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PROMOTION OF THE MULTIPURPOSE APPROACH TO THE MANUFACTURE OF AGRICULTURAL MACHINERY AND OTHER CAPITAL GOODS

REPORT ON IRRIGATION PUMPING BY

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Vienna
7 December 1985

This draft has been submitted without formal editing

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PURPOSE OF THIS REPORT

In preparation for the Third round of consultations on Agricultural machinery to be held in September 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 overshadows 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 multipurpose 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 widened considerably.

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 has been introduced for the grouping of developing countries according to their degrees of technological dependency which should help in adoption of common strategies.

SUMMARY AND CONCLUSIONS

Irrigation is being increasingly depended upon in food production with the aim of eliminating hunger and meeting the rising food requirement of the world's growing population. The importance of water to plant growth 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.

The Negotiations Branch, in its consultaions exercise on capital goods has been focussing attention on the possibilities of manufacturing agricultural machinery locally using the multipurpose approach. In this paper, the pump is brought under focus for similar consideration based on desk review of recent work, the consultant's own experience and a visit to FAO offices in Rome. The findings of the review are as follows:

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

2-Local manufacture of irrigation pumps calls for decissions concerning type of pumping: small scale vs. central pumping stations or a combination of both; type of pump:centrifugal, propeller, others 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.

3-Simplification or downengineering at the expence 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.

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

5 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.

6-To draw broader strategies answers are needed to the many questions as mentioned in item 2 above and more. With the mission just completed by the consultant to FAO offices in Rome 28-31 October 1985, there appeares that whatever information exist are not compiled.A vacuum exists which needs to be filled urgently if the necessary ingredients for drawing strategies are to be prepared. 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 cooperating in the compilation of information, from the field in particular, in order to be able to address the above questions.

7-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.

INTRODUCTION

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 which the supply, pumping became increasingly necessary where it was not very much so earlier.Additionally, 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 distorted price structure that the purchase price of pumps to the farmer is several times greater than in the country of its origin.
Some of these countries, bearing in mind the volume of foreign aid and technical assistance received, suffer from a persisting deficiency in their technological absoptive 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,

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 result in abandonment of equipment purchased earlier.Pumping equipment do ware 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 maintenence is crucial to the development of most agriculture based economies. Some of the benefits of the economies of scale lost due to market size can more than be compensated for by benefits from local manufacture in terms of timely availability of equipment and savings in foreign exchange .PUMPING equipments are among few industrial products where such an argument hold true under a variety of circumstances.This notion shall be more closely examined in this report. Moreover, where local pump manufacturing is a reality, the balance may 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.

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 centifugal 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 cooperation and interdependence. Poor countries that need pumps of the types produced decades ago for irrigation yet they are still popularly used could be provided with prototypes for copying by other manufacturers at competitive costs inorder not to oblige them to "re-invent the wheel" by designing them or by having them <u>reverse-engineered</u>. Such copying prototypes could even be down-engineered if necessary to suit production capabilities available.

Down-engineered versions of pumps with reduced component elements for their lower cost and managable 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.

For countries where the industrial base is relatively limited, the multipurpose approach should be carefully examined. This might mean that the local manufacture of pumps need to be accompanied with 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 manufactureres anyway . Most are part of an industry with diversified engineering and manufacturing capabilities originally established to produce replacements and extentions for the main industrial activity, which could be as remote from pump making as paper pulp and sugar.

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 sytems require similar technological capabilities required for local manufacture of small hydro-electric power plants, where the scope for international cooperation is equally similar. Countries contemplating to develop hydro-electric power plant manufacture may benefit from the similarity. The main emphasis here, is placed,however, on the most commonly used pumps for irrigation;the propeller for low-lift (up to about 6 meters) and the centrifugal for greater lifts.

Wind and Solar powered irrigation pumping systems are gaining more and more popularity. The validity of their use in areas where supply of coventional 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 tecnological developments, the amorphous

Silicon using chemical vapor deposition (CVD) techniques, solar water desalination, desert greenhouses, the proliferation of sprinkler and drip (trickle) irrigation techniques etc. justify some coverage here also.

It is difficult to include all elements used in pumped irrigation to be considered for the multipurpose approach in local manufacture, in this report. But an attempt is made to present a sufficient number and variety of them to choose from in planning such manufacturing facilities. The pump itself is given priority in detailing, and irrigation itself is briefly explained to make possible understanding of the discussion of various aspects of pumping and water related implements.

For this report, to be of use in the process of consultations, 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. The report begins with introduction of the concept of the degree of technological dependency.

CHAPTER I

DEGREE OF TECHNOLOGICAL DEPENDENCY

The Need for a Measurement:

Each developing country has its own unique set of problems to tackle in its path to development. In the context of international cooperation, however, the available mechanisms often treat groups of countries which are considered to be at similar levels of development, rather than on 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 percapita GNP comarable to 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 Brazil , Korea, and India, there is little to help distinguish between Burma and, Sudan with regards to establishment of multipurpose agricultural machinery production units as an example. 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 hyrdoelectric 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. An example is given in chapter ( ) on how a country in the Middle East had to choose an inappropriate 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. And in chapter ( ) an African country, strongly affected by interest rates abroad, due to its high degree of technological dependency, found that diesel pumping was cheaper than solar when in fact the oppsite was true. It can be argued then, that in technologically dependent countries, inapprpopriate 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 each country is treating its own dependency broblem ? How international cooperation can help ?

