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TECHNOLOGICAL DEPENDENCY AND CHOICE OF PUMPING TECHNOLOGIES FOR IRRIGATION SYSTEMS *

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Introduction

In preparation for the Third Consultation on the Agricultural Machinery Industry, to be held in Belgrade, Yugoslavia, from 29 September to 3 October 1986, it has been deemed necessary to bring to focus equipment used in pumping systems for irrigation purposes. Irrigation being one of the main pillars of agriculture, pumping is an essential element in irrigation, land reclamation and drainage.

In industrialized countries, the non-agricultural use of pumps may overshadow its irrigation applications which might explain its affinity with industry rather than with agriculture. In most developing countries, where agricultural development is given first priority, the pump and other irrigation equipment should be treated with the rest of the family of agricultural machinery and inputs. This is the reason why pump manufacturing should be considered in the context of the multi-purpose approach to the manufacture of agricultural machinery.

Irrigation pumping systems include, among other things, gates, valves, pipelines, trash racks, overhead travelling cranes, structures, etc. in addition to the pumps themselves and their driving motors/engines. Taking into consideration the proliferation of sprinkler and trickle (drip) irrigation which depend even more on pumping, solar and wind powered pumps, the scope of equipment needed in agriculture today has been considerably widened.

The report is intended to explain the rationale for the need for such equipment with the emphasis being mainly on the pump. To understand the rationale, irrigation itself is briefly explained. A concept and method have been introduced for the determination of the degree of technological dependency which is assumed to influence technological decision-making and choice of technologies. It is seen as a potentially useful instrument for the identification of constraints and needed remedies and for grouping of developing countries according to their degrees of dependency which should help in adoption of common strategies.

Summary and conclusions

Irrigation is increasingly depended upon in food production with the aim of eliminating hunger and meeting the rising food requirements of the world's growing population. The importance of water to plant growth and to maximizing crop yields cannot be overemphasized. Moreover, water is needed for land reclamation and management as well as for animal and human consumption and for food processing, let alone its need in industry in general. Central to the use and movement of water is the pump. It enables the farmer to irrigate at will and thus puts him in charge of his production.

UNIDO, through its consultations on the agricultural machinery industry, has been focussing attention on the possibilities of manufacturing agricultural machinery locally using the multi-purpose approach. In this paper, the pump is brought into focus for similar considerations based on the consultant's own experience and a visit to FAO offices in Rome. The findings of the review are as follows:

(a) Pumps are being locally produced in several developing countries. They could be produced locally in many other countries that still import them, using the multi-purpose approach for manufacture of agricultural machinery as shown in recent UNIDO studies. The pumps' degree of complexity (levels II and III) is found to be within the range of ordinary farm equipment; subject of the multi-purpose approach. International co-operation based on sound strategies can help in a multitude of manners.

(b) Local manufacture of irrigation pumps calls for decisions concerning: -

Type of pumping
(small-scale vs. central pumping stations or a combination of both);

Type of pump
(centrifugal, axial, others (reciprocating, rotary, etc.) which demand lower technological complexity levels);

Type of drive
(diesel, electric motor: AC or the more suitable for solar power, DC motors);

Source of energy
(fossil fuel, hydro, wind or solar).

Field data on performance of various types of locally manufactured and imported pumps need to be obtained and analysed.

(c) Simplification or down-engineering of components and/or manufacturing at the expense of efficiency is possible and economically sensible for the interim although it is not a substitute for true modernization to benefit from the technological breakthroughs: CAD/CAM etc.

(d) Recent progress in photovoltaic technology puts solar electricity in a more competitive position. Action including training in developing countries to raise their readiness level for its timely acquisition need support.

(e) Countries of similar standards of living usually based on economic consideration do not necessarily share similar technological development problems. The need for their stratification on technological dependency basis is evident. To help achieve this, the concept and method for determination of each country's degree of technological dependency sector by sector has been introduced. This concept can be used in conjunction with the already developed tool of technological complexity levels.

(f) To draw broader strategies, answers are needed to the many questions as mentioned in item (b) above and more. UNIDO may be advised to initiate consultation with other major users of pumps in the UN system such as FAO, WHO and UNICEF with the aim of co-operating in the compilation of information, from the field in particular, in order to be able to address the above questions.

(g) UNIDO may also solicit country papers to be prepared by competent professionals in a selected number of countries which would give current information on irrigation pumping and local pump manufacturing and provide data for determination of the degree of technological dependency, its causes and suggested remedies.

Table of contents

Page

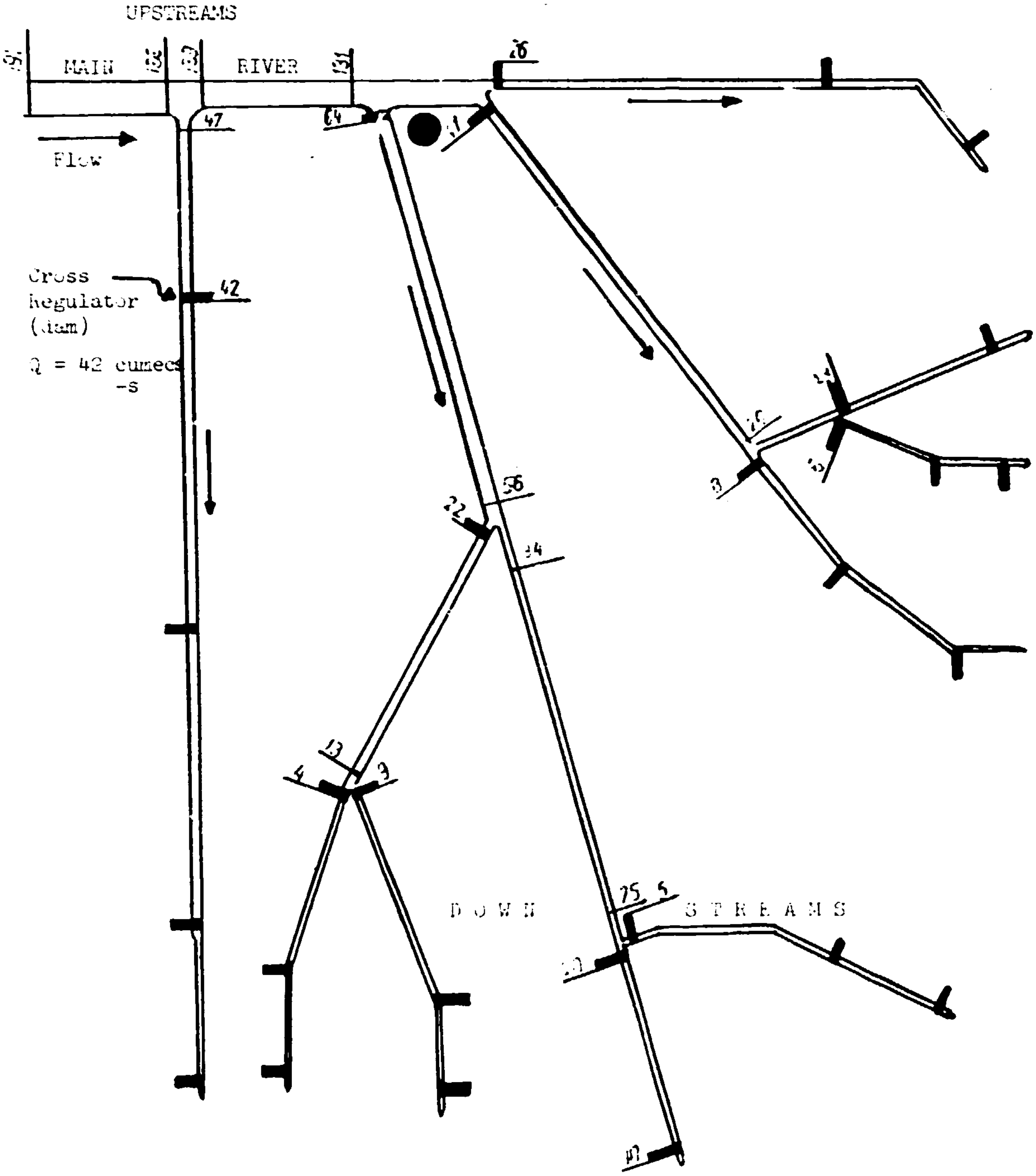
Chapter I. IRRIGATION, DRAINAGE AND RURAL WATER SUPPLY

1. Irrigation is the delivery to the plant of the water needed for the germination of seeds, growth, and maturity of crops. Other functions of irrigation include salt leaching and removal, crop cooling, application of chemicals, frost and freeze protection and delay of fruit and bud development.

2. Rain and flood are natural means of irrigation. Controlled diversion from rivers, lakes, springs and other types of ground water are achieved through technology. Drainage of excessive water can take place naturally but often requires technological intervention. In any case, crop yields can be increased or maximized by proper irrigation and drainage. Water in nature may carry sufficient amounts of energy to be used in conventional gravity irrigation command. This command can be enhanced by erection of cross barrages (dams) upstreams of natural rivers and canals for water to be tapped at higher elevations, then conveyed to the fields using canals with milder slopes. To ensure the quantity of water needed at the right time, reservoirs are added to the system. Water losses due to evaporation and seepage can be in the order of magnitude of half of the amounts reserved for irrigation which would lead to considerable increase in water salinity, soil salinity and damage to crops. When irrigation water is more saline, greater quantities of it are needed in order to prevent excessive soil salinization. Other disadvantages of using the gravity command include blockage of flood paths, interference with fish migration, navigation and a host of ecological imbalances.

3. A typical case where the said argument applies is a major irrigation system planned in the early 1960s for an area in Mesopotamia for which a schematic diagram is shown in Fig. 1. It shows the branching of the main river into branches and subbranches all of which are natural streams and flood escapes crisscrossed with barrages which were mainly intended for achieving a greater gravity command for irrigation in order to avoid pumping. During the planning stage, it was concluded that pumping would be too expensive to adopt. Later it was shown that the said conclusion was based on a state of high degree of dependency in pumping technology. That stage of dependency which was not properly analysed or understood proved to be possible to

overcome when the Saad River pumping station was erected a decade later. Turbopumps and more appropiate technologies which were applied in the Saad River case reduced the capital cost required to less than a half. A sketch showing some features of the conventional (too expensive) pumping system and the more appropriate one is also included. Most of the disadvantages of the barrage-based, gravity conveyance system could have been avoided by pumping water to the required elevations at the most suitable locations where conveyance losses are minimized. The example points to the value of understanding the technological dependency problem, determination of its causes and possible remedies.



22 Cross Regulator (barrage), capacity = 22 cumecs

34 Design capacity of channel at cross section.

Fig. 1: Distribution of flow corresponding with normal irrigation rate (0.60 l/sec/ha); Q = 191 cumecs

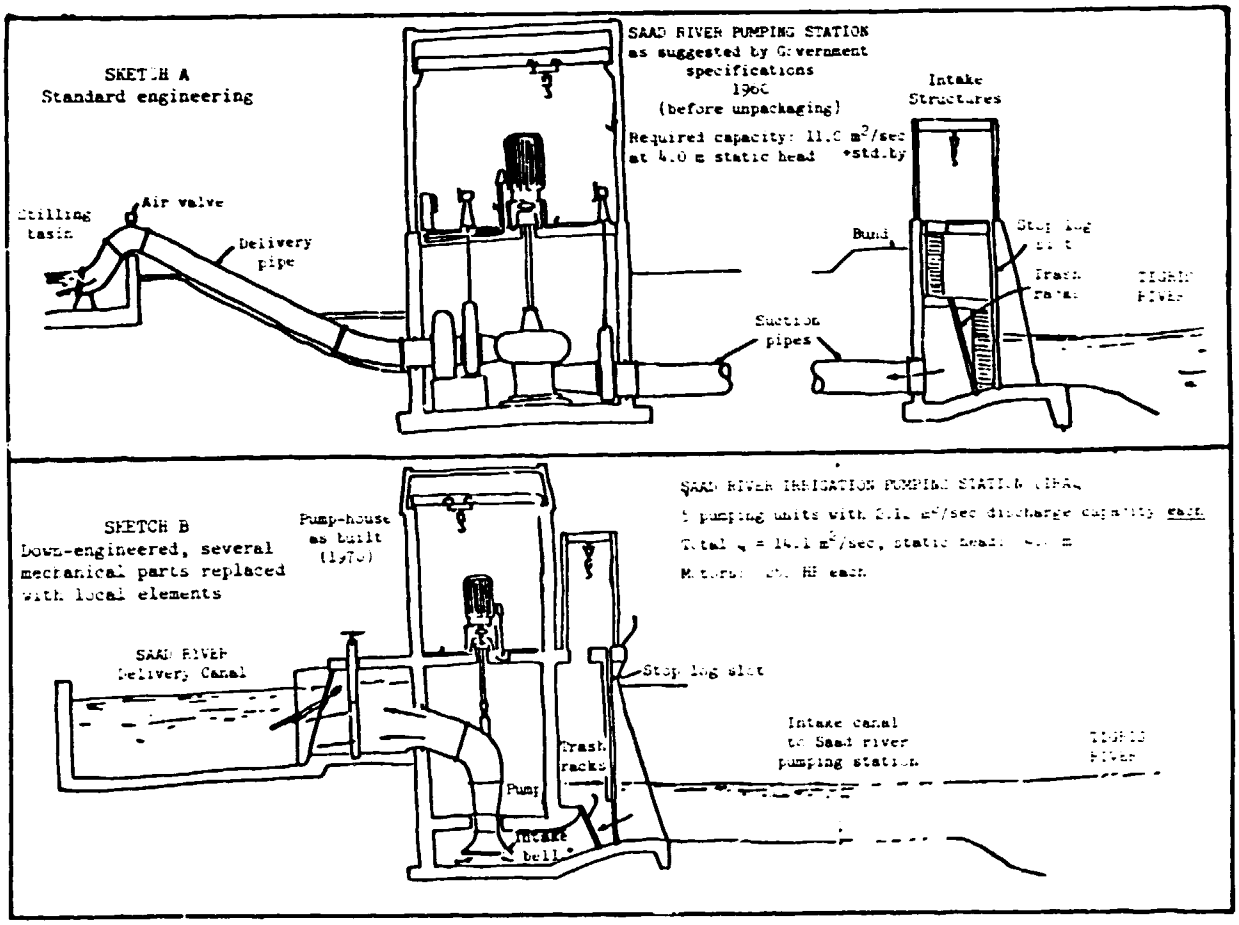


Fig. 2: Saad River pumping station (Iraq). Sketch A standard engineered. Sketch B, same station as built after unpackaging and down-engineering by consultant. Saving to government: 50 per cent.

Examples of pumped irrigation

4. Where the source of water is underground and where irrigation is by sprinkler or drip (trickle) systems, pumping would not be a matter f choice, it becomes a necessity. The most commonly used and most appropriate type of pumps are those popularly called tubewells.

5. The methods used in applying irrigation water on the farm are numerous and the choice depends on the type of topography, soil, crop, drainage conditions, climate, availability of water, degree of mechanization, area of cultivation and economy, etc. It is beyond the scope of this report to go into more detail other than illustrating an example from each broad category.

6. (a) Surface irrigation is the most widely used and oldest method. It generally requires a smaller initial investment than do other types of irrigation. The driving force is gravity (although water may have been lifted to the required elevation by pumping) and water enters the field from an open channel according to a predetermined pattern, flow rate and duration. It is further divided into types of irrigation such as contour ditch, basin, border, contour levee, furrow and corrugation and water spreading. Fig. 3 is a sketch for field layout of a contour dike surface type.

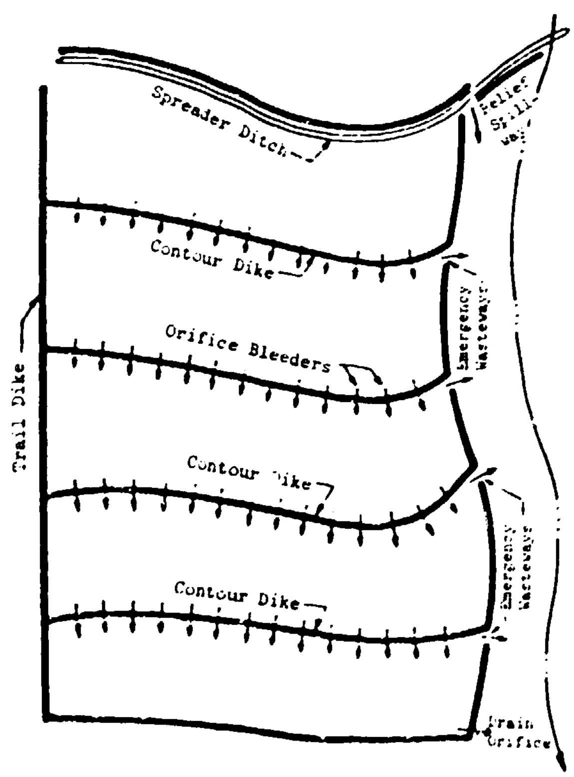


Fig. 3: Field layout of a contour dike surface type.

