POWER:-

Water horse power = GH/33 000 = --------- = 240 hp.

Brake horse power = GH/33000 IOO/E ------= 280 hp.

Assuming E to have the maximum value of 85%

7:- THEORY OF THE CENTRIFUGAL PUMP. -

Apart from external fittings a centrifugal pump has two main parts:

I:- The impeller which is the heart of the ma chine and transmits the power supplied to it on to the water. Incomplete Sentence

2:- THe casing which provides the entry passages and the collecting device.Two forms of which are used :the spiral or volute casing a nd the turbine or guide vanes type.

Water is supplied to the center of the impeller. Due to its rotation it produces a forced vortex in the contained water with consequent increase in pressure in an outward or radial direction and a tendency to outward flow. A partial vaccuum is produced at the center of thr impeller and water is forced up the supply pipe by atmospheric pressure.

The kinetic energy involved in this exit velocity would be wasted if no means was available for for converting it into pressure energy before leaving the pump; and various means are adopted for affecting this conversion.

In the majority of pumps the impeller is surrounded by a spiral volute chamber where the area increases in the direction of flow so that the velocity is gradually reduced before the water leaves the pump. Such a device is capable of converting at most about 40% of the kinetic energy into pressure energy. Where higher efficiencies are to be reached, a ring of guide vanes is used, surrounding the impeller.

These vanes are so designed as to receive the water without shock on leaving the wheel and to direct it through passages having gradually diverging walls into the collecting volute from which it is fed to the discharge pipe. In these passages pressure increases as the velocity is gradually reduced, and under favorable conditions; such anarrangement is capable of converting some 85% of the kinetic energy into pressure energy.

8:- TYPE OF THE PUMP TO BE DESIGNED .-

Guide va ne pumps are usually more efficient than volute pumps. But the latter are much simpler in design,and if well designed,their may well rea ch the efficiency of the guide vane pumps.Some volute pumps were able to deliver water at an efficiency of 85% .

Because a volute pump is simpler in construction and smaller in diameter than the guide vane pump,OUR DESIGN will be that of a VOLUTE PUMP.

9:- DESIGN OF THE IMPELLER .-

The following notations will be used in the design:

U = Velocity at the periphery; in ft./sec.

H = Height in feet to which water is to be raised.

N = Revolutions per minute.

D = Dia meter of the impeller; in inches.

W = Width of the impeller at the periphery; in inches.

d = Dia metr of the discharge pipe ; in inches.

n = number of blades in the impeller.

G = Gallons per minute .

SPECIFIC SPEED :-(Ns). specific speed is a measure of the type of the pump. its use enables us to detrmine what combinations of head per stage,what sp eed and capacity are desirable.

The physica l interpreta tion of Ns is that it is the rotation speed at which a pump will run if it is of such a size as to deliver I g.p.m. at ahead of I ft. per srage.

For the same head and capacity anumber of impellers may be used. The impeller which is desirable is the one which will give a sp ecific speed corresponding to to the maximum efficiency. A value of specific speed less than 500 is never used. It was found that a specific speed ranging between 2000 and 2500 gives a pump with maximum efficiency.

SPEED OF THE IMPELLER:-

$$N_s = \frac{\sqrt{G.P.M.} \times N}{h^{3/4}} = 2\,000$$

Solving for N ; We get

$$N = \text{----------------} = 475 \text{ r.p.m.}$$

DIAMETER OF THE IMPELLER:-

$$D = \frac{1840 \times \phi \times h}{N} \quad ; \text{ where } \quad \phi = \frac{U}{2gh}$$

The value of ϕ_e will depend upon the design of the pump. Thus the smaller the angle - -- and the fewer the number of impeller vanes, the larger the value of ϕ_e.

For normal discharge, ϕ_e -------------------- = 0.90 - I.30

$$D = \frac{1840 \times 1.1 \times 66}{475} \text{ ------------ } = \underline{36 \text{ in.}}$$

The diameter of the impeller is always I.5 to 5d.

In our design, D = 2 d. ;which is a good design.

Number of Blades In the Impeller:- The number of blades is taken to be 8 .