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 <u>degree of dependence</u> 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 sector by sector basis, or on discipline by discipline basis, and for the different levels of technological complexity.

The following method 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 analyzed by first, unpackaging the technologies involved, and then, for each element the degree of complexity (how difficult the know-how is to internalize.) is determined. For preliminary studies it might be sufficient to describe this as high, medium, or low, and assigning to them representative figures such as 125 for high, 75 for medium, and 25 for low.

3-Using averages obtained from the analyzed projects for their percatages of external inputs(external to total in %), and averages of total technological complexity of entire projects, the degree of dependence may be calculated for that sector at any given technological comlexity level by interpolation or regression.

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.

Technological activity	Complexity	Dependence %	Cause	Remedy
Planning & Conception	125	80		
Feasibility studies	75	80	for causes and	
Soil/foundation tests	75	50	remedies select	
structural design	75	20	from lists.(!)	
Mech'l model test	125	100		
Electro/mech design	75	80		
Manufacture	100	80		
Constructio	75	00		
Reproduction	75	90		
Averages for project	89	64		

(!) Lists compiled from reported constraints and suggested remedies in Annex II.

Degree of dependency may be requires for planning in a certain technological discipline rather than sector. In the following table a sample is given for result of hypothetical analysis covering the construction industry over a spectrum of subdisciplines ranging in complexity from dams at the higher end to housing at the lower.

#TECHNOLOGICAL DEPENDENCY ANALYSIS FOR THE CONSTRUCTION INDUSTRY
(% Internal execution)

TECHN / SECTOR	DAMS	MARINE	WATER/ SEWERAGE	BRIDGES	INDUSTRIAL BUILDINGS HOSPITALS HOTELS HI-RISE	HIGH-WAYS	HOUSING
	5	10	20	30	30	40	80
Percent external execution	95	90	80	70	70	60	20
Total technological complexity Tc.	150	120	100	80	110	60	(#) 40

(#) Technological compexity index values shown are estimates for illustration. An index may be developed along the same logic used in the
UNIDO developed index for capital goods for the sake of possible establishment of correspondance between the two.

TABLE

Summary of the Most Persisting Obstacles and their Most Preferred Remedies

(An illustrative example)

Ref. No. of obstacle from list of ...	New Serial No.	The Chosen Remedies Re-stated (from list of remedies)	% occurence in charts	Action Level					REMARKS
				country	bilate-ral	subre-gional	regional	U. N.	
7	1	Establishment of the Regional Science and Technology Fund to finance ...	34				x		
11	2	Increasing the number and capacities of vocational training ...	29	x					
27	3	Adopt measures to increase exports to ...	22	x			x	x	
		etc.							

EFFECT OF DEPENDENCY ON CHOICE OF TECHNOLOGY

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 puts 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 inspite 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.

It is assumed that when a country is technologically more self reliant it can base its judgment in slection of a technology on interst rates which reflect its own realities rather than what goes on in international money markets.

By way of illustration an analytical table is reproduced on the next page from a recent United Nations document (1) 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 (2) of one meter or 490 tons of water against TDH of 2 meters an so on. The procedure used in calculating cost is rather simplistic but accurate enough for the purpose(3). Two annualized charge rates

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(1) Mission Report on Somalia by Derek Lovejoy, Interregional adviser, Energy Resources Branch, DTCD, New York, November 1983
(2) See Chapter on pumps, sec. .
(3) Operation and maintenance charge of 1% may be adequate for the solar system which contains a large investment in non-moving parts. For the diesel system 8% would be more realistic in developing country conditions. And 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.

	(1) Av. daily Prody. ton m	(2) Av. annual Prody. ton m x 10^{-3} (1) x 365 days	(3) Capital Cost $ CIF	(4) Annualized Cost $ 10% x (3)	(4) Annualized Cost $ 18% x (3) (8% Solar) (15% Diesel)	(5) Annualized Cost $ per 1000 ton m 10% (4) / (2)	(5) 18%	(6) Running Cost 1/ (Fuel + operation) $0.35/L	(6) $0.70/L ($0.50/L)	(7) Total Cost $per 1000 ton m 10% ($0.35/L (5) + (6)	(7) 18% $0.70/L	(8) Water Cost per m^3 for 40m dynamic head 10% (7) x 40m / 1,000t	(8) 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	1,088	12,500	1,250	2,250	1.15	2.07	-	-	1.15	2.07	0.05	0.08
Diesel Pump	4000	1,500	4.000 (+2,600)	400	720 (990)	0.27	0.48 (0.66)	3.35	6.20 (4.79)	3.83 2/	6.68 3/ (5.45)	0.15 2/	0.27 3/

1/ Assume $0.50/hour operating cost for diesel pump operation.