7. (b) Drip irrigation (trickle)

With this type of irrigation water is distributed over the field by means of pipes (mostly plastic) under pressure and dripped at the root zone of each plant individually. It offers many advantages primarily in eliminating conveyance and distribution losses of water, thus its increasing popularity in regions of hot climate and limited water availability. Chemicals needed for the plants growth are added to the water beforehand and fields need not be levelled as for surface irrigation since the availability of water pressure in the pipes can overcome level variations. Water drips from emitters or applicators (Figures 5 to 8) which dissipate the excessive pressure through orifices, vortexes, and tortuous long flow paths thus allowing a limited volume of water to be discharged. Drip irrigation systems are energy-intensive. Water must be forced through filters for the removal of suspended solids which otherwise may clog the emitters. With local manufacture of the system components the cost of drip systems can be reduced drastically. It is reported that in one developing country the reduction has been at a ratio of 10 to 1. Primitive versions of the principle involved in drip irrigation are known to have been used in ancient times.

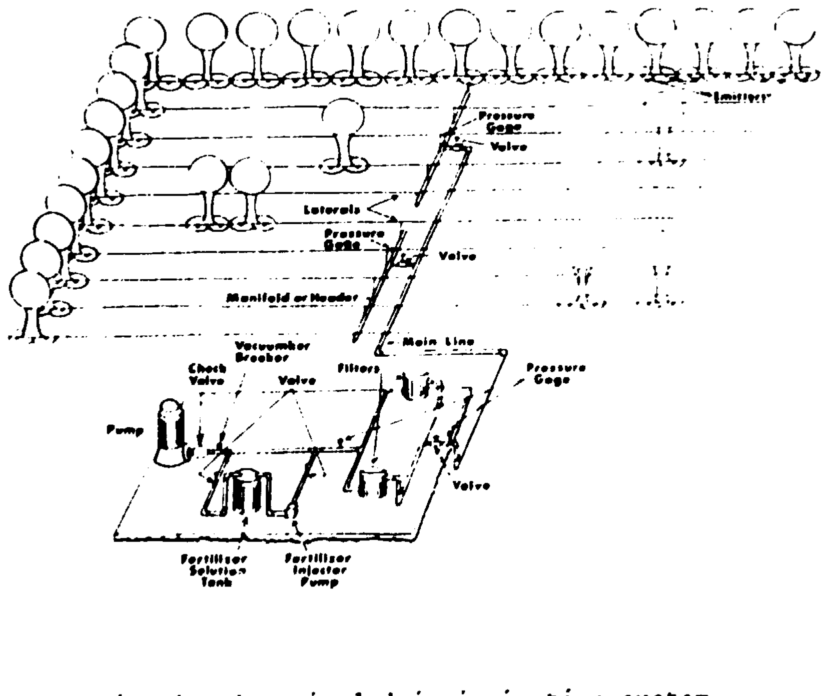


Fig. 4: A typical drip irrigation system.

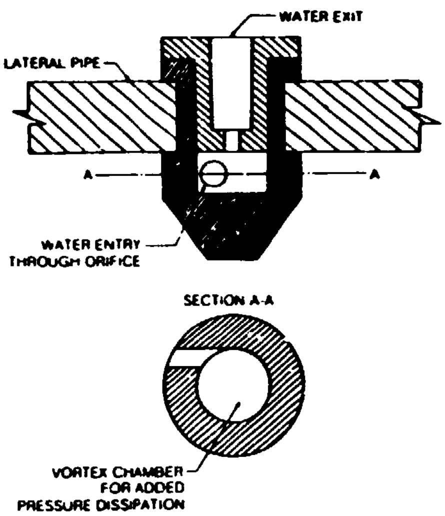


Fig. 5: Orifice-vortex type emitter

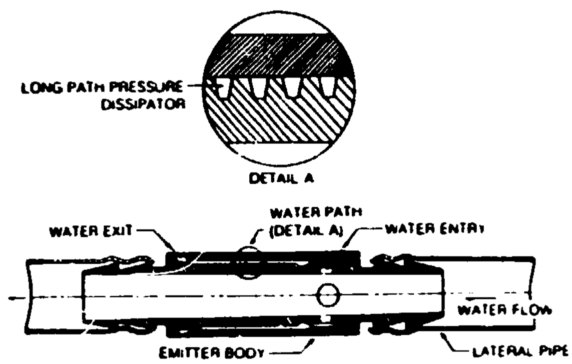


Fig. 6: Single-exit long-path emitter

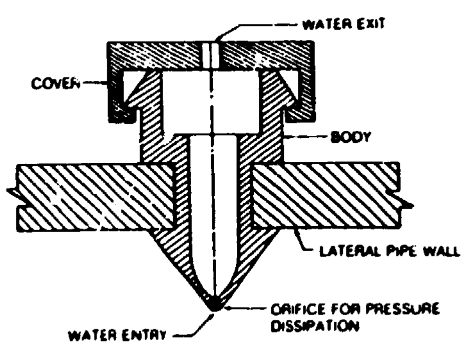


Fig. 7: Single-exit orifice-type emitter

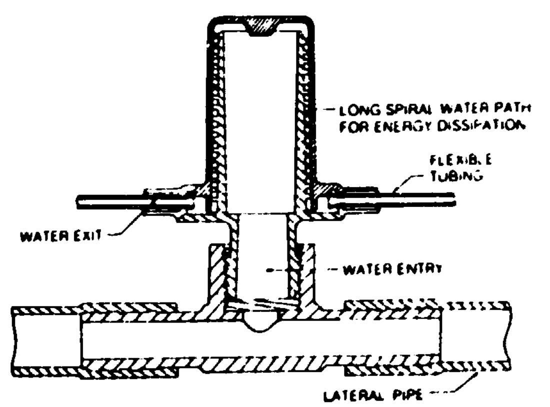


Fig. 8: Multi-exit long-path emitter

8. (c) Sprinkler irrigation is adaptable to many crops, soils, and topographic conditions. They are classified according to whether the sprinkler heads are operated individually (gun or boom sprinklers), or as a group along a lateral, and according to how they are moved or cycled to irrigate the entire field. The solid-set permanent irrigation sprinkler systems are gaining popularity in order to reduce labour and modify the environment.

9. In arid areas centre-pivot systems are used intensively - up to about 2200 hours per season. Water is delivered to the centre either by an open channel or directly from a well to the single lateral moving continuously around the pivot where water is pumped to the lateral. The lateral pipe with sprinklers is supported on drive units and suspended by cables or by trusses between the drive units. The drive units are mounted on wheels, tracks, or skids that are located some 20 to 70 meters apart along the length of the lateral pipe. The lateral pipe may be up to almost 800 meters long. Each drive unit has its own power device that drives the wheels, tracks or skids on which the unit moves.

10. One of the most advantageous uses of sprinkler irrigation is in providing supplementary irrigation to rain-fed fields where permanent systems only occasionally used are not economical. In such cases the Periodic Lateral Move or the Hand-Move Lateral Systems are used. All sprinkler irrigation systems in this category have sprinkler laterals which are moved between irrigation settings. The most common system has a single centre mainline with one or more laterals which irrigate on both sides of the mainline. The lateral, at right angle to the mainline is moved by hand and connected to it at the distances already set by the location of couplings.

11. Lateral-Move Sprinkler Irrigation Systems together with deep wells where groundwater exists can provide supplementary irrigation in drought threatened zones. Two rounds of sprinklers 30 mm each may guarantee a crop which would otherwise be lost to drought. An FAO study shows that after fields planted with cereals have received 100 to 150 mm of rain, which is enough to produce vegetative growth with no grains, every additional millimeter results in

obtaining about 14 to 16 kilograms of grain per hectar.[1/] In other words, the two rounds of 30 mm each would result in obtaining 840 kg to 960 kg per hectar in grain.

Drainage

12. Drainage is the process of removal and disposal of excess water from the surface of land and from the soil pores. The sources of excess water can be precipitation, snowmelt, irrigation, overland flow, or underground seepage from adjacent areas, artesian flow from deep aquifers, flood waters, or water applied for such special purposes as leaching salts from the soil or for temperature control. Agricultural lands need to be well drained for better crop production and drainability of the field is one of the parameters used in evaluating the land. Excessive water on the field's surface hampers performance of agricultural machinery by causing muddy conditions which may further lead to damage to the soil structure and may also lead to soil saturation which is detrimental to plant growth. Soils which are not drained naturally can be drained by means of artificial drainage systems which often require pumping.

13. In arid areas, artificial drainage systems are installed to control watertable level and salinity in the root zone. The draines - mostly open or covered ditches - are installed at a depth of 2 to 3 meters for the purpose of lowering the water table. Water table is lowered when water seeps from the soil pores into said ditches which must have adequately lower beds than the water table itself. Proper irrigation management then ensures a continuous downward movement of the excess water and salts that are concentrated there by the extraction of water by crop plants. Salt also tends to accumulate near and at the surface of agricultural fields in hot climates where soils lose their moisture due to evaporation after moving to the surface by capillary

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1/ Summary from a Report on Consultancy to ICARDA on Supplementary Irrigation by A. Arar, Senior Officer, Water Resources Development & Management Service, FAO, January 1984.

action leaving behind its salt contents. Salinity can be so severe that germination and growth could be impaired. To prevent this process special irrigation practices are needed which usually demand more water and more drainage.

14. In humid irrigated areas, drains are usually installed at a depth of 1.0 to 1.5 meters. Shallow drains mean higher water table and, possibly, a plementary water supply for plants between intermittent rainstorms.

15. Drainage systems usually consist of sets of field drains which lead drained water by gravity to larger and deeper ones which act as collectors and collectors lead to still larger and deeper channels. Drainage water thus loses elevation as it flows. Where after losing so much elevation, drainage water can still be disposed of by gravity to a lower lying disposal area pumping would not be needed. In flat areas this seldom happens and pumping substantial amounts of drainage water is often required.

16. In any case, design of drainage systems should be preceded by adequate knowledge of the soil, climate, crops, and topography. Detailed soil surveys and land classification are strongly recommended as economically justified.

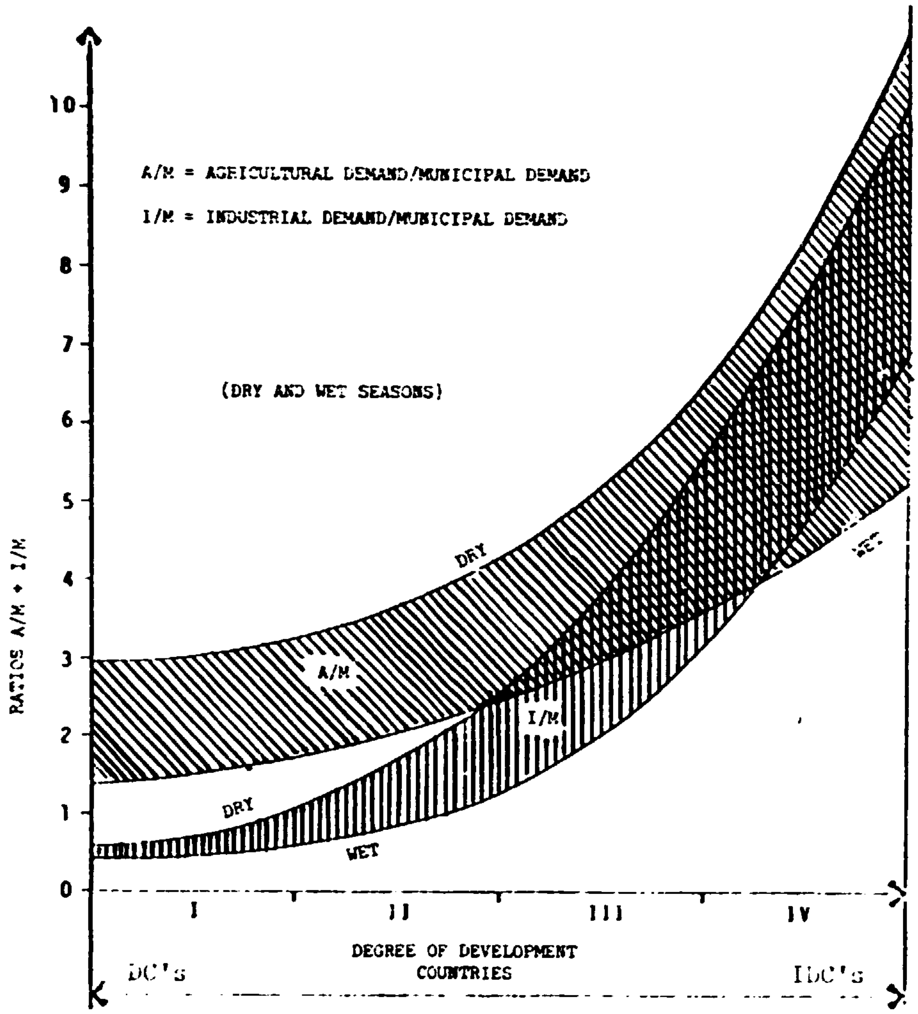
Reservoirs

17. The term reservoir applies to water storage facilities ranging from those for which large dams are built to store billions of cubic meters of water for flood control, power generation, provision of water during cycles of dry years etc. down to the service tanks of few cubic meters capacity to equalize between average daily consumption and hourly peak demand within small communities. The types, functions, and parameters involved in determining the kind of reservoir needed for a given situation are too many to cover in this report. It can only be stressed that reservoirs are needed for community water supply and on several occasions for pumped irrigation, in both cases to ensure continuous service when pumps are put to rest and to maintain the required pressure and provide for emergencies.

Rural water supply

18. Rural communities need water for municipal consumption which is distinct from irrigation and land reclamation requirements. Drinking grade water is piped to living dwellings after it has been purified, treated and sterilized. The same water is used for washing, cleaning and fire extinguishing as well as for house gardening. The management of this type of water supply is usually different from that of irrigation as it is normally tied to the municipality together with electric power supply. Water supply is regarded as a public health concern and as vital to disease prevention and control. The availability of potable water for human and municipal consumption in rural areas has similar effects on agriculture to that of agricultural machinery in terms of making life more bearable for the farmer and his family and reducing the temptation to abandon agriculture and moving to the urban centres.

19. In terms of water resources management, however, municipal, rural and industrial water demands must be treated together for the purpose of proper allocations and conservation as one of the most vital national wealths. Without proper planning this wealth can be severely harmed. Without going into details, Fig. 9 shows the relationships between municipal, agricultural and industrial water requirements and other aspects of water resources management. Pumping for non-irrigation water use may be considered in the multi-purpose approach for the manufacture of agricultural machinery.



Source: Engineering Enterprises, Inc. Water Demand Models prepared for UNECWA, 1976.

Fig. 9: Showing the ratios I/M and A/M for levels of development.
IDC - Industrially Developed Countries
DC - Developing Countries

Chapter II. PUMPS

20. The discussion on irrigation and drainage in Chapter I was designed to illustrate the most common situations where pumping could be used to improve agricultural production. Major pumping stations to lift irrigation water at a rate of several cubic meters per second by 2 to 4 meters for instance, were suggested to replace dams (barrages) accross natural canals (see page 9). The type of pumps most suitable for such a purpose would be axial flow (propeller) pumps, whereas sprinkler irrigation would require smaller capacity pumps which should force irrigation water under higher pressure through nozzles of the sprinkler system in order to cover areas as far as possible from the nozzle. In this case, axial flow (propeller) pumps are practically useless. The most suitable type would generally be the radial flow (centrifugal) pump,[2/] not to mention the effect of the source of energy and type of driver and the entire range of factors given in the following basic data chart.

21. Knowledge of pump characteristics as well as such ratings as specific speed etc. are vital to proper selection of pumps. Pumps of high specific speed give high energy efficiencies while making the pump vulnerable to the destructive effect of cavitation.[3/] An attempt is made in this chapter to describe the main parameters involved in the selection of the most commonly used pumps.

22. Knowledge of irrigation water requirements, water source, energy etc. is basic to proper selection of pumping systems. When the required system justifies the cost of engineering, or when proper performance is critical to the success of the irrigation scheme, the selection would involve contributions by an irrigation engineer to determine water requirement, an electrical engineer to deal with securing electric power from high-tension lines, transformer station, controls, switch gear and motors etc., then a mechanical engineer for the proper selection/design of pumps and piping based on knowledge of pump characteristics, and finally civil engineer(s) for the pump house, intakes, delivery structures etc.

2/ However, in general, the selection of the right pump, according to its characteristics and in close relation with the irrigation system considered, is not a trivial exercise. On the contrary, costs and operating behaviour will be permanently taxed in a given project if pumps do not correspond to the appropriate ones.

3/ See page 38, para. 48.