THE THICKNESS OF THE BLADE:- The blades should have such a thickness that is enough to resist the torque on them. This depends on the head against which the pump is working.

Athickness of I/2 in. is good for our case.

Width of bla des at the periphery:-

$$W = \frac{d^2}{4D - I.27nt} = \frac{I8^2}{4 \times 36 - I.27 \times 8 \times 0.5} = \underline{2.3\ in.}$$

VANE ANGLE OF THE IMPELLER:-

The characteristics of a centrifugal pump depend essensially on the vane a ngle of its impeller, and under suitable conditions, its overall efficiency may attain a value as high as 85%.

at the inner periphery the vane angle, B, should be such that the wa ter enters the impeller without shock.

This condition is satisfied if-----$\tan.B = \frac{vi}{ui}$ -------- where vI is the radial component of the velocity of water, and ui the peripheral velocity of the impeller at this point.

At the point of discharge may either be radial, or may be curved forwards or ba ckwards from rhe direction of rotation, depending upon the duty for which the pump is designed. In the majority of pumps the vane angle at discharge is between 30° and 75°, the value increasing with the hight of the lift.

$$\tan.B = \frac{I2 \times 60}{2 \times 3.I40 \times 0.75 \times 520} = 0.295$$

$$B = \text{--------------------} = \underline{I6^\circ - 30}$$

If a be the blade angle at the point of discharge in the impeller, And if U^3 be the perip heral velocity and f3 the radial component of the velocity of the water, the gain of pressure head in the impeller is, neglecting friction, equal to:

$$= \frac{u_3^2 - f_3^2 \operatorname{cosec} a + f_2^2}{2g} \quad \text{feet.}$$

In the best designed impellers the pressure head gained does not exceed 40% of the total head developed by the pump.

Substituting and solving for a ;we get:

a --------------- ----= 30°

THE IMPELLER AREA:- These a re so fixed so as to give velocities within the impeller that cause the least shock or frictional losses.

$$A = \frac{q}{v_2} = \frac{21.2}{13} = 1.63 \text{ sq. ft.}$$

THE VOLUTE OR SPIRAL CASING:-The velocity of water in the spiral casing ranges from $0.15\sqrt{2gh}$ To $0.20\sqrt{2gh}$, the higher factor being used for lower heads.A spiral case should be soproportioned that it delivers the liquid with uniform velocity and everywhere in the same relative direction.It acts both ash a guide apparatus and a diffuser in which the velocity head is converted into pressure.If the cross section of the case is circular, it is known that the radius of a point on the outer boundary is given by $r = \sqrt{co} + K$ where c and K are consrants,and o the sbtended angle. This curve will give an area which is directly proportional to the angle.For any other change in the cross section,it is easy to determine the form necessary by applying the principle that the area must va ry as the subtended angle at the impeller axis.

Dividing the casing into 8 arcs we find that that the radius to each successive point on the spiralis is increased by a value equal to 1/8 q. where q is equal to the capacity in ft^3/sec.

1/8 q. ------------ 1/8 x 21.2 = 2.65 in.

The different radii will then be:-

ro = 36 in. ; rI = 38.65in. ; r2 = 41.30 ; r3 =43.95 ; r4 = 46.60

r5 = 49.25 ; r6 = 51.90 ;r7 = 54.55 ; r8 = 57.20 ;

Design of shaft :-

$$Hp = \frac{T \times 2\pi \times N}{33\,000} \quad ; \text{ where } T = \frac{Ss \times \pi \times R^3}{2}$$

Substituing for T a nd solving for the diameter of the shaft we get:-

$$D = 3.3 \sqrt[3]{\frac{H.\ P.}{N}} = 3.3 \sqrt[3]{\frac{280}{475}} = 2.765 \text{ or } 3.0 \text{ in.}$$

CONSTRUCTION:- Impellers are made either single suction or double suction, according to whether water is admitted at only one or both sides of the impeller. The latter constructionpermits of a smaller diameterof impeller for the same capacity. For the sake of simplicity our design considered single suction only. Water leakage from the discharge to the suction side is minimized by the use of clearance rings,and sometimes labyrinth rings are used so as to provide a more tortuous passage for the leakage water.The leakage of air along the shaft on the suction side should be prevented by a water sealin addition to the usual packing.