2/ Mostly fuel cost at $0.35/litre. 18% charge rate. 123 ton m/litre

3/ Mostly fuel cost at $0.70/litre. 18% charge rate. 123 ton m/litre

(XXXX) Recomputed figures on 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/L
- Lifespan = 20 years

All other figures are from Derek Lovejoy, DTCD, 1983 Mission Report on Somalia are used in the calculations; 10% and 18% per annum both containing depreciation, interest, operation and maintenance (O & M) costs. The first rate of 10% is based on 15 year depreciation period, 5% interest plus 1% for operation and maintenance bundled all together to 10%. The second rate of 18% is based on 10 year depreciation period, 15% interest and 1% for O & M bundled together to 18% .

Column 7 of the table shows that the cost per 1000 ton meters pumped is US$ 4.34 and 7.80 for the solar system using 5% and 15% interest rates per annum which correspond to 10% and 18% annualized costs respectively. For the diesel system interest rates on capital made little difference, most of the annualized cost being fuel, the figures US$ 3.63 and 6.68 are computed for costs of diesel fuel $0.35 and 0.70 per liter respectively, both based on the same annualized charge at 18% 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% interest and using the 4% interest rate for all investments(1) and 8% per year for operation and maintenance(see page) 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 $5.45 for diesel. In other words Solar pumping is cheaper than diesel at 4% interest considering acceptable O&M charges for the diesel. At high interest rates, moreover, when the Present Worth Value (Tables for discounting are on page) of the diesel's fuel and maintenance costs are sharply discounted. Even when discounted at 4% interest (for the sake of consistency in this illustration) the cost per 1000 ton meter appears as little over $2.0, which is much less than the $5.45 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.
In column 3 the capital cost for the solar pump which would yield 358000 ton meters yearly is $15500 while for the diesel which yields about 4 times as much is $4000. In most developing countries where banking and money instruments are embrionic, high 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.

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(1) The Capital Recovery Factor (CRF) approach is used where,

$CRF = i(1+i)^{n} ((1+i)^{n} - 1)^{-1}$, and i=interest(4%); n=20 years
= 0.07 (The revised annualized capital charge)
Therefor the annualized capital charge plus O&M cost would be:
0.07 + 0.01= 8% for solar, and 0.07 +0.08= 15% for diesel