Basic data for irrigation and drainage pumping

Data for planning irrigation systems and water/pumping requirements

LAND	- Size of holdings - public/private ownership - type of management
CROPS	- Evapotranspiration[a/] - crop rotation
SOILS[b/]	
WATER	- Resources[c/]
TOPOGRAPHY	- Flat/hilly determines conveyance systems and pump lift/energy water delivery costs
CLIMATE	- Temperature, wind, precipitation etc. affect type of crops, ET, irrigation, drainage, water and energy requirements

Pumping systems

ENERGY	- National electricity grid - internal combustion engines - solar - wind	) - INTERACTION WITH THE DEGREE OF TECHNOLOGICAL DEPENDENCY
TECHNOLOGY	- Choice of pumping technology - technological infrastructure - quality of local skills - efficiencies of pumping systems	) - IDENTIFICATION OF OBSTACLES AND CONSTRAINTS CAUSING DEPENDENCY
		) - PRESCRIPTION OF REMEDIES TO ALLEVIATE DEPENDENCY
FINANCE	- Type and source of finance (public/private) - foreign exchange - foreign aid - soft loans - interest rates	) - ACTION ON NATIONAL, REGIONAL AND INTERNATIONAL LEVELS

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a/ Evapotranspiration (ET) of crops as an indicator of water demand which is a function of type of crops, stage of growth, soil and climatic conditions. There are several methods for determining ET and irrigation water requirements based mostly on works of Blaney and Criddle, Jensen-Haise and Penman with a large number of variations which the irrigation engineer may choose from according to the peculiarities of his project.

b/ The soils factor: soils information needed to determine - together with other factors - the agricultural water requirements, irrigation and drainage in particular, are available in soil survey and land classification manuals. However, for the purpose of this report general description such as sandy or clay soils, water holding capacity, ground and surface drainability and estimates of water duty and its quality, salinity etc. would suffice.

c/ Water resources: availability of water, seasonal variations, floods, ground water, recharge, depth of aquifers, etc. would be needed to determine irrigation pumping parameters.

WATER DEMANDS

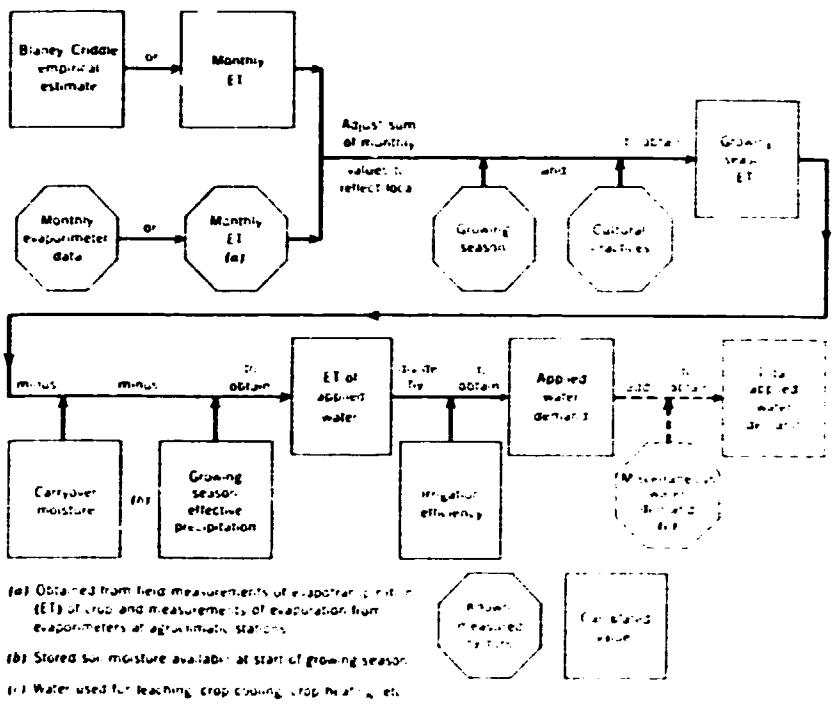


Fig. 10: Steps in determining agricultural applied water demand.

TECHNOLOGY LEVEL			
I	II	III	IV
Lever-type hand pump	Hydraulic ram	Engine-driven pump (over 6 hp)	Diesel or electric pumping plants 1000 hp & over
Rotary hand pump	Animal-drawn pump	Electric-motor-driven pump over 6 hp	Control structure
Animal-drawn pump	Engine-driven pump (up to 6 hp)		Measuring device
Hand-operated diaphram pump			Head gates

<------Water from well, borehole, stream canal or channel------> <-Water from stream, river, catchment area, ground water storage->

<---------Farm delivery system---------> <----Project delivery system---->

Farm Size

<--Less than 2 ha-->

<---------2-5 ha--------->

<---------5-50 ha--------->

<---50-1000 ha--->

<-------------1000 ha-------------->

Source: UNIDO Monograph No. 4, Appropriate Industrial Technology for Agricultural Machinery and Implements, 1979.

Table 1: Mechanization levels for pumps; Choices for different farm sizes.

23. The pump is described to help follow the negotiation when types of pumps and how they perform are referred to in the way of choosing strategies for local manufacture. The degree of involvement has been set to help just that.

24. Strategies for pump manufacturing are largely affected by the choice of technologies appropriate to given situations. The choice depends on consideration of technical factors explained in the following paragraphs, some of which are briefly summarized below for additional clarity.

Technical Factor	How it affects technological choice
Water demand	Basic to selection of appropriate pumping approach. Full dependence on irrigation or only complementary which may justify movable sprinkler systems which in turn determine the type of pump.
Water source	Determines whether pumps should be for high lift, low lift or tubewell.
Energy source	Type of drive.
Characteristic curves	Type of pump and its impeller for a given condition with regard to the pumps' required discharge capacity, total dynamic head and efficiency.
Specific speed	Efficiency, type of drive, transmissions for speed adjustment and couplings.
Pump efficiency	Appropriate manufacturing standard and overall economics.
Overall efficiency	Energy economies.
Cavitation	Affects type of material and durability of castings for impellers, type of suction pipe/bellmouth/channel and channel lining. Tradeoffs based on performance maintenance costs and construction costs.
Net positive suction head	Affects depth of pumps position relative to water source, hence cost of construction. Trade-offs between mechanical components and civil works.

25. Trade-offs between manufactured components which require foreign exchange even if locally manufactured and civil works are possible. They may result in considerable savings as demonstrated in the case of the Saad River pumping station (see Fig. 2). Such trade-offs can be successfully implemented only when based on sound knowledge of all factors involved in the choice of pumping systems.

26. Pumps are hydraulic machines which are used for applying mechanical energy to fluids (water in this case) in order to utilize the resulting increase in pressure (hydraulic head) to move water to higher elevations or force it through pipes and other delivery systems. They are of two categories, depending upon the principle of operation:

1 - turbopumps
2 - positive-displacement pumps.

Turbopumps

27. Under the first category - turbopumps - fall the most widely used pumps by far; the centrifugal pump and axial flow pump and variations of both (mixed flow pumps). Hydraulic head is developed by a rotating impeller (or propeller) within a confined circular casing. The impeller (or propeller) is composed of a set of vanes which force the water to the outside of the casing by centrifugal action (radial flow), or normal to plane of the blades by a propeller-type action (axial flow). Some pumps combine both such actions (mixed flow). These are the main types concerning this report.

28. (i) Radial flow pumps develop the pressure principally by rotating an impeller with an intake at the center and discharging the water by centrifugal force into the casing surrounding the impeller. The pressure head developed by the pump is entirely the result of the velocity imparted to the water by the rotating impeller and is not due to any impact or displacement. A centrifugal pump which admits water on only one side of the impeller is called a single suction pump; if it admits water on both sides of the impeller, it is called double suction pump. The latter type is used for large volume/high head pumping. Radial flow pumps may be further subdivided into two subclasses, viz.: (a) volute pumps and (b) diffuser (turbine) pumps. In the case of volute pumps, the impeller is surrounded by a spiral case, the outer boundary of which may be a curve called a volute. In the case of diffuser pumps, the impeller is surrounded by diffuser vanes which provide gradually enlarging passages to effect a gradual reduction in velocity in favour of gains in hydraulic pressure.

29. The principal advantages of radial flow pumps are smooth and even flow, a decrease in pressure head, for instance when water level at the source is high, capacity and power consumption rise, and an increase in the head reduces capacity and power consumption. The effect of closing the valve on the pump discharge is to increase the pressure head by approximately 15 to 30 per cent and reduce power by 50 to 60 per cent from those values at the most efficient operating point.

30. These characteristics make a radial flow pump a very easy load for any driver. The torque required to start the pump is very small, suitable for direct coupling even to squirrel cage AC motors, while the operating load is smooth and free from shock.

31. (ii) Axial flow pumps develop the pressure head principally by the propelling or lifting action of the propeller vanes on the liquid. They have a single inlet impeller (propeller) with flow entering axially (referring to the axis of rotation of the propeller) and discharging nearly axially. Diffusion vanes are often installed on the discharge side of the propeller to reduce the swirling action caused by the rotating propeller. This type is often used for cases requiring low head lifting, up to about 6-8 meters. It is suitable for very large volume and in cases where the propeller pitch is adjustable to flow requirements (volume of discharge and head).

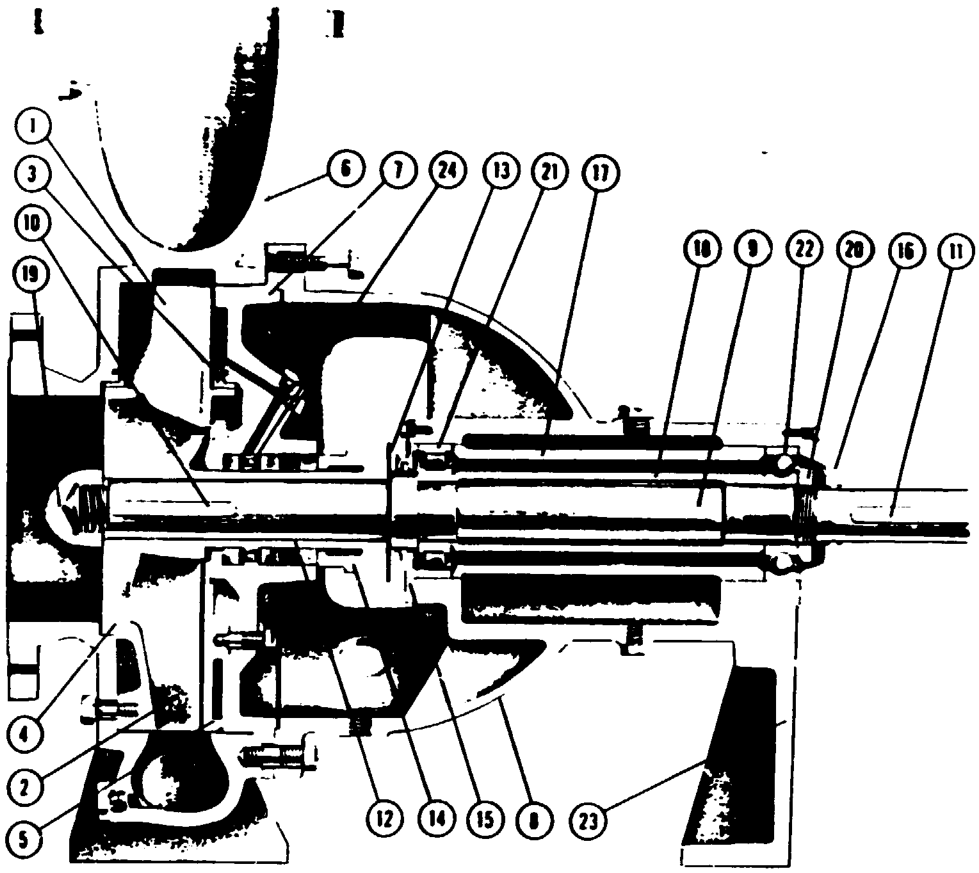
32. (iii) Mixed flow pumps develop the pressure head partly by centrifugal force and partly by the lift of the vanes on the liquid and have a single inlet impeller with the flow entering axially and discharging both axially and radially. This type is often used in cases requiring high volume and medium heads of discharge just beyond heads manageable by the simpler axial flow or pure propeller pumps.

Positive displacement pumps

33. Under the second category - positive displacement pumps - fall a host of types with relatively limited use in irrigation but popular among intermediate technology and village technology enthusiasts for their relative simplicity and ease to make. These types are designed to increase the hydraulic head fluid out of the pump under the motion of a slid body displacing the fluid. They fall again under two subcategories:

(i) Reciprocating pumps containing a piston which moves in alternating directions within a close fitting cylinder. Moving in one direction the piston creates a partial vacuum into which water flows through an intake port. As the direction of the piston motion is reversed, the water is forced out through an outlet port. The flow tends to be pulsating.

(ii) Rotary pumps consist of a casing containing gears, cams, screws, vanes, plungers, or similar elements actuated by the rotation of the drive shaft. Water is trapped in the spaces between the rotating element and the casing and forced through the pump to the discharge side. Flow through this type is continuous rather than pulsating.



List of parts

1.	Impeller, shrouded	9	Shaft	17	Distance sleeve
2.	Impeller, open	10	Impeller key	18	Distance sleeve
3	Casing wear ring	11	Coupling key	19	Impeller nut
4	Side plate, suction side	12	Shaft sleeve	20	Bearing nut
5	Side plate delivery side	13	Flinger	21	Roller bearing
6	Volute casing	14	Stuffing box gland	22	Ball bearing
7.	Stuffing box cover	15	Bearing cover, pump side	23	Support foot
8	Bearing housing	16	Bearing cover, drive side	24	Latern ring

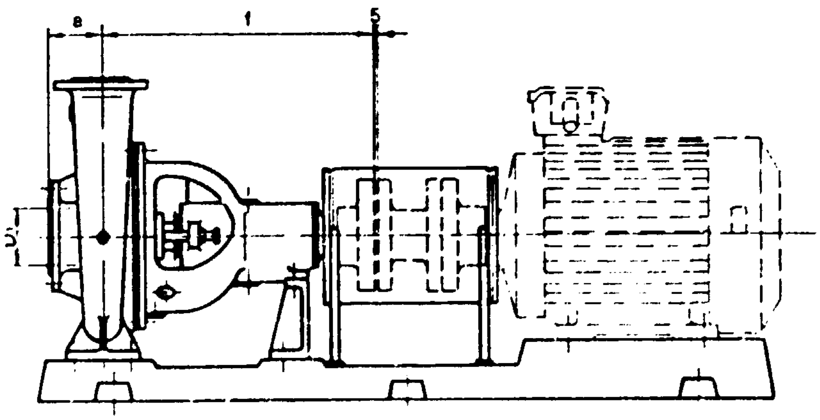


Fig. 11: Centrifugal pump - single suction.
Above: cross-sectional view and list of parts.
Below: View of pump and motor assembly.

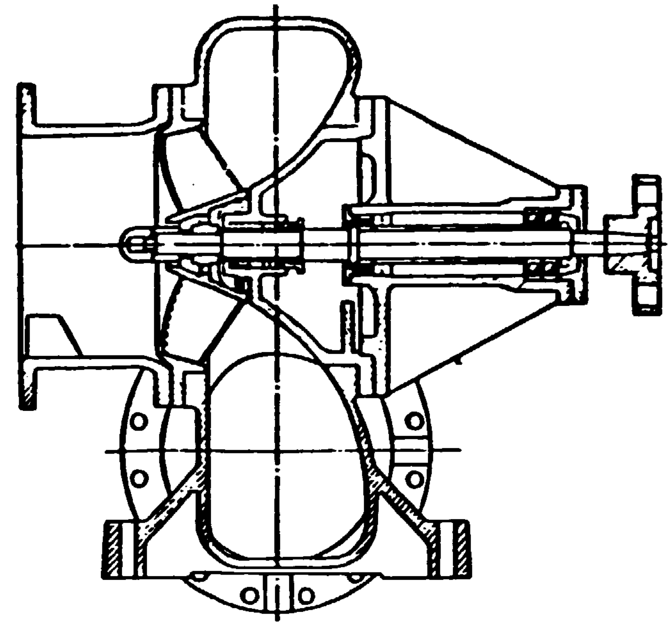
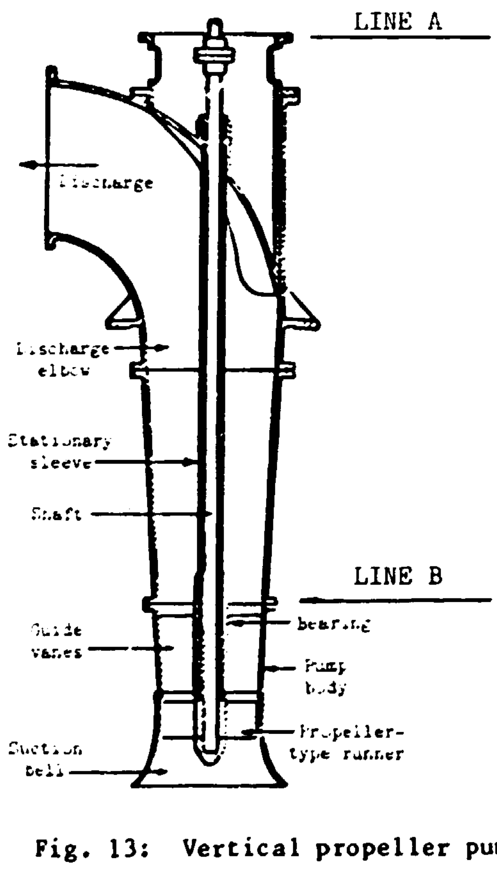


Fig. 12: Worthington mixed-flow pump.



In the axial-flow propeller pump all parts except the shaft and bearing can be omitted, and their functions taken over by concrete works.

This principle was successfully applied in the Saad River pumping station in Iraq in 1969.

French companies are offering to apply the same principle in Morocco in order to save on the cost of imported parts.

Fig. 13: Vertical propeller pump.