The end thrust is taken care of a thrust bearing,by symmetrical construction,as in the case of the double suction pump or a multi-sta ge pump with the impellers set back to back,or by the use of an automatic hydraulic balancing piston.THE majority of multi-stage pumps are built with the impellers all arranged the same way in the case as this permits the most direct flow from one impeller to the next and also simplifies the mechanical construction.

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Jreo.

Slab over Pumps Rooms:-

Span --------------- ℓ_I = 7m. ; ℓ_2 = IIm.

a = 0.635 ; BI = 0.772 ; B2 = 0.077

MI---------------- ± 3060 Kg.m.

μ_1 ± 0.772 x 3060 = 2380

dI ± 0.367x2380 = I8 cm.

As =0.694 x I8 = I2.5 sq. cm.

Which is furnished by 8-I4 mm. round bars.

Long Dirction:-

M2 -------- = 7600KG;m.

μ_2 = 0.077 x 7600 = 585

d2 = 0.367 x 585 = 8.9 cm.

As = 0.694 x 8.9 = 6·I5 sq. cm.

which is furnished by 8- IO mm. round Bars.

Slab over oil room and office:-

ℓ_I = 4.5m. ; ℓ_2 = 4.5m. ;a = I.00 ; BI =.333; B2 =.333

MI ----------- = I325 Kg. m.

μ_1 = 0.33 x I325 442 " "

d2 = 0.367 x 442 = 7.7 cm.

As = 0.694 x 7.7 5.36 sq. cm;

which is furnished by 7- IO mm. round bars.

Both directions are the same.

C H A P T E R III

INSTALLATION, OPERATION? AND CHARACTERISTICS

of

THE PUMP

I:- LOCATION OF THE PLANT:-The majority of centrifugal pumps are driven vy electric motors, steam or oil engines,as it is in our design and these machines are more vulnerable to bad conditions of working than the pump itself. Location of the pump itself is therefore mainly governed by hydraulic reasons, the layout of the suction pipe,and the suitability of the site for the driving motor or engine.

2:- PREPARATION OF THE FOUNDATIONS:- Centrifugal pumps do not impose any serious load on the foundation other than dead weight. This is because they are free from vibrations. Foundations that are solid into the ground are that is required,and the depth need not be more than that necessary to prevent its settlement. This is not the case when the pump is driven by belt as the effect of belt pullhas to be taken into account.

Square holes should be left in the foundation for the bolts, which are ultimately grouted in position when the bed-plate has ben levelled up.

3:- SETTING DOWN THE BEDPLATE:- With the foundation bolts in position,place the bedplate over iron wedges on its foundation.

These wedges should be fitted at each foundation bolt and as near to them as possible,so that proper support is given when finally tightening the bolts.The bedplate should then be brought approximately level in both directions by adjusting the wedges as required and checking by a spirit level.

Grouting in the foundation bolts should now be done,in order that the cement may harden before tightening up.

4:- DISTORTING PUMP BY PIPES:- A pump casing can easily be distorted or pulled out of line if the suction or delivery pipes a re allowed to impose a load on it. Special care should be taken to avoid this,and if necessary,the piping near the pump should be supported either on stools from the floor or steel hangers from roof beams.

5:- NEED FOR CAREFULL ALIGNMENT:- A flexible coupling should be aligned as carefully as a solid coupling.The object of a flexible coupling is to allow for end movement and expansian and does not allow for inaccuracies in shaft alignment.Bad alignment results in vibrations and senere wear on the supporting bearings.

6:- LINING UP OF PUMP AND MOTOR:- In the case of a belt driven pump with no coupling between the pump and pulley shaft it is not possible to line up so accurately as in the case of an electric motor drive. Wedges are adjusted until the shaft can be revolved by hand. If this is done,no severe loads will be imposed on the supporting bearings.The alignment should be made with suction and dischrge pipes uncoupled .