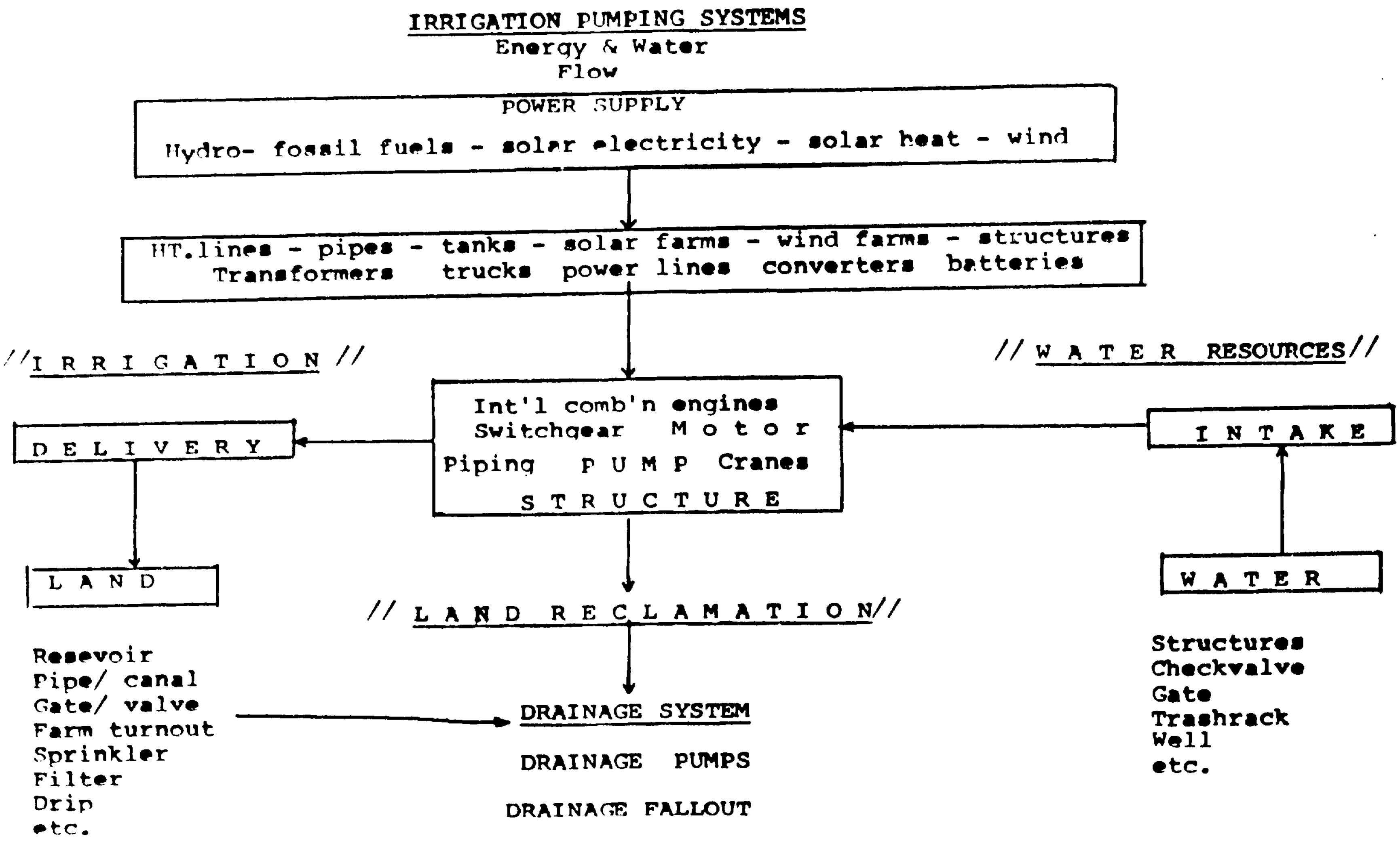

Fig. 1 The pump in a pumping system serving agriculture in irrigation and land reclamation.

Chapter II

IRRIGATION

Irrigation is the process of delivering to the farm the water needed for the germination, growth and maturity of crops.[1] Rain and floods are natural means. Controlled diversion from rivers, lakes and springs require human intervention. Drainage of excessive water can also take place either naturally of by human effort. In any case, crop yield per area cultivated can be increased and maximized with proper human intervention which is one or another aspect of irrigation and drainage. Where the potential energy in the water itself and activated by gravity is depended upon for the process the term gravity irrigation applies. To ensure gravity command of water on large areas of land, cross barrages upstreams are built across rivers and canals. To ensure the quantity of water needed at the right time resevoirs are needed. And in addition, conveyance networks would usually be needed to carry water over long distances. Water losses due to evaporation and seepage increase and to cope with problems these structures create, such as blockage of flood paths, fish migration & navigation a host of additional structures would be needed and still the ecological balance would remaine threatened with adverse results some of which incalculabe appearing after decades.

In Fig. 2 a schematic diagram showing the disposition of cross regulators on natural rivers in lower Mesopotamia of which the sole purpose is to raise the water surface by some 2 to 4 meters. Instead of cross regulators (Barrages) pumping stations can be installed to raise the water level for distribution via canals to the vicinity of farms. In this case natural rivers remain unblocked not requiring the heavy structures which would be needed to pass floods, navigation locks or fish ladders. At the farm water may flow either by gravity or by pumping. This would depend on topography and/ or design.

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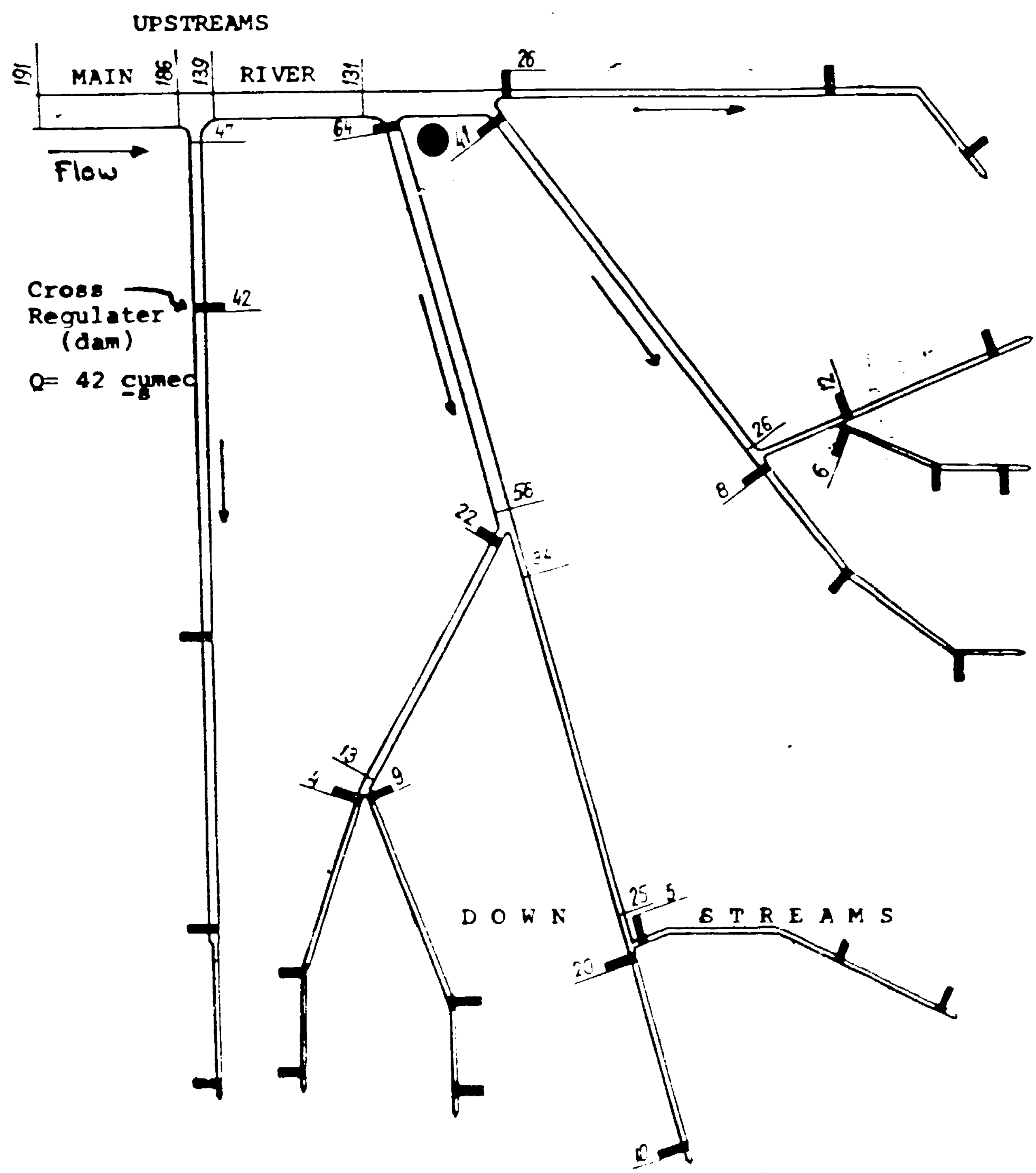
1) There are several other benefits which can be gained from irrigation which include salt leaching and removal, crop cooling, application of chemicals, frost and freeze protection and delay of fruit and bud development.