Turbopump characteristics

34. As mentioned earlier, knowledge of pump characteristics, usually expressed in terms of performance curves, is vital to optimum selection of pumping units and pumping systems. The magnitude of capital invested in pumping machinery, piping and structures, as well as operating and energy costs, depend squarely on proper selection which in turn would determine the pump manufacturing strategy a country needs to adopt.

35. The pump characteristic curves, also referred to as "performance curves", show the relationship between head developed by the pump, its efficiency (e), its brake horsepower (BHP), and the rate of discharge. In addition, each pump has a required NPSH (net positive suction head), i.e. the head that causes water to flow into the eye of the impeller, a factor which varies with the capacity and speed of the pump. The head, horsepower, and efficiency are plotted as ordinates of the characteristic curves with the discharge rate as the abscissa as shown in Figure 14. A particular set of these curves defines the relationships for a given pump at a given speed. The curves obtained from the manufacturer are based on actual pump tests performed on the given pump or a similar unit such as a scale model. Pumps of identical design will have nearly identical characteristics with only slight differences due to unavoidable foundry and assembly variations. The general shape of these curves varies with size, speed, and design of a particular pump.

36. A pump operating at a given speed is rated at the head and discharge which give the maximum efficiency. This is called the B.E.P. (best efficiency point). The pump characteristic of Figure 17 shows this to be 900 gpm (3.4 cu.m/min) discharging at a head of 145 ft (44 meters). The shut-off head is the head developed when the pump discharge valve is closed.

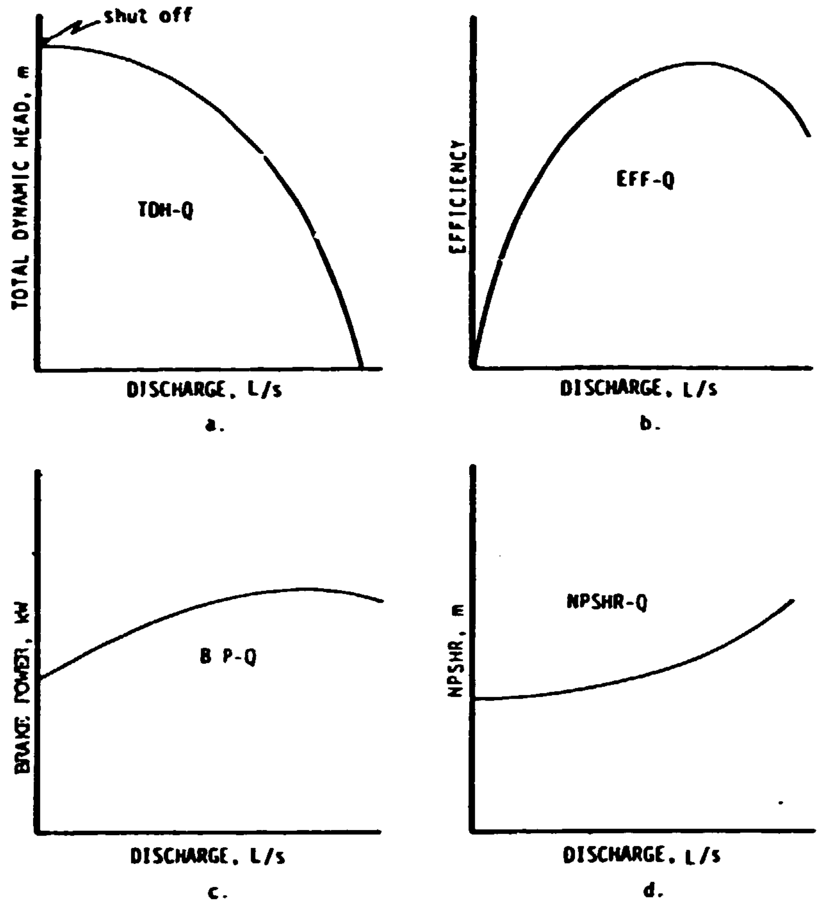


Fig. 14: Typical characteristic curves for a pump.

There are four different characteristic curves that are most commonly provided by a manufacturer (see Figure above).

The performance of pumps will change with time depending upon the environment in which they are operated. For example, when pumping muddy water or water from a well containing sand, both the centrifugal and turbine pumps will be subjected to above normal wear. Replacement of the impeller, wear rings, or even entire bowl assembly may be required every year if wear is excessive. This is best determined by carrying out field pumping tests to verify the above characteristic curves.

Note: NPSHR in curve d (above) is the net positive suction head required as defined in another section in this report.

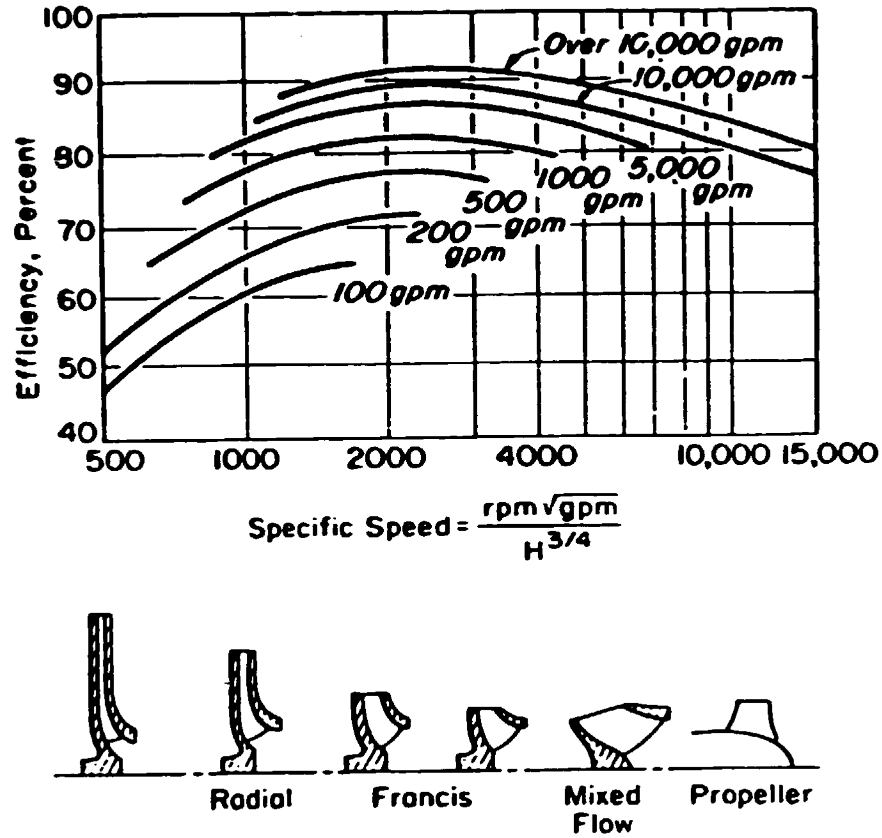


Fig. 15: Optimum efficiency as a function of specific speed.

<u>Pump rating and efficiency</u>

37. Pumping units operated by individual farmers in the range of say 5-20 hp, which are usually diesel driven, run at low overall efficiencies of about 5 per cent in most developing countries. This is about half the efficiency (about 10 per cent) achieved by farmers of developed countries, even though in both cases the pumps may have been manufactured to the same internationally accepted standards.

38. The greatest single factor to which this low performance level in developing countries could be attributed is perhaps the farmer's inability to select the proper pump for his needs. He usually shops for a 4" or 6" pump and so on referring to the diameter of the pump delivery pipe. The supplier may have or may even not have the manufacturer's characteristic curves or selection tables; he merely gives him a 4" or 6" pump with a matching motor in terms of revolution per minute, usually oversized in terms of power, and wishes the buyer good luck. The farmer would have to be extremely lucky not to burn double the amount of diesel fuel than actually needed for his pumping operation. He is unaware that total dynamic head affects the amount of water pumped per minute, or that a pump designed to have its best efficiency at a certain total dynamic head (TDH) delivering so much water per minute may be less efficient (wasting energy) and would deliver smaller quantities of water at greater TDH. Therefore knowledge of pump ratings and efficiencies is vital to proper selection of pumps, and strategies for manufacturing of pumps for local farmers should be based on knowledge of all said factors.

39. Pumps are usually rated at a certain capacity in gallons per minute (gpm), liters per second or cubic meters per second for very large ones for given total or static head. The rating may be controlled by the pump design or by the size of the driver expressed in horsepower (hp) or kilowatt (kW).

40. Pump efficiency is a direct measure of its hydraulic and mechanical performance and is defined as the ratio of energy output of the pump to the energy input applied to the pump shaft by the driver (actor/engine). The energy output of the pump is the water hp or kW (whp or wkW). The water energy output is the product of the total dynamic head developed by the pump and the rate of pumping (discharge rate Q), adjusted for units used.

$$\text{Water horsepower} = w\,Q\,H/550$$

where w is the specific head of water (62.4 lb/cu.ft.), Q is the volumetric flow rate in cfs, and H is the total dynamic head in feet of water. The energy input at the pump shaft is, in this case, the brake horsepower (bhp).

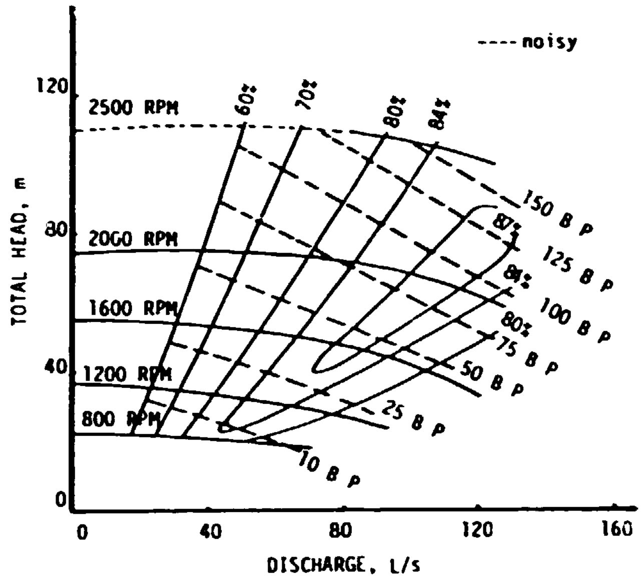


Fig. 16: Characteristic performance curves of a single stage pump for several operating speeds.

Overall pumping efficiency

41. The overall pumping efficiency takes into account all energy losses in lifting the water to the desired level including power conversion losses. In the case of electric motors being the drivers, overall efficiency is computed from wire to water which reflects losses in converting electricity into mechanical energy disregarding the losses in the generation and transmission of electric power to the motor. In the case of combustion engines, however, conversion losses from fuel to water power are considered. The energy contents of most commonly used fuels, diesel and gasoline are 39020 and 34560 kilo joules per liter, respectively; (one kilowatthour = 3 600 000 joules).

Overall efficiency = product of efficiencies of all components

42. Properly selected pumps run at efficiencies between 65 and 80 per cent. Electric motors loaded between 75 and 125 per cent of their nominal power rating should run at near their peak efficiencies of fuel consumption which

are realistically considered to be 20 to 25 per cent. Other useful efficiency figures are:

Gearbox transmission	95%
V-belts	90%
Flat belts	80%
Direct coupling	100%

43. The maximum theoretically possible values for overall efficiency are 72 to 77 per cent (electric drive). In reality, as shown in Table 2, average values obtained from field tests in the USA are considerably lower; 45 to 55 per cent for electrically driven and 13 to 15 per cent for diesel.

Power source	Maximum theoretical	Recommended as acceptable	Average values from field tests*
Electric	72-77	65	45-55
Diesel	20-25	18	13-15
Natural gas	18-24	15-18	9-13
Butane, propane	18-24	15-18	9-13
Gasoline	18-23	14-16	9-12

* Typical average observed values reported by test teams.
Source: American Society of Agricultural Engineers.

Note 1: The relatively high efficiencies shown for electrically powered pumps are due to the high efficiency of electric motors not reflecting energy losses in electric power generation and transmission.

Note 2: The 9 to 5 per cent efficiency range for non-electric pumping shown above are for USA conditions. In developing countries, in general, where technological lack of familiarity of farmers and workers, scarcity of replacement parts and/or fund for their purchase are major constraints, efficiencies should be expected to be considerably lower.

Table 2: Typical values of overall efficiency for representative pumping plants, expressed in per cent

Pumping at other than B.E.P.

44. For pumps to operate at the best efficiency point (B.E.P.), water levels at the source and delivery sides must be at optimum design value. Pump speed must be kept at the nominal required regardless of the condition of the driver

- most likely a diesel engine working in exposed conditions. Most of the time such ideal conditions do not prevail and pumps would have to work at different points on their performance curves than at the best efficiency point. The result would of course be far from catastrophic. Since this lower efficiency performance represents a controversial issue in official attitudes towards the quality of industrialization, it deserves a brief analysis which will follow.

45. Two types of the most commonly used irrigation pumps are taken up for making the case that some sacrifice in pump efficiency, if that helps encourage local manufacture is not too bad after all and in fact it is normal. An ordinary centrifugal pump whose characteristic curve (Fig. 17) shows its best efficiency point as when pumping against 145 ft head, efficiency being at 72 per cent. When this pump operates against 125 ft head, only 20 ft less than for best efficiency head, the drop in efficiency is 10 per cent, e.g. from 72 to 62 per cent, an accepted reality in irrigation pumping, since such fluctuation in water head is normal. To make the case more general, an axial flow pump used in irrigation for low lifts is considered. Its characteristic curve (Fig. 18) shows its best efficiency point as when pumping against a total head of 4.76 meters, efficiency being 78.8 per cent at this point. If the same pump operates against a total head of 2.76 meters, a normal variation in low head pumping, its efficiency drops by 10 per cent, e.g. from 78.8 to 68.8 per cent, once more proving the case.

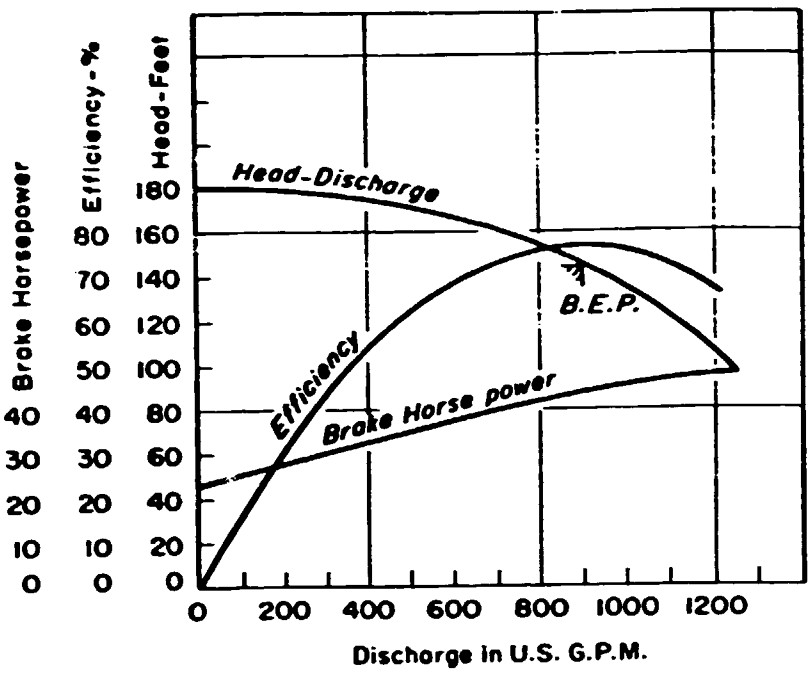


Fig. 17: Typical centrifugal pump characteristic curves

At Best Efficiency Point (B.E.P.),
efficiency = 72%, head = 145 ft.
At 10% deviation from B.E.P.,
efficiency = 62%, head = 125 ft.

In other words, only 20 ft. deviation out of 145 - very normal in pumping - reduces efficiency of a well-designed, well-made, well-selected pump by 10%. It has never been regarded as a threat to the national economy of any country.