7:- FINAL GROUTING IN OF BEDPLATE:- When the alignment is satisfactory, final grouting if the set ca n be done by pouring cement under the bedplate. The cement should be filled in to a depth of about I/2 in., so that the wedges or shims will not shift, and should extend about I/2 in. beyond the bedplate for the same reason and to give a finished appearance.

8:- DRAIN GUTTER IN FLOOR:- The slight trickle or sealing water which escapes from the glands should be led to the nearest drain. It is frequently more convenient to form a drain gutter in the concrete floor than to lead a drain pipe. The gutter should have a slight gradient in order that effective drainage could be accomplished.

9:- TRYING PUMP FOR FREENESS:- After everything is ready for starting the pump, it is necessary to see that pump and motor can be rotated by hand. Small pumps can easily be rotated, But big pumps require considerable effort.

IO:- METHODS OF PRIMING CENTRIFUGAL PUMPS:- When the liquid flows into the pump by gravity, no priming devices are necessary other than an air release cock on the pump casing.

A:- Priming of pumps fitted with a footvalve. Such pumps can be filled by hand, or if the suction pipe is very large and a water supply is available, by a pipe discharging into the casing through a special valve.

Where there is a static head on the discharge side of the pump, and a non return valve is not fitted, the pump is readily primed after the initial filling by opening the discharge sluice valve on the enough to admit water to the pump. The air release cock on the pump casing should be left open till water appears.

When the static head is high, it requires too much effort and puts too much strain on the valve to open it with the static head on one side of the valve only. Under these circumstances it is usual to fit a small by-pass pipe and valve. This applies also to the non-return valves fitted for the purpose of preventing water hammer from reaching the pump.

Water hammer ~~is~~ occurs when the pump ceases to deliver with the delivery valve open. When this occurs, and a non-return valve is not fitted, the vertical column of water rturns, its momentum is suddenly destroyed, and a severe rise of pressure may occur which can burst the pump.

B:- Priming by a steam exhauster:- When a steam supply is available, the air in the suction pipe can be exhausted by fitting a steam operated exhauster. Tus, no foot valve is necessary. In operating an exhauster, the dischrge sluice valve on the pump should be kept shut. The exhaust steam should be led outside the pump house, and the pipe should slope downwards, so, that condensation is automatically cleaned, and the least possible back pressure is imposed on the priming unit.

C:- Priming by a water exhauster:-Water operated air exhausters are also used, and the method of opperation is similar to that of steam exhausters.

C:- Priming by power driven exhauster:- Air can be exhausted from the suction system by fitting a mechanical exhauster. The exhauster can be driven by a separate,motor,or by the pump motor either direct or by belt.

Power driven air exhausters can be divided into three main types:

I:- Positive action piston type of single or double acting type.

2:- Positive action rotary type employing a circular disc with sliding plates in an eccentric casing.

With both of the above types it is necessary to prevent the air pump from drawing water over from the system,and this is usually accomplished by fitting a float which automatically cuts off the communication between suction system and the air pump when the water has filled the pump.

3:- Rotary air exhauster of the fluid ring type:- This type of air exhauster requires to filled with a small amount of water before being set to work.No special precautons are necessary to prevent the water from being pulled over from the system.

E:-PRIMING BY SUCTION PUMP:-A small suction hand pump having the suction pipe of the centrifugal pump for its suction pipe also can be used to empty the air from the pump.The hand pump is operated till water begins to flow from it;then the pump is run and the valve to the hand pump closed.

II:- ATTENTION TO PLANT WHEN RUNNING:- The person in charge of the pumping station should attend to the following things during the actual running of the plant:

I:-Pump and motor bearings:- the temp erature of the bearings should be ta ken at regular intervals and assurance made that the oil rings a re revolving

2:- Pump stuffing boxes:-Soft packing should be used in order that the wea r on pump spindle or sleeve may be reduced to a min. When a water seal is fitted to the pump stuffing boxes,the glands should be adjusted so that water tickles outward through them. If the glands are screwed up so tight that water dos not escape excessive heat will be generated in the stuffing box and the life of the sleeve or spindle reduced.In some cases,the water pumped is not suitable for sealing the stuffing boxes and a clean supply of ;pressure water is not available. Under these conditions a grease lubricator with an isolating cock is frequently fitted,so that the packing may receive a certain amount of lubrication.