DISTRIBUTION OF FLOW
CORRESPONDING WITH NORMAL IRRIGATION RATE
(0.60 l/sec/ha.)
Q = 191 CUMECS

Fig.



22 Cross Regulator (Barrage), capacity = 22 cumecs.

34 Design capacity of channel at cross section

A case for Irrigation Pumping as an Internalized Technology

The question which poses itself about the lower Mesopotamian example given earlier is; Why should any planner recommend the gravity system shown then have to provide for the passage of flood waters many times greater in amounts than the irrigation requirements and for navigation locks, fish ladders etc. and not just pump the required amounts for irrigation and let the rivers alone ?

The following factors contributed to the loss of the pumping solution in favour of gravity irrigation in the example given as a project planned for lower Mesopotamia in 1960s.

1-The most appropriate and cheaper propeller pumps needed for the low-lift requirements of the topography were virtually unknown in the country. All previously established pumping stations were either mixed flow or centrifugal pumps. The price guidelines used in the analysis did not reflect the lower cost of the axial flow propeller pumps both the initial and the maintenance.

2-Cost of pumping was based on diesel drives rather than the cheaper to install and run electric drives due to the long distance to the nearest point on the national grid. By the time the irrigation project got under construction , the national grid had already covered the area.

3-Fear of indefinite dependence on foreign inputs for the pumping solution in terms of maintenance and replacement parts.

Briefly, it was lack of proper interdisciplinary coordination and the supremacy of economics devoid of technological planning and overiew. Maybe one well places multidisciplinary person could have reversed the outcome. Only a few years later, the Saad River electrical pumpingstation was built (see Fig 15. Skt B) using propeller pumps and special civil works design at half the estimated cost.

Where the source of water is underground and where irrigation is by sprinkler or the drip (trickle) systems, pumping would not be a matter of choice, it becomes a necessity.

The methods used in applying irrigation water on the farm are enumerous and the choice depends on 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.

1-Surface irrigation is the most widely used and the oldest. It generally requires a smaller initial investment than do other types of irrigation. The driving force is gravity 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.

Below is a sketch for field layout of a contour dike surface type.