850 mm propeller pump
Discharge, head, power input
and efficiency

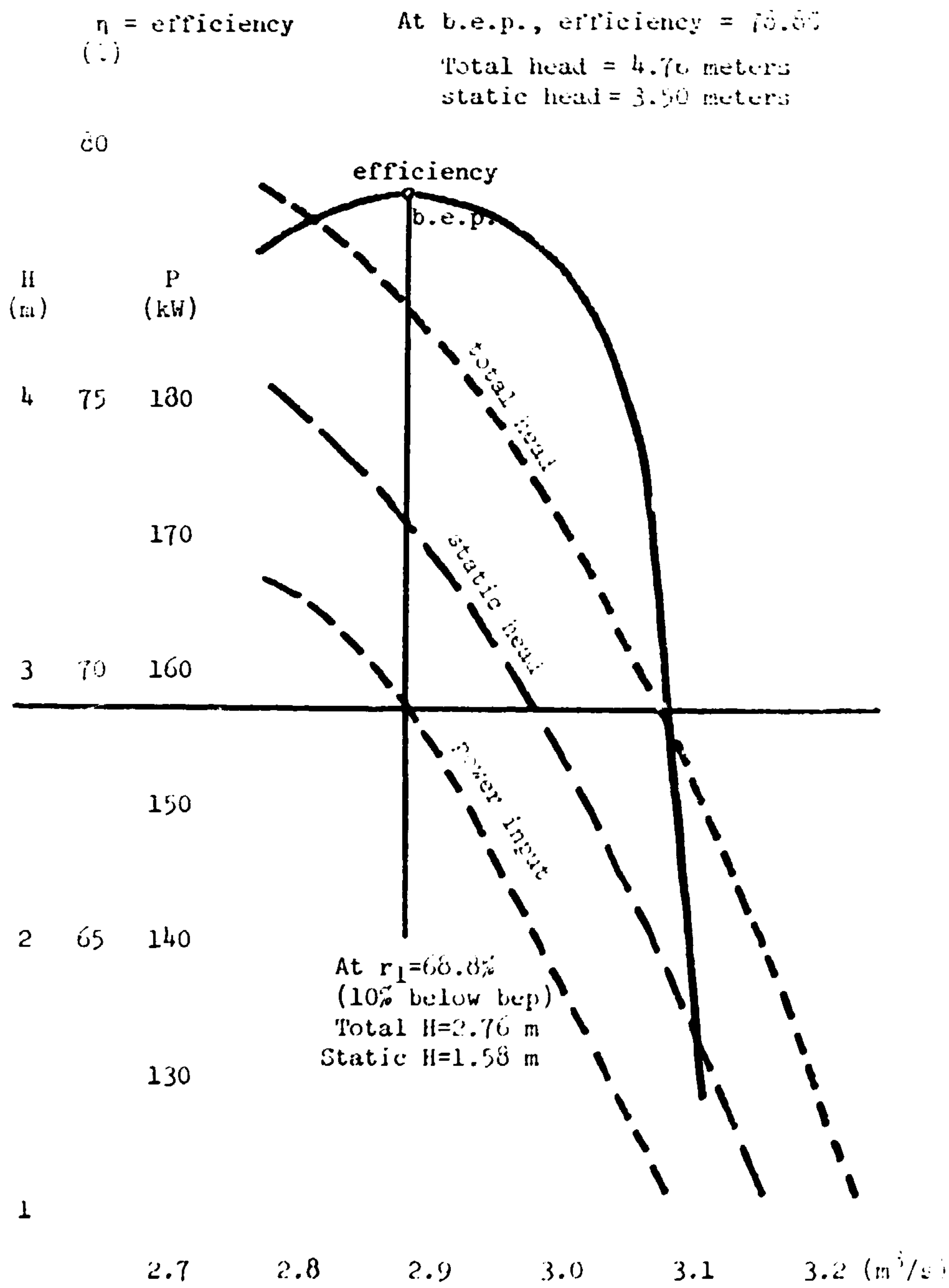


Fig. 18: Discharge, head, power input and efficiency of a propeller pump

Specific speed (Ns)

46. Specific speed is a correlation of pump discharge (Q), head (H), and rotational speed (N) at optimum efficiency, used to classify the pump impellers with respect to their geometric similarity and to compare the performance of dissimilar pumps. Specific speed is a type characteristic and can be used to predict the behaviour of one pump based on tests of similar pumps, however of different size. Properly designed and constructed pumps show that the efficiency is a function of the specific speed. The specific speed of a single suction pump is usually expressed as:

$$\text{Specific speed, } N_s = N.Q^{1/2}.H^{-3/4}$$

where H is in feet, and Q is in gpm. Physically, the specific speed is the rotational speed at which a geometrically similar impeller would be operated to produce a discharge of one gallon per minute against a head of one foot.

47. Pumps of high specific speed give high energy efficiencies while making the pump vulnerable to the destructive effect of cavitation (see below). To reduce the risk of cavitation, pumps should be positioned at lower levels which usually increases construction costs.

Cavitation

48. Pump impellers/propellers act as batteries in electricity where voltage is negative on one side and positive on the other. On the negative side the propeller/impeller is exposed to bubble formation and collapse activity resulting from formation of vapour bubbles and their eventual collapse. The repetition of this bubble formation and their collapse cause pulsation producing sounds as if stones were hitting the pump casing while being pumped with water. This phenomenon causes drop in pump discharge and efficiency in addition to damage to the impeller. It can be controlled to a considerable extent by the design of the pumping station and considerations of the net positive suction head (NPSH).

Net positive suction head (NPSH)

49. A certain portion of the pump's water energy is used to get the water to the eye of the impeller. This is the required NPSH (or NPSHR). The NPSHR is a function of pump speed, impeller shape, liquid properties, and discharge rate. If available NPSH is below requirement, water will evaporate and cavitation activity initiated. The available NPSH (or NPSHA) is computed as follows:

NPSHA = (barometric pressure)/specific gravity - friction -
- suction lift - vapour pressure

If NPSHA is not greater than NPSHR as determined in laboratory tests, then the pump will cavitate.

Affinity law

50. The following three equations describe the relation between discharge Q, head H, and the required brake horsepower BP when pump speed RPM is changed:

$$Q1/Q2 = RPM1/RPM2$$
$$H1/H2 = (RPM1/RPM2)^2$$
$$BP1/BP2 = (RPM1/RPM2)^3$$

in other words, ratio of discharge varies directly with ratio of RPM, ratio of heads varies with the square of the ratio of RPM and ratio of required power varies with the cube of the ratio of RPM.

51. This concludes a very brief description of the most relevant pump characteristics for simple pumping where only one pumping unit of single stage is operated.

52. When the conditions require several pumping units which could be operated in different combinations and/or with one or more units being multistage pumps, pump characteristics of more complex nature need to be considered. Such conditions usually arise when water needs to be pumped through long pipelines to satisfy variable demand.

Lifespan - Maintenance and repair

53. The economic analysis which usually precedes investment in a pumping system requires knowledge of the expected useful life, maintenance and repair costs of the system, in addition to the cost of capital and energy. Estimates of these factors are given in the following two tables for various components of irrigation pumping systems.

	Annual hours of use			
	500	1000	2000	3000
Well	25	25	25	25
Pump	15	15	15	10
Gearhead	15	15	15	10
Drive shaft	15	15	7	5
Engine	15	15	10	7
Gas line	2	25	25	25
Engine foundation	25	25	25	25
Electric motors	25	25	25	25
Electric controls and wiring	25	25	25	25

Note: The above values are for USA conditions. In developing countries useful life is considerably lower. UN experts report that in Senegal's capital area, for instance, lifespan of diesel and pump is reduced to 7 years while in the remote rural areas it is assumed to be 2-3 years only.

Table 3: Estimated useful life of various pump components (years)

54. There are several reasons for the short useful life of pumping units in developing countries, one of which is the lack of preventive maintenance. Maintenance work is usually undertaken only after total breakdown and stoppage have actually occurred. By that time, the damage would have spread to other parts which could have remained undamaged if a simple repair, such as replacement of a bearing, had been carried out before the breakdown. When stoppage happens during a critical period of the plant's growth, which is

normal, crop yields suffer. Lack of preventive maintenance is not always attributed to ignorance. In many instances, due to the high cost of spare parts, farmers cannot afford the cost of inventory for vital spare parts. This can be taken up in the consultations since some suppliers do furnish some of the spare parts with the initial purchase of pumping units along with recommended time of their replacement at relatively low cost - a practice worth being encouraged and generalized.

Component	Depreciation (hours)	Period (yr)	Annual Maintenance and repairs (% of initial cost)
Pumping plant			
structure	-	20-40	0.5 - 1.5
Pump, vertical turbine			
bowls	16000-20000	8-10	5 - 7
columns, etc.	32000-40000	16-20	3 - 5
Wells and casings	-	20-30	0.5 - 1.5
Pump, centrifugal	32999-50000	16-25	3 - 5
Power transmission			
gear head	30000-36000		5 - 7
V-belt	6000	3	5 - 7
flat belt, rubber/fabric	10000	5	5 - 7
flat belt, leather	20000	10	5 - 7
Prime movers			
electric motor	50000-70000	25-35	1.5 - 2.5
diesel engine	28000	14	5 - 8
gasoline engine			
air cooled	8000	4	6 - 9
water cooled	18000	9	5 - 8
propane engine	28000	14	4 - 7
Open farm ditches (permanent)		20-25	1 - 2
Concrete structures		20-24	0.5 - 1.0
Pipe, asbestos-cement and PVC (buried)		40	0.25 - 0.75
Pipe, aluminium, gated surface		10-12	1.5 - 2.5
Pipe, steel waterworks class (buried)		40	0.25 - 0.50
Pipe, steel coated and lined (buried)		40	0.25 - 0.50
Pipe, steel coated, buried		20-25	0.50 - 0.75
Pipe, steel coated, surface		10-20	1.5 - 2.5
Pipe, steel galvanized, surface		15	1.0 - 2.0
Pipe, steel, coated and lined (surface)		20-25	1.0 - 2.0
Pipe, wood, buried		20	0.75 - 1.25
Pipe, aluminium, sprinkler use (surface)		15	1.5 - 2.5
Pipe, reinforced plastic mortar (buried)		40	0.25 - 0.50
Pipe, plastic, trickle, surface		10	1.5 - 2.5
Sprinkler heads		8	5 - 8
Trickle emitters		8	5 - 8
Trickle filters		12-15	6 - 9
Mechanical move sprinklers		11-16	5 - 8
Continuously moving sprinklers		10-15	5 - 8

Source: Design and Operation of Farm Irrigation Systems; The American Society of Agricultural Engineers, December 1980.

Table 4: Depreciation guidelines for irrigation system components

Notes on solar and wind pumping

Solar pumping

55. Solar energy may be used for pumping in a variety of ways. This section is limited to its application by means of electricity generated by photovoltaic technology.

56. Over the past decade, photovoltaic technology has been the subject of quiet but rapid evolution, starting with the development of cells based on crystalline silicon wafers to provide power to satellites. As an outer space technology, serious attention to its application back on Earth developed soon after the 1973 oil crisis and the rocketing rise in energy costs. The cost of generating electricity with this new technology was still considerably higher than conventional electricity and therefore its application was largely limited to small power systems in remote, stand-alone locations.

57. More recently, further technological development brought about a reduction in the cost of manufacturing cells so that the new technology began to compete with conventional energy applications in a wider range of situations, particularly in telecommunications and irrigation pumping. Companies which make complete solar powered communications and pumping units proliferated globally, offering their products at competitive prices. Such products are usually priced by the peak watt (Wp). To start with, a peak watt is the unit used to quantify electricity produced by a photovoltaic device. It is defined as the maximum electrical output at peak solar intensity, specifically noontime on a clear day.

58. To calculate the cost of the more commonly used energy unit, namely the kilo-Watt-hour (kWh), the following formula is given for the conversion of cost/Wp to cost/kWh.

$$\text{Cost/kWh} = \frac{\text{cost/Wp} \times 1000}{(\text{yrs. of life PVUnit} \times \text{hrs. of peak sunlight/yr}) + \text{accumulated interest on outstanding principal}}$$

59. Assuming a 20 year life, 12 per cent interst costs, linear amortization of principal, a 2000 hour peak sunlight equivalent per year, a photovoltaic array with a cost of US$ 10 per Wp (excluding balance of system cost) will generate electricity at US$ 0.55/kWh. Solar pump makers are offering complete pumping systems for lifting 48 cubic meters of water per day by 10 meters for US$ 10,000. In the following, Chronar's (a leading US firm) projections for cost of electricity based on its newly developed technology are given.

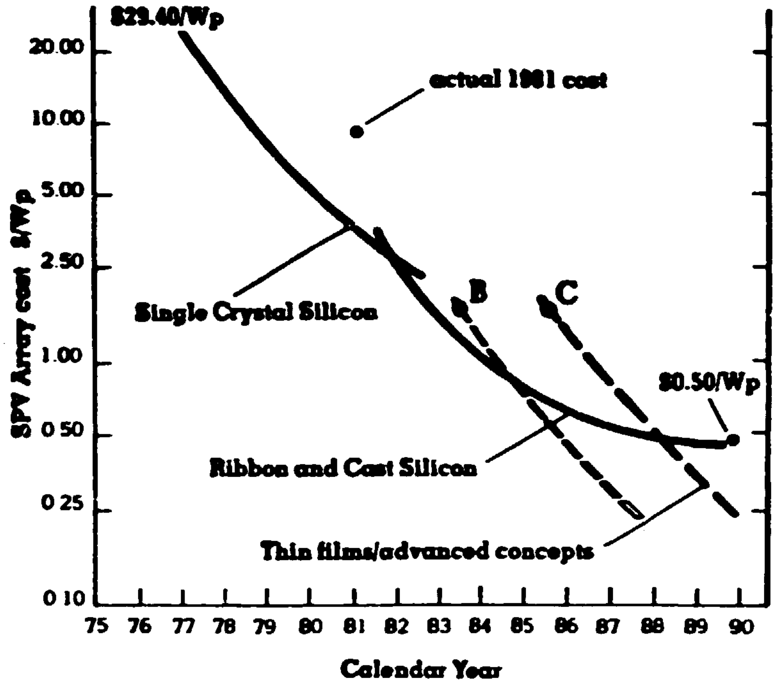


Fig. 19: SPV price history and goals (1980 US$)

Key features of figure:

1. The drastic cost reduction achieved by current technology (single crystal silicon solar cells) over the past 20 years from US$ 1000/Wp to US$ 10/Wp by 1979.
2. The further cost reduction projected for single crystal silicon to US$ 0.50/Wp by the late 1980s.
3. The emergence of thin film devices after 1986 and their price reduction to US$ 0.22/Wp by 1990.

SPV = Solar Photovoltaic

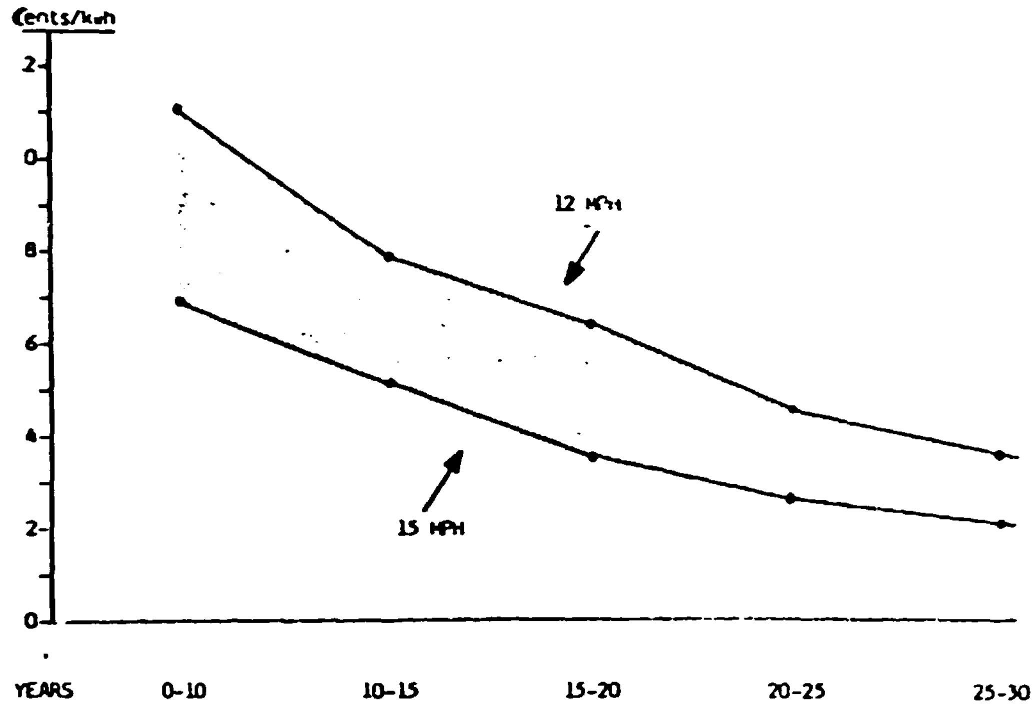


Fig. 20: Wind generation of electricity - cost per KWH

60. Wind energy has been in use for pumping water on a small-scale basis for generations past. As in the case of solar pumping, it received a new thrust in the wake of the 1973 energy crisis. The economy of small-scale pumping utilizing wind power in suitable locations where winds of 5 meters per second (11 miles per hour) or more blow about five hours per day is well established. On a complementary basis with other forms of power generation wind generated electricity on a large scale is advocated by manufacturers of wind turbines. In this report only small-scale wind water pumping for irrigation is considered as an alternative to conventional pumping using fossil fuel. Due to the intermittent nature of winds, the pumping system should include water storage. A stand-by electric power generator, batteries and an AC/DC inverter is recommended. Reports from the field also recommend replacement of mechanically driven reciprocal pumps with electrically driven turbomachines for greater efficiency.

61. In Fig. 20 above wind generation of electricity-cost per KWH is shown; source: Energy Applications Corporation USA. The Figure is based on 1980 prices of equipment using 12 per cent interest and 10 year amortization.

62. Later in this report comparative costs of water pumping based on figures obtained in Somalia in 1983 will be given, showing very favourable results for wind pumping in comparison to diesel and solar. Somalia has excellent wind conditions.