3:- When to renew a reverse packing:- If packings were hard or charred when in contact with the spindle,they should be removed.When repacking a gland,ensure that the joints are in line with each other,as this would cause a leaking stuffing box.

4:- Pressure and vaccuum gauge readings:-If reliable gauges are fitted,it is possible to detect the changes in the resistance of th of the pipe system.An increase in vaccuum on the suctiong gauge, with normal suction lift and discharge conditions,points to a choked strainer or other restrictions in the suction system.

5:- Increase in pressure:- An increase in pressure gauge rea-ding on a condenser circulating pump,assuming normal suction conditions,would indicate that foreign matter has passed through the pump and has partially choked the condenser tubes.Or it is possible that an air leak has developed in the siphonic discharge pipe.

6:- Stopping the pump :- Before stopping a pump the vaccuum gauge covk should be closed so that,when priming,a pressure may not be imposed on it with consequent damage to accuracy.This is particula rly important on units having high static head ava i-lable for priming,in which case the gauge would be burst.

7:- NOISE IN PUMPS :- No loud mechanica l noise should be app-arent,but a small amount of noise is usually present,due to the flow of water through the pump and pipes.

Excessive noise is usually caused by :

a:- Clearance between cut water and impeller too small.

B :- Pump operating on a higher suction lift than that ror which it was designed.

c :- Layout of suction is bad.A bend in the suction pipe next to the pump will cause overfeeding to one side of the im-peller and under feeding to the other side.This bad distribution of water will result in a noisy pump and will also impose an axial thrust on the location bearings.

8:- Lubrication :- When grease lubricated bearings are fitted An adequate and continuous supply of suita ble grea se is required. Lubrucation on small units is usually made by grease cups,and the type of grease cup which will continue to feed lubricant for a long period after filling is to be recommended. Large installations specially those employingn vertical shafting,use mechanically operated grease lubrica ters.THESE lubricaters are driven by the main motor,usually through a reduction gear,and a seperate regulator to each bearing is fitted.

I2:- PUMP CHARACTERISTICS:- Curves are drawn to represent the relation between head,capacity,speed,a nd horsepower required to drive the centrifugal pump.These curves are plitted either from calculations or test data.They represent the characteristics of the particular impeller chosen. Without altering the pump casing to a great extent,any one of a variety of impellers,each having separate and distinct characteristics,may be used; so that for any givem size of pump,capacity may remain constant while head, speed,and horsepower are varied over a wide range.

As long as cavitation is not encountered,the effect of the change of speed is a s follows:

q varies as N .

h varies as N^2 .

W.hp. varies as N^3 .

and the efficiency increases very slightly with N .

For a series of homologous impellers of different sizes but of exactly the design,if they are to run at the same r.p.m. ;

h varies as D^2 .

q varies as D^3

W.hp.varies as D^5 .

Wile the efficiency will increase slightly as the size increases. Thus the brake horse power will not increase quite so much as the preceding expression indicates.

I3:- DEFINITION OF PUMP EFFICIENCY:-

$$\text{Total efficiency} = e = \frac{W.hp.}{b.hp.}$$

$$\text{Mechnical efficiency} = em = \frac{w(q + q')h''/550}{b.hp.}$$

$$\text{Hydraulic efficiency} = eh = \frac{w(q+ q') h}{w(q + q)h''} = \frac{h}{h''}$$

$$\text{Volumetric efficiency} = ev = \frac{q}{q + q'}$$

where q' is the amount of leqkage through the clearance spaces, a nd h'' is the head imparted to the water by the impeller.

I4:- FACTORS AFFECTING EFFICIENCY:- Efficiency varies with the capacity.A small change in the speed under a constant head has a marked effect on the efficiency and less effect on the capacity. In small sizes,disproportionate water losses reduce the efficiency.