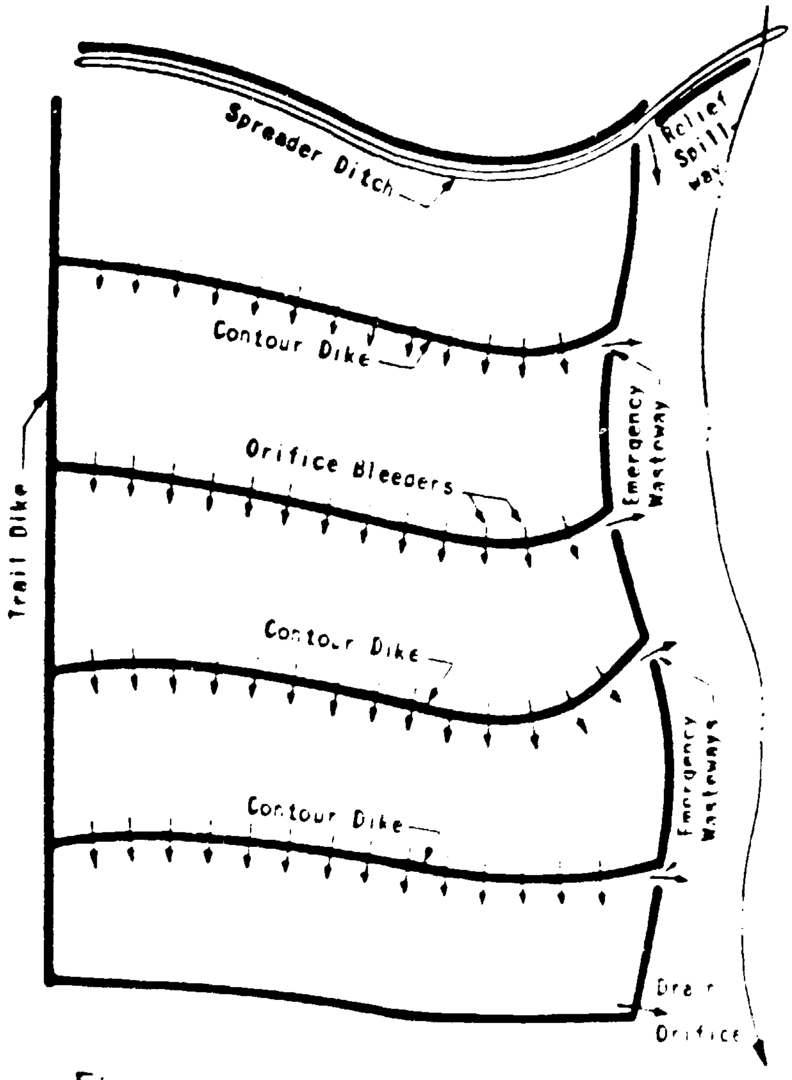


Fig.

2-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 prssure in the pipes can overcome level variations. Water drips from emitters or applicators which dissipate the excessive pressure through orifices, vortexes, and tortuou 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 the ratio of 10 to 1 . Primitive versions of the priniple involved in drip irrigation are known to have been used in ancient times.

The filters remove suspended solids from the water but are not capable of chemical filtration.