Chapter III. SELECTION OF PUMPING SYSTEMS

63. Pumps are probably the first mechanically powered devices ever used in agriculture be it in the developed or the developing worlds since water is regarded as the most critical input in agricultural production. Neither China nor India could have reached the present stage of food sufficiency without having first produced their own pumping systems needed in irrigation. The green revolution created additional demand for water for the supply of which pumping became increasingly necessary where it had not been so earlier. In addition, lands suitable for gravity and rain fed irrigation are getting more and more scarce leading to further reliance on pumped irrigation whether basic or supplementary, just between rains to prevent damage to crops. Several developing countries are still paying dearly and in foreign currency for irrigation pumping. The scarcity of foreign currency creates such a distorted price structure that the purchase price of pumps to the farmer is several times greater than in the country of its origin.

64. Some of these countries, bearing in mind the volume of foreign aid and technical assistance received, suffer from a persisting deficiency in their technological absorptive capacities which could at least partly be responsible for the apparent ineffectiveness of aid - a subject which deserves rethinking. The others are most likely behind in the process of backfilling and levelling having achieved substantial progress in industrialization across a broad front.

65. The high cost of pumping systems as imported commodities may alone render an otherwise feasible agricultural undertaking not feasible due to high cost of importation and maintenance. And sometimes lack of spare parts results in abandonment of equipment purchased earlier. Pumping equipment does wear out and break rather often, particularly the small units operated by individual farmers. Where there is a choice to be made between gravity irrigation and pumping, government planners often choose gravity due to the above factors. Local manufacture of pumping units with the ensuing benefits to the farmer in terms of financing arrangements and the reduced cost of repair and maintenance is crucial to the development of most agriculture-based economies. Some of

the benefits of the economics of scale lost due to market size can be more than compensated for by benefits from local manufacture in terms of timely availability of equipment and savings in foreign exchange. Pumping equipments are among the few industrial products where such an argument holds true under a variety of circumstances. This notion shall be examined more closely in this report. Moreover, where local pump manufacturing is a reality, the balance my tilt in favour of pumped irrigation against gravity irrigation in planning major irrigation schemes. Such a tilt usually adds another bonus in averting ecological damage caused by the cross-river barrages usually needed for gravity irrigation.

66. Technologies used in ordinary pump making are generations old and non-proprietory. It must be remembered that a good mechanic with casting, lathing and welding capabilities and the like, can indeed make simple centrifugal pumps of the types most commonly used by farmers with small holdings by copying. This is totally different from copying patent-protected products and vandalism of industrial rights which should be curbed in the environment of international co-operation and interdependence. Copying prototypes could even be down-engineered if necessary to suit production capabilities available, and sold to local manufacturers.

67. Down-engineered versions of pumps with reduced component elements for their lower cost and manageable technological complexity/simplicity are not without certain disadvantages in terms of exportability and slightly higher running costs. However, neither should be regarded as unsurmountable obstacles.

68. For countries where the industrial base is relatively limited, the multi-purpose approach should be carefully examined. This might mean that the local manufacture of pumps needs to be accompanied by other manufacturing activities to justify the required investment due to better utilization rates, and to provide the other elements of agricultural mechanization at low cost at the same time. Few suppliers of pumps to the international markets are dedicated pump manufacturers; most of them are part of an industry with diversified engineering and manufacturing capabilities originally established to produce replacements and extensions for the main industrial activity, which could be as remote from pump making as paper pulp and sugar.

69. Pumping units over a certain size are normally manufactured upon orders of 4 or 5 units. This clearly demonstrates the inapplicability of the notion of the "economies of scale" for most large irrigation pumps. Such pumps are used by governments that choose to deliver irrigation water to the small farms' turnouts (gates) by gravity flow in canals after lifting the water from a larger canal or river to higher grounds. The local manufacture of such large pumping systems requires technological capabilities similar to those required for local manufacture of small hydro-electric power plants, where the scope for international co-operation is similar, too. Countries contemplating to develop hydro-electric power plant manufacture may benefit from the similarity. However, the main emphasis here is placed on the most commonly used pumps for irrigation: the propeller for low-lift (up to about 6 meters) and the centrifugal for greater lifts. In this respect, Burma's success in manufacturing small hydropower turbines with some assistance from Austria can be taken as a model for overcoming common constraints and for an effective type of foreign technical assistance. There are examples of such successes in Egypt, Jordan and other countries, also involving UN organizations. Such examples merit careful analysis and comparison with the many cases of failure in countries like Somalia, Sudan etc. for identification and rectification of maladies using the technological dependency method explained in Chapter IV.

70. Wind and solar powered irrigation pumping systems are gaining more and more popularity. The validity of their use in areas where supply of conventional energy is unusually expensive is well established, if not common practice. But considering the fact that the cost of solar photovoltaic panels is on the decline, plus other technological developments, such as the amorphous silicon using chemical vapour deposition (CVD) techniques, solar water desalination, desert greenhouses, the proliferation of solar photovoltaic powered irrigation techniques are expected to accelerate.

71. An attempt has been made to present a sufficient number and variety of elements used in pumped irrigation to choose from in planning multi-purpose manufacturing facilities. The pump itself was given priority in detailing, and irrigation itself was briefly explained to make possible understanding of the discussion of various aspects of pumping and water-related implements.

72. An attempt has been made to suggest a method for grouping developing countries by their degree of technological dependency where members of a group are likely to have similar problems which may require similar or common action.

73. Strategies for promotion of national manufacturing capabilities of pumping systems needed in the agricultural sector must be based on rationalized choice of pumping technologies which must, in turn, be based on the right choice of irrigation technologies needed for the improvement of agricultural production.

74. A distinction is made between the pump itself and the device which drives it (the driver: electric motor, diesel engine etc.). While choice of the pump is directly affected by irrigation/drainage requirements and techniques, the most appropriate driver is, in addition, dependent on the source and cost of energy and on the degree of technological dependency of the country involved (see Chapter IV). Where electricity mains are near, AC electric motors are generally chosen; whereas in the case of solar energy being competitive in cost, DC motors would be more appropriate - both easier to manufacture and cheaper than diesel engines which are more difficult to manufacture, require more maintenance, have shorter lifespan - that is in the more common power range of 5 to 20 horsepower which furthermore run on low overall pumping efficiencies of around 5 per cent in most developing countries. No further discussion of the drivers is made in this work other than some brief references and in the examples given in the following paragraphs.

75. Automation of irrigation systems is not discussed in this report either. The reason for this is not the popular view that automation is irrelevant to developing countries that can bearly sustain traditional irrigation. In fact, automation deserves particular attention by developing countries short of water, energy fertilizer and skilled manpower as the microchip can help alleviate these shortages to a considerable extent and help maximize crop yields with minimum inputs.

76. Sensors, for example, planted at the root zone of the plant would send messages of soil moisture and available nutrition. The information is matched with other information and the optimum requirements for yield maximization in

computer programmes which issue instruction as to water and fertilizer complements needed. Execution in response is carried out automatically or manually according to the degree of automation at hand. Many other computer applications exist and are possible.

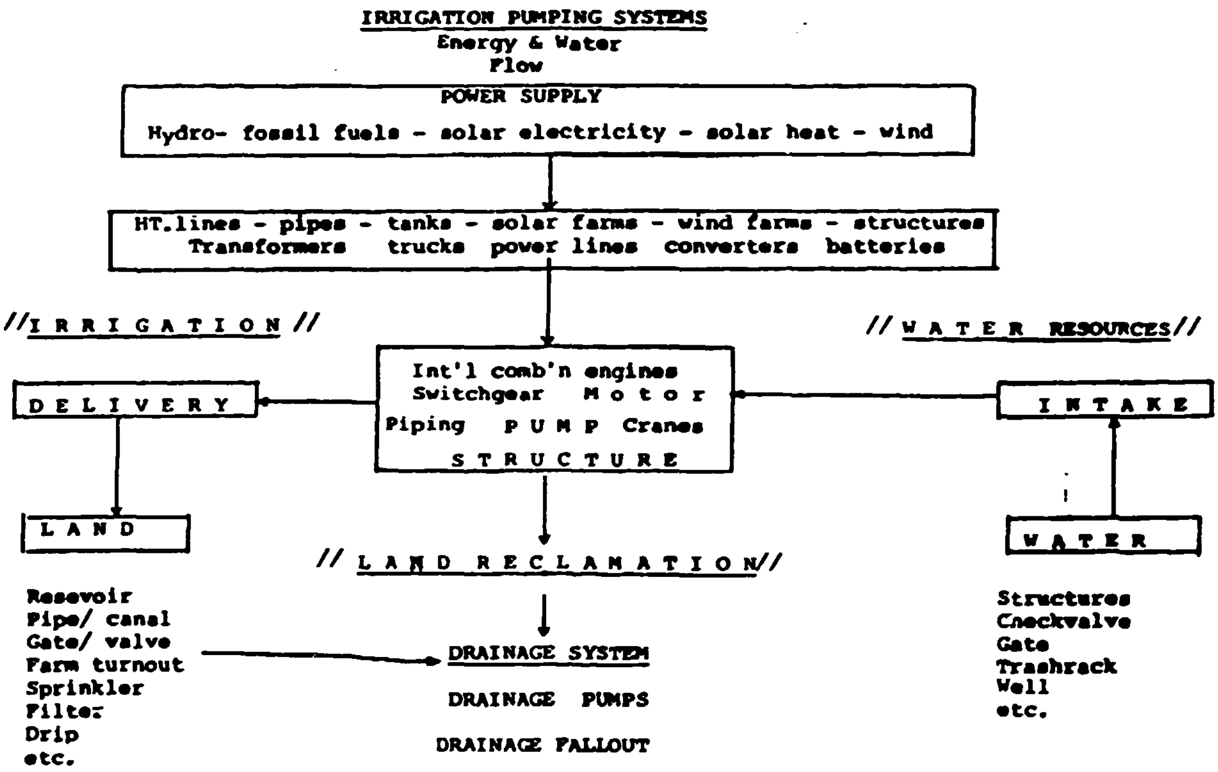


Fig. 21: The pump in a pumping system serving agriculture in irrigation and land reclamation.

An economic consideration of down-engineered low efficiency pumps

77. Rigid standards and efficiency requirements may constitute insurmountable difficulties to entrepreneurs who plan to start an industry, in particular a small-scale one. They are often individuals with limited capital and technical knowledge but a lot of courage and vision. Government planners, economists and decision-makers in developing countries, those with high training abroad often overemphasize the need and the necessity of attaining standards for locally manufactured goods comparable to their imported

counterparts using economic justifications which are not entirely correct. Such requirements may deal fatal blow to an industry in its embryonic stage, or where government licensing is mandatory, the industry may not be able to get off to even a start. Let us, for example, examine the validity of such an argument which is quoted from a formally submitted document.

78. "In any case, robustness, life-time and efficiency should not be sacrificed under the pretext of encouragement of locally-made machinery. For example, an axial flow pump similar to the type developed by IRRI and produced now by thousands per year in the Philippines, Thailand and Indonesia, needs about 4 HP. Assuming that this pump will run about 2000 hours/year, this means a gas oil consumption in the range of 2000 kg/year. Improving the efficiency by, e.g. 10 per cent, will result in saving 200 kg of gas oil per year or about US$ 100 (this depends on the local cost of energy). If the life-time of this pump is 10 years, this means a saving of US$ 1000 which is much more than its purchase price."

79. The above reasoning is challenged as follows:

1. Fuel consumption is proportional to the OVERALL EFFICIENCY and not to the efficiency of the pump alone (see sections on efficiency).
2. Improving the pump efficiency by 10 per cent may result in improving overall efficiency of a diesel driven pump by probably a mere 2 per cent since the overall efficiency for such pumps measured in developed countries is not over 18 per cent (see p. 35, Table 2).
3. Using the figures from the above quotation, the saving per year would be about US$ 20 at best and the total for 10 years would be US$ 200.
4. Present day value of a benefit of US$ 20 per year over a period of 10 years compounded annually using a modest interest rate of 10 per cent per annum, is found to be 20x6.14=122.8. US$ 122.8 is considerably lower than US$ 1000 and the farmer who may not have the skills to calculate would usually reject the misleading figure using common sense.

Effect of dependency/interest rates on choice of technology

80. In comparative economic analysis and evaluation of choices of technology interest rates dictated by external factors play an important role in selecting the most economical solution according to the country's degree of technological dependency. The more dependent a country is on external support in technology utilization the more it is affected by interest rates determined in major technologically advanced countries. High interest rates for instance put at disadvantage the solar pumping solution which requires a larger initial investment and smaller operating costs while they put the diesel pumping solution at an apparent advantage due to its lower initial cost in spite of its higher running costs. In the case of the solar solution, its already disadvantageous initial capital cost is further augmented when this cost is annualized using the high interest rates and its benefits in terms of savings in operation costs are steeply discounted when computed on present worth value basis. The opposite is true for the diesel solution where the main cost of pumping is fuel and maintenance being incurred in the future.

81. It is assumed that when a country is technologically more self-reliant, it can base its judgement in selection of a technology on interest rates which reflect its own realities rather than what goes on in international money markets.

82. By way of illustration an analytical table is reproduced on page 54 from a recent United Nations document[4/] which reflects comparative studies made for Somalia by several experts from various aid organizations on water pumping using diesel, wind and solar powered pumps. In the table, costs are computed for units of ton meters where for example 980 ton m represents 980 tons of water pumped against a total dynamic head[5/] of one meter or 490 tons of water against TDH of 2 meters and so on. The procedure used in calculating

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4/ Mission report on Somalia by Derek Lovejoy, Interregional Adviser, Energy Resources Branch, DTCD, New York, November 1983.

5/ See Chapter II.

cost is rather simplistic but accurate enough for the purpose.[6/] Two anualized charge rates are used in the calculations; 10 per cent and 18 per cent per annum both containing depreciation, interest, operation and maintenance (O & M) costs. The first rate of 10 per cent is based on a 15 year depreciation period, 5 per cent interest plus one per cent for operation and maintenance bundled together to 10 per cent. The second rate of 18 per cent is based on 10 year depreciation period, 15 per cent interest and one per cent for O & M bundled together to 18 per cent.

	(1) Av.daily productivity ton m	(2) Av.annual productivity ton m x 10³ (1) x 365 days	(3) Capital cost $ CIF	(4) Annualized cost $ 10% x(3)	18% x(3) (8% solar) (15% diesel)	(5) Annualized cost $ per 1000 ton m 10% (4)/(2)	18%	(6) Running cost[a/] (fuel+operation) $0.35/1	$0.70/1	(7) Total cost $ per 1000 ton m 10% $0.35/1 (5)+(6)	18% $0.70/1	(8) Water cost per m³ for 40 m dynamic head 10% (7) x 40m/1,000tm	18%
Solar pump	980	358	15,500	1,550	2,790 (1240)	4.34	7.80 (3.46)	-	-	4.34 (3.46)	7.80	0.17	0.31
Wind pump	2980	1086	12,500	1,250	2,250	1.15	2.07	-	-	1.15	2.07	0.05	0.08
Diesel pump	[illegible]	1500	4,000 (+2,600)	400	720 (990)	0.27	0.48 (0.66)	3.35	6.20 (4.79)	3.33[b/] (5.45)	6.68[c/]	0.15[b/]	0.27[c/]

a/ Assume $1.50/hour operating cost for diesel pump operation.
b/ Mostly fuel cost at $0.35/litre. 10% charge rate. 123 ton m/litre. } Corresponds to about 5% overall efficiency;
c/ Mostly fuel cost at $0.70/litre. 18% charge rate. 123 ton m/litre. } small-scale pumping - 5-20 hp.

(XXXX) Recomputed figures on the basis of:

- 4% interest rate
- 7% capital recovery factor (CRF)
- 1% operation and maintenance for solar
- 8% operation and maintenance for diesel
  - diesel replaced at age 10 yr. at non-escalated CIF cost of $4000 discounted to PW of $2600
  - constant diesel fuel cost of $0.50/1
  - lifespan = 20 years.

All other figures are from Derek Lovejoy, DTCD, 1983, Mission Report on Somalia.

Table 5: Comparison of water pumping using diesel, wind and solar powered pumps.

6/ Operation and Maintenance charge of 1 per cent may be adequate for the solar system which contains a large investment in non-moving parts. For the diesel system 8 per cent would be more realistic under developing country conditions; and a lifespan of 20 years is more reasonable for the solar while for the diesel replacement would most likely be needed after 10 years at the most.

83. Column 7 of Table 5 shows that the cost per 1000 ton meters pumped is US$ 4.34 and 7.80 for the solar system using 5 per cent and 15 per cent interest rates per annum which correspond to 10 per cent and 18 per cent annualized costs, respectively. For the diesel system interest rates on capital made little difference, most of the annualized cost being fuel, the figures US$ 3.83 and 6.68 are computed for costs of diesel fuel US$ 0.35 and 0.70 per liter, respectively, both based on the same annualized charge at 18 per cent per annum, only marginally cheaper than the solar alternative. In fact, using the same initial figures of columns 1 and 2 but adjusting the analysis for US$ 0.50/liter for fuel, considering a 20 year lifespan for the analysis with the diesel replaced at age 10 years with the cost of replacement discounted to present worth value at 4 per cent interest and using the 4 per cent interest rate for all investments[7/] and 8 per cent per year for operation and maintenance (see page 42, Table 4) of the diesel's small capital cost, the new results in column 7 would be US$ 3.46 per 1000 ton meters for the solar and US$ 5.45 for the diesel pumps. In other words, solar pumping is cheaper than diesel pumping at 4 per cent interest considering acceptable O & M charges for the diesel. At high interest rates, moreover, when the present worth value of the diesel's fuel and maintenance costs is sharply discounted, the cost per 1000 ton meter appears much less than before discounting. The solar alternative has no fuel costs to discount. The greater the interest rate used for discounting fuel and maintenance the cheaper it appears today in favour of the diesel alternative.