CHAPTER IV

COST OF IRRIGATION BY PUMPING

I:- The cost will be expressed in terms of the amount of money spent in irrigating one hectare of land, under the given head of 66 ft., during the summer season, considered to be 90 days. This cost is then balanced against against the returns from the land and the economic feasibility of pumping is examined. The rise in the value of the land after it is irrigated is very great; amounting to 3 to 4 times its value before irrigation. The net returns from irrigation are variable according to the kind of crops planted, their value, and their water requirements. Prices vary considerably from one year to another, and a cost of irrigation which is p rofitable in years of high prices may not be so when the price of agricultural products fall down.

The determination of the economic feasibility of pumpingis an engineering, agricultural, and economic problem.

2 :- COST OF PUMPING:- The total costs of pumping are:

I:- Interest on the capital invested in the construction of the intake, pumping station, and reservoir and the installation of the piping system, pumps, and motors.

2:- Depreciation in perishable things as pumps, motors, and pipes. The life of cast iron pipes is estimated to be equal to 50 years; that of the centrifugal pumps and motors is 20 years.

3:- Repaurs of breakages and maintenance.

4:- Fuel,oil,and lubricants.

5:- Attendance and supervision.

COST OF PUMPING STATION

Kind of Work	Unit	Quantity	Unit price	Costs
Excavation in soil	m^3	I860	L.L 2.50	L.L.4650.00
Excavation in rock	"	90	" 9.00	8I0.00
Masonry	"	745	" 40 .00	29800 .00
Concrete,plain	"	95	" 40 .00	3800.00
Reinforced concrete	"	35	" 90 .00	3I55.00
Wood work	m^2	50	" 35 .00	I750.00
Plaster	"	675	" I.50	I0I2.00
Inlet gates	unit	4	" 50 ;00	200.00
Cast iron pipes I8-20in.	m.	470	" 25 .00	II75.00
I8-20-in. pumps	unit	2	"4000;oo	8000.00
Diesel motor,280 hp	"	2	"25000.00	50000.00
valves	"	4	" 80.00	320.00
Instruments	-	-	" ---	500.00

TOTAL COAST OF STATION = L.L. I05,I70.00

I0% INTEREST = L.L. I0,5I7.00 ?

(1 year ?)

2:- Sinking fund reserve to cover depreciation:-

$$x = \frac{r}{(I + r)^n - I}$$; where

x = annual payment made at end of each year to accumulate L.L.I.O at the end of n years, the installments bearing interest at r per year, coumpounded annually ;

Taking the current rate of interst as I0%, and the life of the whole thing as 25 years, the percentage set aside yearly is 2%.

AMOUNT OF DEPRECIATION = L.L. 2I00.00

3:- REPAIRS AND MAINTENANCE:- These charges are to be estimated, and they they vary from one year to another. when the pump is still new, and the motors also, very little repairs are necessary. On the other hand, these charges will constitute a higher percentage of the total operating costs when the machinery becomes used up.

REPAIRS AND MAINTENANCE = L.L. I 000.00

4:- FUEL, OIL, and LUBRICANTS:-

Diesel Engines rquire a bout 0.0625 gal. of crude oil/hp./hr.

Total amount of crude oil consumed = 37 675 gal. =I42,000 Lit.

Price of oil at P.L. I2/Kg.	=	L.L. I7,000
Price of lubricants		L.L. 500

5:- ATTEDANCE AND SUPERVISION:- 3 men should be employed to attend to the engines and pumps when running: 90 days.

Cost of labour ------------------ = L.L. I700

A weekly visit by a comp etent engineer is necessary

Expert supervision ----------- -- -=L.L. I000

SUMMATION OF COSTS

I:-	Interest on first costs ------------	L.L.	IO 5I7.00
2:-	Depreciation ----------------	"	2 IOO.00
3:-	Repairs and ma intenance ------------	"	I 000.00
4:-	Fuel, Oil, and Lubricants -----------	"	I7 500.00
5:-	Attendance and Supervision -----------	"	2 700.00

TOTAL COSTS PER Y EAR --------------- L.L. 33 820.00

COST PER HECTARE --------------L.L. 32.00

NOTE : THE 33,820 IS ONLY THE COST OF PUMPING WATER. TO FIND THE TOTAL COST OF IRRIGATING ONE HECTARE THE COST OF THE DISTRIBUTION CANALS and the structures must be IS ADDED

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