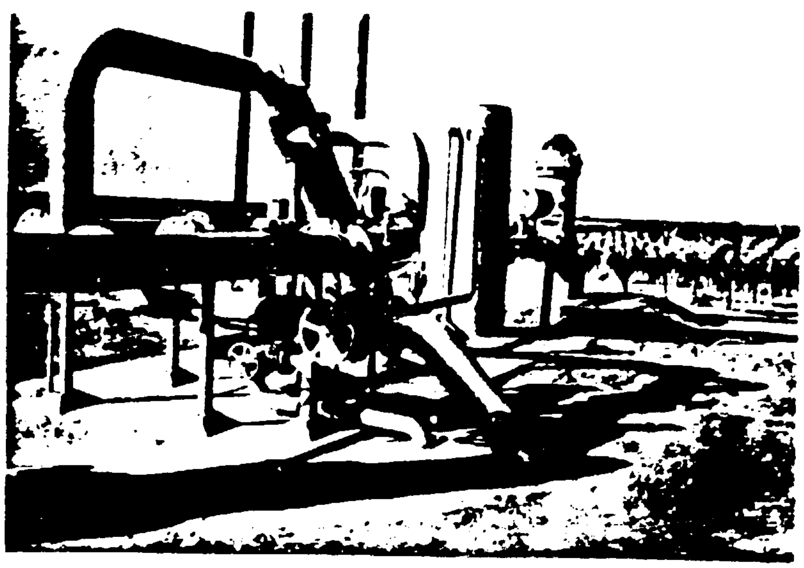


Figure A typical control head for a drip irrigation system

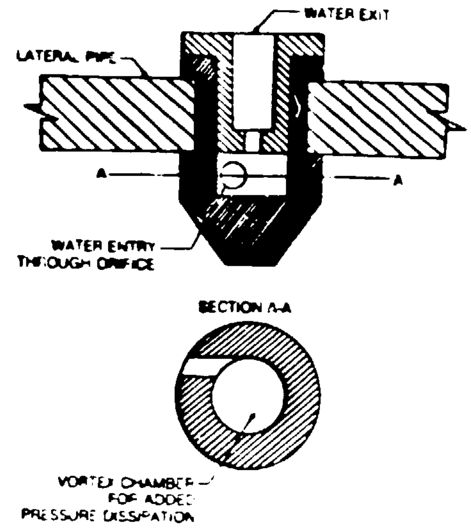


Figure Orifice-vortex type emitter

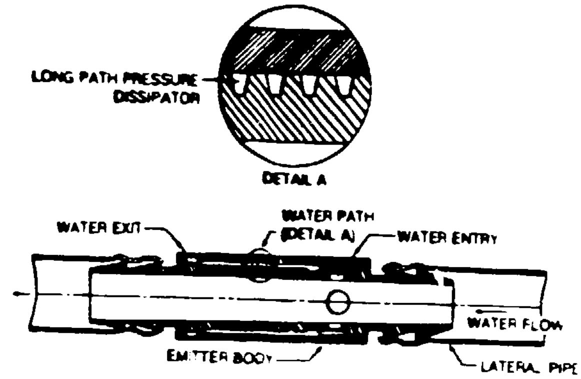


Figure Single-exit long-path emitter

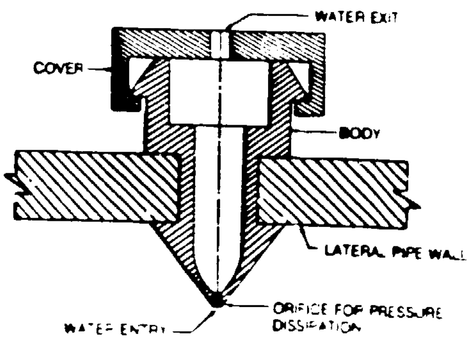


Fig Single-exit orifice-type emitter

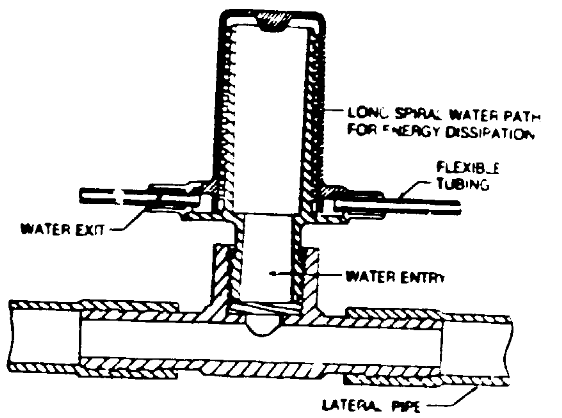


Figure Multi-exit long path emitter

Fig. A young orchard with one emitter lateral per tree row

3- Sprikler 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 labor and modify the environment.

In arid areas center-pivot systems are used intensively - up to about 2200 hours per season. Water is delivered to the center 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.

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 center mainline with one or more laterals which irrigate on both sides of the maineline. The lateral, at right angle to the maineline is moved by hand and connected to it at the distances already set by the location of couplings.

Lateral-Move Sprinkler Irrigation Systems together with deep wells were groundwater exists can provide supplementary irrigation in draught threatened zones. Two rounds of sprikles 30 mm each may guarantee a crop which would otherwise be lost to draught. (*) An FAO study shows that after fiels 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, in other words the two rounds of 30 mm each would result in obtaining 840 kgs to 960 kgs per hectar in grain.

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

DRAINAGE

Drainage is the process of removal and disposal of excess water from the surface of land and from the soil pores. The sources of exceess 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 hamper 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.

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 tabe itself. Proper irrigation management then insures a continual 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 loose their moisture due to evaporation after moving to the surface by capillary 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.

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 supplementary water supply for plants between intermittent rainstorms.

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 looses elevation as it flows. Where after loosing 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.