84. Moreover, investors would consider initial capital requirements as critical. As seen from columns 2 and 3 of Table 5, the capital cost for the solar pump which would yield 358,000 ton meters yearly is US$ 15,500 while for the diesel which yields about 4 times as much it is US$ 4000. In most developing countries where banking and money instruments are embryonic, high

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7/ The Capital Recovery Factor (CRF) approach is used where

$$CRF = i(1+i)^n \left((1+i)^n-1\right)^{-1}$$

and i = interest (4%), n = 20 years; CRF = 0.07 (the revised annualized capital charge). Therefore, the annualized capital charge plus O & M costs would be: 0.07 + 0.01 = 8% for solar, and 0.07 + 0.08 = 15% for diesel.

interest rates usually result in a clear bias for selecting technologies which require the least initial capital regardless of the known disadvantages of such selection. This is a malady of underdevelopment and the state of technological dependency.

85. To illustrate the significance of interest rates in the choice of technology, curves have been computed and presented on the following pages for the relationship between interest rates and both the annualized costs and the present worth of total costs for the two alternatives (solar and diesel) for various oil prices.

86. It is interesting to note in these curves that the break-even points between solar and diesel for all three fuel prices occur at around the same interest rates, namely 5, 10 and 14 per cent.

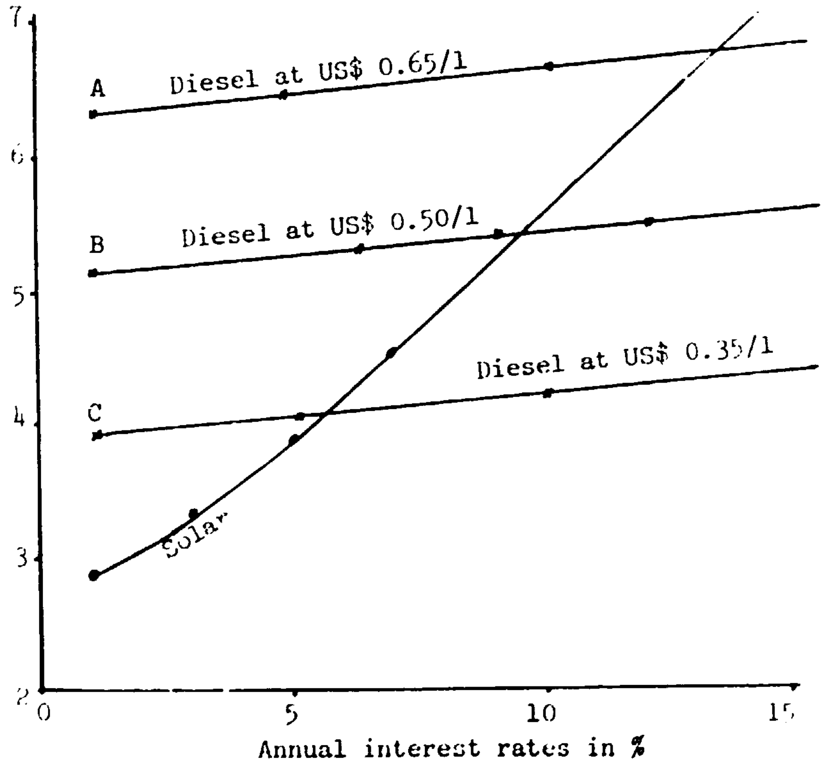

Fig. 22: Annualized total costs per 1000 ton meters pumped water in Somalia in 1983 US dollars, vs. interest rates for solar and diesel alternatives using 0.35, 0.50 and 0.65 dollars/liter as fuel costs.

Note: The higher interest rates go, the more fuel should cost for solar to equal diesel in cost.

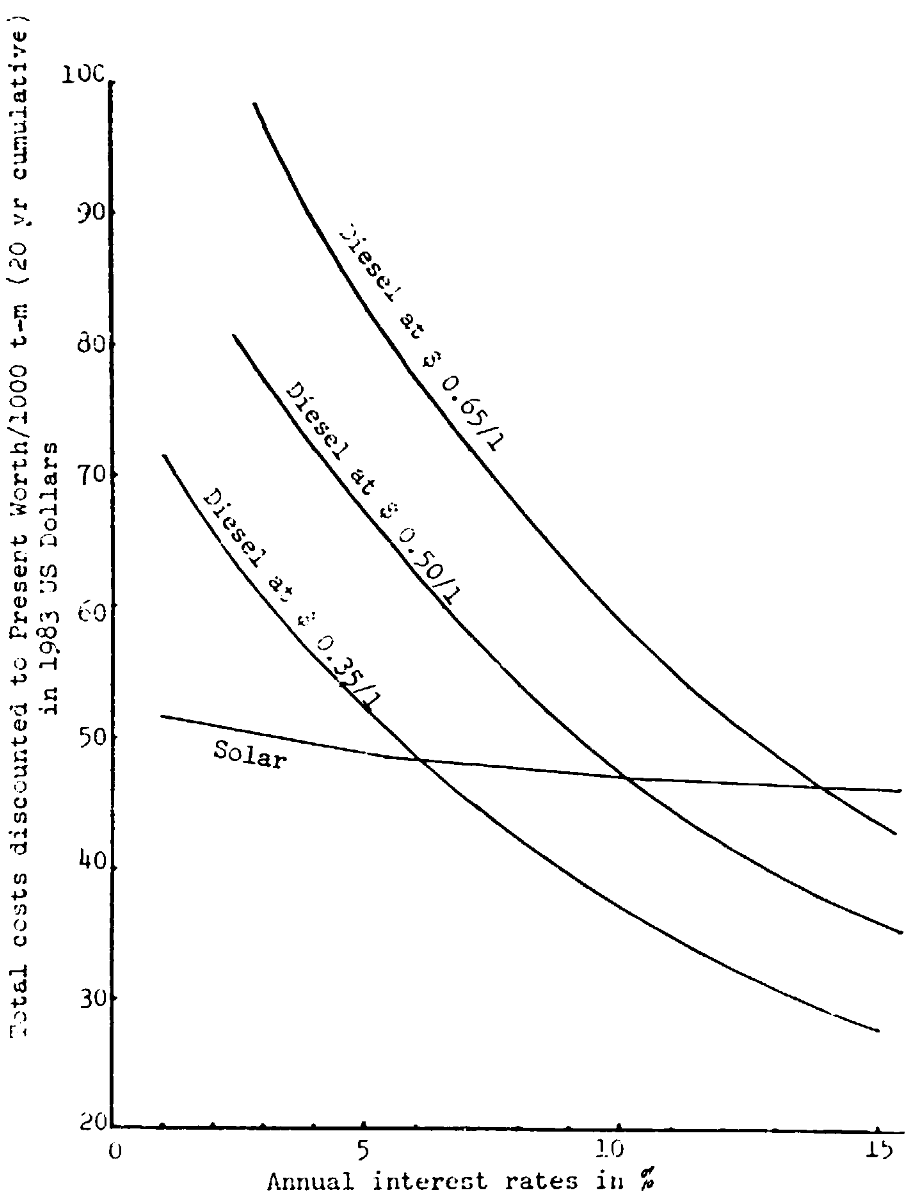

Fig. 23: **Total pumping costs vs. interest rates for solar and diesel at three different fuel prices.**

Note: **Data based on Somalia example reported by Lovejoy 1983 for small-scale pumping - 5-20 hp.**

I	Z	E	O	R	R2	U	Sp
0.00	0.35	4.92	0.43	19.99	98.39	102.79	51.96
0.01	0.59	5.16	2.83	18.04	88.78	93.18	51.11
0.02	0.62	5.19	3.08	16.35	80.44	84.84	50.38
0.03	0.64	5.21	3.34	14.87	73.19	77.59	49.74
0.04	0.67	5.24	3.61	13.59	66.86	71.26	49.18
0.05	0.70	5.27	3.90	12.46	61.31	65.71	48.70
0.06	0.73	5.30	4.20	11.46	56.43	60.83	48.26
0.07	0.76	5.33	4.52	10.59	52.12	56.52	47.89
0.08	0.80	5.37	4.84	9.81	48.30	52.70	47.55
0.09	0.83	5.40	5.17	9.12	44.91	49.31	47.25
0.10	0.86	5.43	5.51	8.51	41.88	46.28	46.98
0.11	0.90	5.47	5.87	7.96	39.17	43.57	46.75
0.12	0.94	5.51	6.22	7.46	36.74	41.14	46.53
0.13	0.97	5.54	6.59	7.02	34.56	38.96	46.34
0.14	1.01	5.58	6.97	6.62	32.58	36.98	46.17
0.15	1.05	5.62	7.35	6.25	30.79	35.19	46.01

I = Annual interest rate

Z = Annualized cost of principal and maint. per 1000 ton meter
or depreciation (amortization) + 8% of principal/1000 t-m

E = Z + cost of fuel and operation per 1000 t-m
cost of fuel being US$ 4.07 and operation US$ 0.05 = US$ 4.57/t-m

O = Annualized principal + 1% maint. for solar per 1000 t-m

R = Cumulative discount factors for years 0 to 20

R2 = Present worth of fuel + O&M costs per 1000 t=m (R x US$ 4.92)

U = Total initial cost per unit (R2 + 4.4), US$ 4.4 being principal/unit

SP = PRINCIPAL/UNIT for SOLAR = Present Worth of 1% yearly On'n
last column

Table 6: Curve data

87. The present day value of an amount to be received after n years is calculated by multiplication of the amount by a discount factor. The discount factor is $1/(1+i)^n$.

n = number of years

i = interest rate

Chapter IV. DEGREE OF TECHNOLOGICAL DEPENDENCY

The Need for a Measurement

88. Each developing country has its own unique set of problems to tackle in its path to development. In the context of international co-operation, however, the available mechanisms often treat groups of countries which are considered to be at similar levels of development, rather than on an individual basis. The similarity factor is often determined by parameters involving economic or geographical notions, the per capita gross national product, for instance, such as in the case of the group of least developed countries and the groups of most affected or land-locked countries. Their grouping on the basis of such parameters is insufficient for the treatment of development maladies caused by technological factors including industrialization even in the agricultural sector. India which has a per capita GNP lower than that of Sudan has built its breader atomic reactor, let alone the fact that it produces most of its irrigation pumps, while Sudan still has to import such pumps. Aside from the distinction accorded the group called the newly industrialized nations such as Argentina, Brazil, China, India, Republic of Korea, Mexico and Singapore, there is little to help distinguish between Burma and Sudan with regard to establishment of multi-purpose agricultural machinery production units as an example.[8/] The high quality of technical training available at Khartoum University in Sudan has not put Sudan in a more advantageous position in the manufacture of small hydroelectric power generation units. There may be similarities between the two countries in terms of technological dependency which defy their dissimilar size, population and available training institutions and vice versa. An example is given in Chapter I on how a country in the Middle East had to choose an inappropriate irrigation technology with the costly obstruction of natural rivers when it could have used pumping instead, simply because it did not have control on pumping technology at the time. In this chapter, an African country is considered which is strongly affected by interest rates abroad, due to its high degree of technological dependency, found that diesel

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8/ A new typology of countries has recently been developed by UNIDO in its document UNIDO/IS.507-509 dated January 1985, entitled Electric Power Equipment Production in Developing Countries. The typology is based mainly on present absolute capabilities and future market potentials.

pumping was cheaper than solar when in fact the opposite was true. It can be argued then that in technologically dependent countries, inappropriate technological alternatives may be chosen due to lack of command on the most appropriate ones or due to high interest rates which are dictated externally. How is each country treating its own dependency problem? How can international co-operation help?

89. Since development projects are the main vehicles for raising the standard of living in most developing countries, and their internalized execution is one of the most effective ways for technology transfer, a more direct measurement of the status of its development engine would probably be its degree of dependence on external help in the execution of such projects. Countries which have similar dependency degrees and patterns in one particular sector are likely to be found suffering from similar maladies of development in that sector and perhaps even more broadly in the entire development planning policies including nature of the technical assistance they receive. The degree of dependency can be quantified on a sector-by-sector basis, or on a discipline-by-discipline basis, and for the different levels of technological complexity.

Method for Degree of Technological Dependency computations

90. The following method using specially designed forms is suggested for determination of the Degree of Technological Dependency:

1. For a given sector in a given country the dependency on external inputs can be determined by several ways, say by the percentage of the cost of foreign inputs in the execution of projects in that sector by making cost and place of origin analyses for a number of recently completed development projects in that sector.

2. For every project analysed by first unpackaging the technologies involved, and then, a degree of complexity (how difficult the know-how is to internalize) is assigned for each element. For preliminary studies it might be sufficient to use a scale of numbers from 8 for the most difficult to one.

3. Using percentages of external inputs (external to total) for each of the technological activities and the eight[9/] complements of the technological complexity figures of one project or averages obtained from several analysed projects, the degree of dependency may be calculated, as shown in the examples which will follow.

4. In case knowledge of the degree of dependency for an entire industry is required, a different form is used which provides for recording percentage of external execution figures and technological complexity figures (Tc) for each branch or sector in that industry without unpackaging any project for various elements. An example of this type of dependency computation is given for the construction industry in a certain Near Eastern country.

91. From the first two computed examples which will follow, one for a project, namely realization of a major irrigation pumping station, and the second being for the construction industry as a whole, both in the same country and during the same period, it can be seen that the degree of dependency for the first was 189 and for the second 273. In other words, the country was more dependent on the construction industry as a whole than on the process of realizing that particular pumping station - a reality which would have been hard to guess.

<u>Diagnosis of constraints and prescription of remedies to alleviate dependency</u>

92. The form used for determination of the degree of dependency for the pumping station project has two columns where constraints, which are thought to have caused the condition of dependency, and their recommended remedies are referred to, using numbers/symbols assigned to causes and remedies picked up from prepared lists. Summarizing those causes and remedies based on dependency forms completed for several projects from various sectors and industries valuable guidelines could be obtained for action which would help alleviate the dependency condition on a priority basis.

9/ The reason for multiplication of the per cent external execution by the eighths complement of the complexity level rather than by the complexity figure itself is the need to reflect the fact that dependency at high complexity levels may be normal not reflecting a serious malady, while dependency at lower complexities should represent serious problems. Thus the lower the complexity of the activity where dependency persists, the greater is the degree of dependency.

93. Estimating the cost of the remedies needed in each sector, and knowledge of the cost of external involvement in project execution, cost benefit analysis for technological dependency in each sector can be achieved. This is a highly desirable tool for the process of technology transfer.

94. Example

A project is selected in the agricultural sector. A major irrigation pumping station actually installed in one Near-Eastern country.

Technological dependency analysis of an irrigation pumping station

Country A

Technological activity	Complexity	Dependency %	Causes (from lists) a/	Remedies (from lists) a/
Planning & Conception	6	80	4-c,d; 5-a	3-a,d; 4-b,d,f
Feasibility studies	4	80	4-c,d; 5-a	3-a,d; 4-b,d,f
Soil/foundation tests	4	50	8; 4-h	3-b,d
Structural design	5	20	3-1; 6-b,c	3-a; 6-b
Mechanical model test	6	100	8; 2-j; 4-h	3-b,e; 7-c,d
Electro/mech. design	5	80	3-m,n; 7-c	2-a; 3-a,d,e; 4-d; 7-c,d
Manufacture	6	80	2-a,b,f; 4-d; 5-d,e,f	3-c,d; 6-f; 7-c
Construction	3	00		
Reproduction	4	90	4-a,c; 6-b	2-a,b; 3-c,d

Degree of dependency estimate for feasibility studies:

$$= (8-4)^{(*)} \times 80 = 320$$

Degree of dependency estimate for structural design:

$$= (8-5) \times 20 = 60$$

And so on for all items of activities.

The sum of 320 and 60 and so on is divided by the number of items of technological activities - in this case 9. The resulting figure of 189 is used as the degree of technological dependency for the said pumping station.

a/ Lists are compiled from reported/suggested constraints and remedies.

(*) Since dependency at lower complexity activities represents a greater degree of dependency than at higher levels, complements of the complexity figures are used. The figure 8 is arbitrarily chosen for complementing although the highest complexity figure used is only 6, in order to avoid multiplication by zero when complexity is 6.

95. <u>A computed example based on figures estimated for a Near-Eastern country</u>

Technological dependency analysis for the construction industry

Technology/ Sector	Dams	Marine	Water/ Sewerage	Bridges	Industrial Buildings Hospitals Hotels Hi-rise	High-ways	Housing
Per cent (%) external execution	95	90	80	70	70	60	20
Technological complexity figure (Tc)	6	5	4	4	3	2	1
Dependency estimate % x (8-Tc) =	190	270	320	280	350	360	140

Industry Ave. = Sum of figures above line divided by 7 = 1910/7 = 273.

<u>Note</u>: In this example, the percentage of external execution is assumed to include all elements of technological activities as was the case in the previous example: the pumping station. This assumption introduces some distortions due to the fact that certain elements included in construction are industrial products of which the importation may represent dependency in other industries. Introduction of a correction factor is possible but feared unjustifiable at this stage before the entire method has been field-tested.

96. Third example

Technological dependency analysis ot a drainage pumping tation

Country B

Technological activity	Complexity	Dependency %	Causes (from lists)	Remedies (from lists)
Planning & Conception	6	90	4-d,g,i; 5-a 7-a,b	2-a; 3-a,d; 7-a,c
Feasibility studies	4	90	same as above	
Soil/foundation tests	4	0		
Structural design	5	0		
Mechanical model test	6	100	8; 7-a; 4-i	3-b,e; 7-a,d
Electro/mech. design	5	100	8; 4-c,i;7-c	2-a; 3-a,d,e; 4-d; 7-a,c
Manufacture	6	100	2-a,b,f; 3-r; 3-u; 4-g,h,i	2-a,c; 3-c,d; 4-d,f; 7-a,c
Construction	3	0		
Reproduction	4	90	4-a,c,f; 6-b	2-a,b,c; 3-c,d 7-a,c

Degree of dependency

for 1st item: Planning & Conception	= (8-6) x 90 = 180
for 2nd item	= (8-4) x 90 = 360
for 3rd item	= (8-4) x 00 = 000
for 4th item	= (8-5) x 00 = 000
for 5th item	= (8-6) x 100 = 200
for 6th item	= (8-5) x 100 = 300
for 7th item	= (8-6) x 100 = 200
for 8th item	= (8-3) x 00 = 000
for 9th item	= (8-4) x 80 = 320
TOTAL	= 1560

Degree of dependency for project = 1560/9 = 173.

97. Blank form for computation of degree of technological dependency for any irrigation/drainage project

Technological activity	Complexity Tc	Dependency %	Causes (from lists) a/	Remedies
Planning & Conception	6	a		
Feasibility studies	4	b		
Soil/foundation tests	4	.		
Structural design	5	.		
Mechanical model test	6	.		
Electro/mech. design	5	.		
Manufacture	6	.		
Construction	3	.		
Reproduction	4	n		

Degree of dependency estimate for technological activity 1:

$$= (8-Tc^{(*)}) \times a\% \text{ dependency} =$$

Degree of dependency estimate for technological activity 2:

$= (8-Tc) \times b\% =$ and so on for all items of activities.

The sum of all resulting figures is divided by the number of items of technological activities - in this case 9. The resulting figure is used as the degree of technological dependency for the project.

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a/ Lists are compiled from reported/suggested constraints and remedies.

(*) Since dependency at lower complexity activities represents a greater degree of dependency than at higher levels, complements of the complexity figures are used. The figure 8 is arbitrarily chosen for complementing although the highest complexity figure used is only 6, in order to avoid multiplication by zero when complexity is 6.

98. Knowledge of the degree of dependency may be required for planning in a certain technological subsector of an industry. The following table may be used to estimate/compute the degree of dependency in the construction industry over a spectrum of subdisciplines ranging in complexity from dams at the higher end to housing at the lower.

a/ Technological dependency analysis for the construction industry

(Blank form)

Technology/ Sector	Dams	Marine	Water/ Sewerage	Bridges	Industrial Buildings Hospitals Hotels Hi-rise	High-ways	Housing
Per cent (%) external execution							
Technological complexity figure (Tc) a/	6	5	4	4	3	2	1
Dependency estimate % x (8-Tc)							

Industry Ave. = Sum of figures above line divided by 7.

Note: It is obvious that a country dependent at low technological complexity values, say in highways (Tc = 2) should be regarded as suffering from a greater degree of technological dependency than a country which is dependent at a higher technological complexity value, say dams (Tc = 6). Therefore, to reflect this fact in computing the degree of dependency the eight complements of the complexity numbers are used as multipliers to the percentage of external execution - 8 being set as the highest complexity figure. Example for estimating the degree of dependency of a country in the construction industry based on figures estimated for a Near-Eastern country is given on one of the previous pages.

a/ Technological complexity figures (Tc) shown are estimates for illustration. An index may be developed along the same logic used in the index for capital goods developed by UNIDO for the sake of possible establishment of correspondence between the two.

List of obstacles and constraints

99. The following list has been provisionally compiled from available literature and personal experience. It includes observed and reported causes of the dependency status and obstacles to technological self-reliance which are generally blamed for the status of underdevelopment which persists in many countries. Dependence in irrigation pumping as a major factor in agricultural underdevelopment can be dealt with more effectively after identification of its causes.

100. For practical purposes, each item is given a number and sub-items are further defined with a letter. They serve as identification symbols of each cause or obstacle in the list and are used in filling out the forms suggested earlier for determination of the degree of dependency. Selection of the appropriate constraints so identified while in the atmosphere of "dependency" would at the same time lead to identification of the required remedies.

1 - Social and cultural constraints

a) Traditional underprivileged status of professionals and technicians.

b) Distaste for technological details.

c) Insensitivity/blindness to technological solutions.

d) Public's technological unfamiliarity.

e) Inability of ordinary citizens to lubricate a squeaky mechanical joint.

f) Inability to replace a part by simple unplugging/plugging, unscrewing/screwing and the like.

g) Tendency of engineers to occupy non-technical posts.

2 - Capital constraints

a) Foreign exchange.

b) Local currency.

c) Interest rates.

d) Foreign exchange mal-allocation.

e) Local currency mal-allocation (a problem of priorities).

f) Underdeveloped financial infrastructures and banking.

g) Money instruments and capital raising mechanisms.

h) The investment environment for foreign exchange.

i) The investment environment for local currency.

j) Market size and purchasing power.

k) Trade agreements with other countries.

3 - Technical human resources constraints

Number of scientists and technologists per million population.

a) Less than 500.

b) 500 - 1000.

c) 1000 - 5000.

d) 5000 - 10000.

e) 10000 - 25000.

Number of technicians per million population.

f) Less than 500.

g) 500 - 1000.

h) 1000 - 5000.

i) 5000 - 10000.

j) 10000 - 25000.

k) 25000 - 50000.

Sector of technological human resources deficiency.

l) Civil engineering.

m) Mechanical engineering.

n) Electrical engineering.

o) Chemical engineering.

p) Scientists (please specify).

q) Technicians.

Management and administrative skills.

r) Managerial skills for technologists.
s) Technical familiarity for production managers.
t) Technical skills for industrial engineers/economists.
u) Marketing and sales skills.

4 - Factors contributing to low productivity of available technologically trained manpower

a) Lack of incentives
b) Indiscriminate incentives.
c) Obsolescense of technological managers.
d) Scarceness of multidisciplinary technological managers.
e) Lack of journals and periodicals.
f) Rare attendance of international technological gatherings.
g) Absence of clear science and technology policies.
h) Unfair competition by foreign companies and their "influential" national agents on opportunities to carry out technical tasks and be recognized for accomplishing them.
i) Unfair competition by foreign aid institutions that provide needed capital, but not required experts.

5 - Technological institutional constraints

a) Consulting engineering bureaux.
b) Engineering and contracting.
c) Construction contracting.
d) Steel/metal fabrication.
e) Multi-purpose manufacturing.
f) Specialized services and testing.
g) Electronic data processing.
h) Computer Aided Design (CAD) and Computer Aided Manufacture (CAM) capabilities.

6 - Information systems

a) Technical libraries with access to periodicals.
b) Documentation archives for conservation and reproduction of technical reports and project drawings.
c) References and manuals prepared for engineers, industry etc. as non-proprietory information.
d) Proprietory information available for sale.
e) Expired and unexpired patent information.

7 - Maladies associated with foreign aid

a) Deprivation of trained national expertise of their opportunity to gain experience on aid financed projects degrading them to onlookers or backstoppers at best. The net result is reverse technology transfer and diminished net flow of aid resources.
b) Restriction on appropriate choice of technology.
c) Suppression of occasionally available local wisdom under the overwhelming weight of expatriate opinion in a technologically not so mature environment.

8 - Indifference to basic needs of scientific and technological activities

It is not uncommon in developing countries to bring the basic needs of scientific and technological activities under the same stingent austerity measures applied to normal activities and expenses. For instance, a ban on purchases of new equipment may apply to the purchase of office furniture and to a vital replacement for an important apparatus in a testing laboratory or to spare parts of a machine tool.

List of remedies

101. The following list of remedies is being suggested for use in connection with the list of obstacles or constraints in the degree of dependency forms suggested earlier. It has been compiled from existing literature and personal experience as was the case with the list of obstacles. They are also referenced with identification numbers/symbols for ease of use on the said forms and for further analysis.

1 - Cultural transformation

a) Popularization of traditional and new types of handicraft from carpentry to micro-electronics among school children in schools.

b) Execution of programmes in adult education for both literates and illiterates for popular science and technology applications in daily life including workshop practice for repair of household equipment in evening schools (such programmes exist in developed countries).

c) Programmes to support b) utilizing TV and radio.

d) De-emphasize into perspective the esteem and glory accorded to statesmen, politicians and fighters to make some room for artists, artisan inventors, scientists, great builders etc.

e) Propagate public awareness of indiscriminate transplantation of imported technologies to engage the public in scientific debate on the ecological impact as a national priority issue.

2 - Technological human resources and reversal of brain drain

a) Establishment of new and strengthening of existing technological institutes and colleges staffed by instructors/professors with proven field achievements. Imitating developed countries in strictly requiring the highest degrees regardless of practical experience for instructors should be avoided. In developed countries highly developed institutions can use scientists with little or no practical orientation while in developing countries scientists and engineers are often left alone to do their jobs with little support. For example, the total Arab PhD population in 1980 was comparable in number to that of either the USA, Germany or the UK during the period 1939 to 1945.[10/]

The contrast between present dependency of the Arab region and capabilities of said countries then explains the point.

b) Establishment of new and strengthening of existing vocational training institutes.

c) Treat every construction, industrial, irrigation etc. project as training grounds for nationals training regardless of nationality of contractor/supplier.

d) Establishment of adult education centres to upgrade skills of existing technically oriented citizens.

e) Arrangement of mobile fairs and exhibitions.

3 - Institutional infrastructure

Scientifically and technologically trained nationals need suitable institutions where they can function. Only the most gifted and broadly educated can function on their own in a suitable social climate. The quality of technological training based on that in developed countries presupposes existence of institutions, such as consulting engineering bureaux, which provide guidance by experienced supervisors, e.g. for model design procedures and model drawings showing technical details to copy from which was not taught in colleges. The same argument holds for research institutions and R&D facilities attached to industry. Such institutions must first be created, properly structured, staffed and equipped, pooling available and obtainable resources. International co-operation can play a vital role in this regard. The following arrangements are suggested:

a) Establishment of consulting engineering bureaux within Government and in the private sector.

b) Establishment of laboratories and special technical services enterprises for geological exploration, soil testing, evaluation, feasibility studies etc.

10/ The Arab Brain Drain, Proceedings of a seminar organized by ECWA, Beirut, 1980, published for the United Nations 1981, edited by A.B. Zahlan; Ithaca Press.

c) Production workshops should be treated as new industries.

d) Treatment of the above not as commercial entities which are normally taxed and subjected to stringent measures but similar to the preferential treatment and encouragement approved to encourage agriculture and industry.

e) Nationals involved in the above should enjoy their privileges and exemptions enjoyed by their expatriate competitors; freedom to travel, foreign exchange etc.

4 - Area of needed support

a) Engineering bureaux; consumer oriented housing, villas, furniture etc.

b) Civil engineering; capital oriented; industrial buildings, bridges, dams, pumping stations, water supply/sanitary etc.

c) Electrical engineering; consumer oriented.

d) Electrical engineering; capital oriented.

e) Mechanical engineering; consumer oriented; furniture, air coolers, car repairs etc.

f) Mechanical engineering; capital oriented; irrigation/water/industrial pumps, agricultural machinery, construction equipment etc.

g) Chemical engineering; consumer oriented; soaps, cosmetics, food processing etc.

h) Chemical engineering; capital oriented; industrial chemicals, industrial petrochemicals, cement and industrial ceramics etc.

i) Others (please specify).

5 - Capital raising

Methods for raising capital are well known to governments, corporations and entrepreneurs. The desirable solution depends on the type of constraint as illustrated in the list of obstacles and constraints. Certain remedies may help.

a) Allocation of soft low interest bearing convertible currency loans available from IDA, OPEC-Fund etc. to interest sensitive technological investment as demonstrated earlier in the example on solar pumping.

b) Allocation of convertible currencies to efforts which contribute to technological self-reliance such as the remedies listed herein on a priority basis in clear preference to direct importation of technologies.

c) Stimulation of export activities.

6 - Information systems

The world is experiencing an increase in the amount ot available information on a scale described as an explosion. Yet for many developing countries lack of timely availability of certain types of information represents a major constraint in applying technology to development. Main areas of possible improvement are:

a) Ordinary references and library material.

b) Documentation centres for recently implemented projects including all reports and engineering drawings which could be used as models for elaboration by nationals of similar work. Reference guides for industrial products.

c) Closer co-operation with UN-WIPO on patent information.

d) Linkage to current information systems using micro-computers.

e) Linkage to data banks, commercial and by courtesy through TCDC.

f) Requesting technical information from UNIDO library and other specialized agencies of the UN system.

g) Improving the quality of signal transmission on dedicated telephone lines (if necessary) for electronic linkage.

7 - International co-operation

There is always room for improving international co-operation. The following areas should be of particular interest:

a) Review of foreign aid practices; bilateral, the UN, World Bank, etc.

b) Conduct of transnational corporations.

c) Joint ventures.

d) TCDC.

e) Interest rates on non-convertible currencies.

f) Barter arrangements.

g) Other areas of equal co-operation.

For more detailed explanation of above constraints, a number of published documents are accessible. Among them are:

- Statistical survey of endogenous capacities in science and technology for development by UN Centre for Science and Technology for Development. May 1983.

- Electric power production in developing countries. An analysis of eleven country case studies. 1985, UNIDO Sectoral Studies No.s 25 & 26.

- Methodology for analysis of obstacles and their remedies in technology transfer in the Arab region. E/ECWA/NR/SEM.3/BP.5, 1981.

Chapter V. RECOMMENDATIONS

Pumps in the multi-purpose approach

102. Pumps and pumping of any significant proportions have somehow been left on the margins of the scope or family of agricultural machinery although it is widely acknowledged that the pump is perhaps the dearest piece of mechanical equipment to the farmer under a great variety of circumstances. In industrialized countries, the non-agricultural use of pumps may overshadow its irrigation applications which might explain its affinity with industry rather than with agriculture. This not being the case in most developing countries, a different approach is needed where agricultural development is given first priority. This is the reason why pump manufacturing should be considered in the context of the multi-purpose approach to the manufacture of agricultural machinery.

Mechanical workshops

103. Mechanical workshops are at the core of multi-purpose manufacturing plants. Yet it has been noted that governments seldom give them the special treatments given to industrial and agricultural enterprises such as concessional financing, import privileges, customs and tax exemptions etc.

104. Recommended action

A - At the Government level:

1. Accord workshops in both public and private sectors the same privileges and protection accorded to young industries. With the advent of multi-purpose approach, workshops can always be regarded as young industries.

2. Unpackage to the extent possible imported plants which are deemed likely to contain elements that can be locally manufactured.

3. Create constant demand for existing and potential production facilities by ordering elements of newly ordered plants in whatever sector and of extensions needed for existing plants, based on technology unpackaging, reverse engineering and down-engineering as explained earlier.

4. Allocate sufficient part of R&D capabilities to universities, research centres etc. for the solving of problems associated with new lines of products: their durability, efficiency, performance etc. Mechanical workshops can rarely afford the cost of such technical support.

5. Provide the legal protection needed for possible copyright infringement cases which may arise; some of the claims may be legitimate requiring appropriate settlement.

6. Underutilized capacities in university laboratories, mechanical workshops, workshops for railways and whatever existing industries in the public sector is usually caused by lack of motivation on behalf of the highly trained faculty and staff who give such excuses as the lack of certain equipment, components, and other inputs. This can be treated as follows:

   An invitation for "tenders" issued to all possible participants to undertake the transformation of those unused capacities into productive capacities.

   The least costly bidder wins a contract under which he undertakes to do the transformation.

   Upon performance, the agreed compensation is awarded progressively.

7. Status of local manufacture of irrigation pumping systems in developing countries is not known to a sufficient degree for negotiations on strategies for incorporating them in the multi-purpose manufacturing approach of agricultural machinery wihin the framework of international co-operation. More information is needed on the subject. Such information can be gathered by means of surveys, seminars etc. The following information is needed:

   The degree of technological dependency to help establish the basis for economic assessments, since this is related to credit and financing arrangements as shown earlier.

Efficiency, cost of operation and maintenance, performance, life-span of locally manufactured and imported pumps by type and rating.

Cost of electricity, its accessibility and future plans for its production and distribution.

Cost of fuel.

Source of water, topography, climatology, size of holdings, crops, soil conditions, land classification if available and construction practices and materials.

Solar insolation.

Wind regime.

B - At the international level:

Once the forms for determination of the degree of technological dependency are filled out where causes and remedies are identified, countries which may require similar types of action may find it useful to co-operate in implementing a plan of action derived from the suggested common remedies. Other countries may find opportunities for co-operation on an individual or collective basis. The information gathered under item 7 above will prove very useful in the choice of pumps, their drives and power supply which will narrow further the manufacturing approach to its most appropriate solution.