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

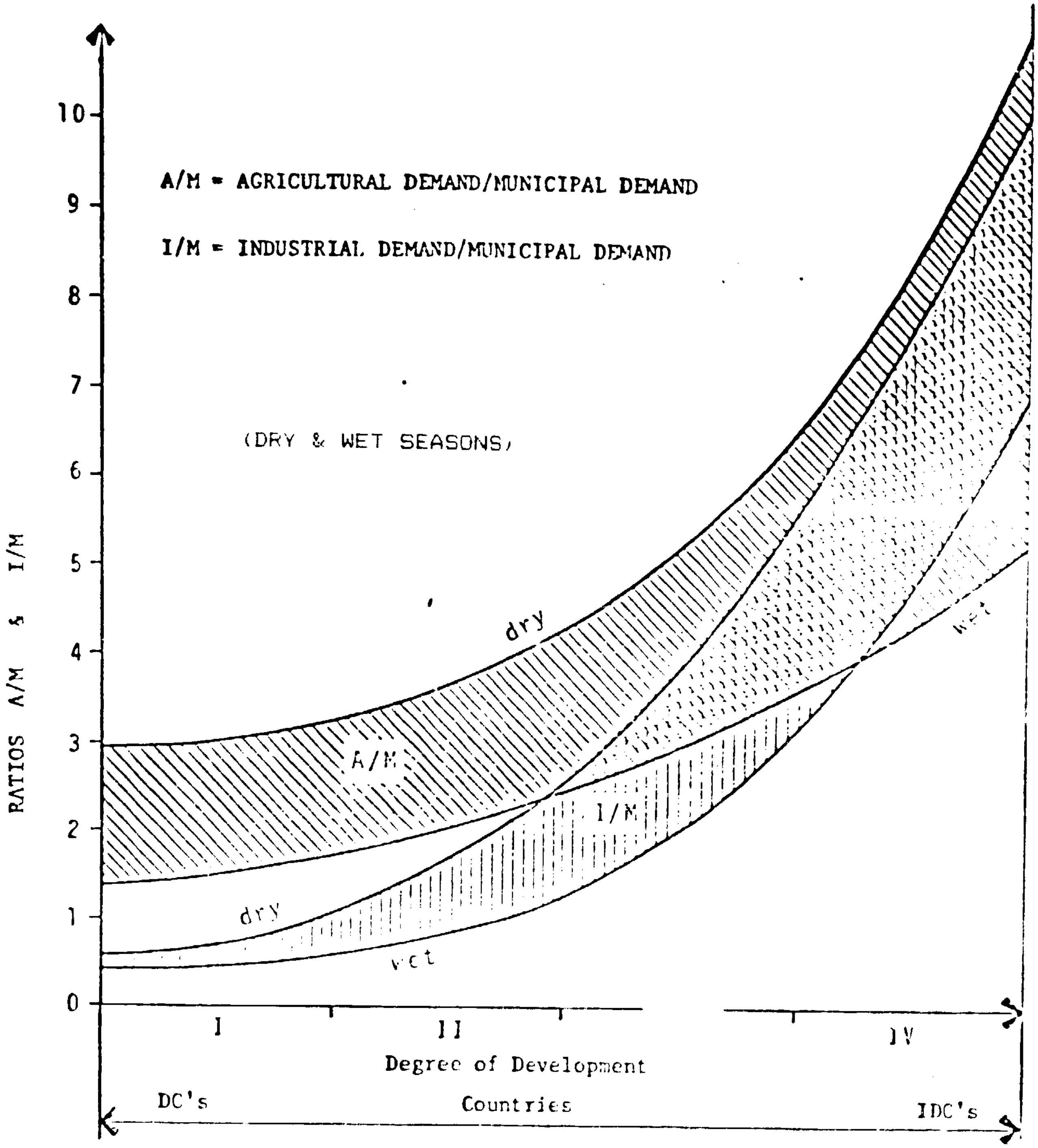
RURAL WATER SUPPLY

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 desease 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 machninery 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 centers .

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, charts showing the relationships between municipal, agricultural and industrial water requirements and other aspects of water resources management are given in the next two pages for illustration. Pumping for non-irrigation water use may be considered in the multipurpose approach for the manufacture of agricultural machinery .

RESEVOIRS

The term resrvoir 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 determing the kind of resevoir needed for a given situation are too many to cover in this report. It can only be stressed that resrvoirs are needed for community water supply and on several occasions for pumped irrigation, in both cases to ensure contiuous service when pumps are put to rest and to maintain the required pressure and provide for emergencies.



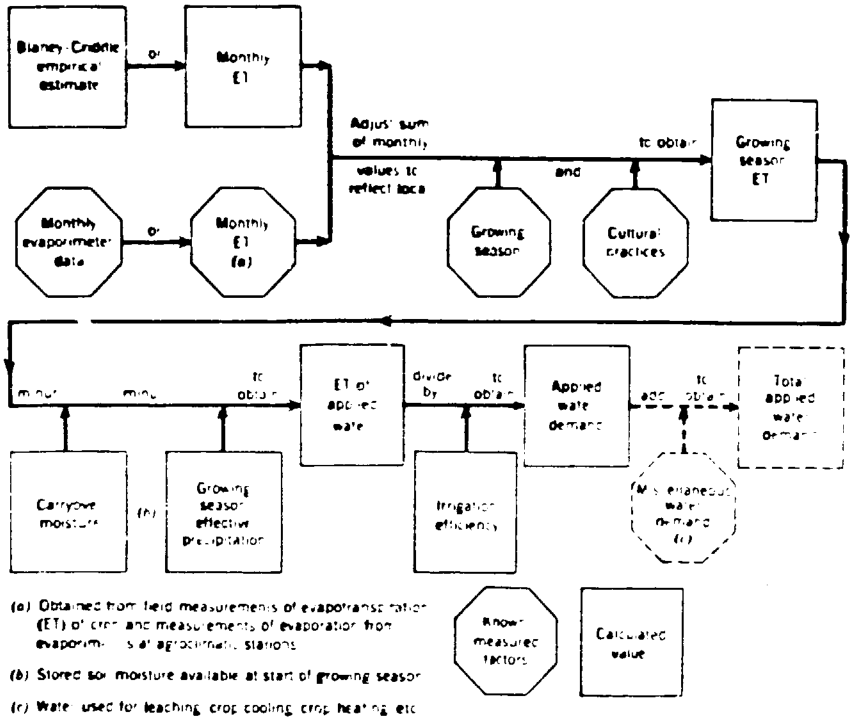
Source: Engineering Enterprises, Inc.
Water Demand Models prepared for UNECWA 1976

Figure : Showing the Ratios I/M and A/M for Levels of Development

IDC - Industrially Developed Countries

DC - Developing Countries

WATER DEMANDS



(a) Obtained from field measurements of evapotranspiration (ET) of crop and measurements of evaporation from evaporim... s at agroclimatic stations

(b) Stored soil moisture available at start of growing season

(c) Water used for leaching, crop cooling, crop heating, etc.

FIG. —STEPS IN DETERMINING AGRICULTURAL APPLIED WATER DEMAND

GROUND WATER MANAGEMENT

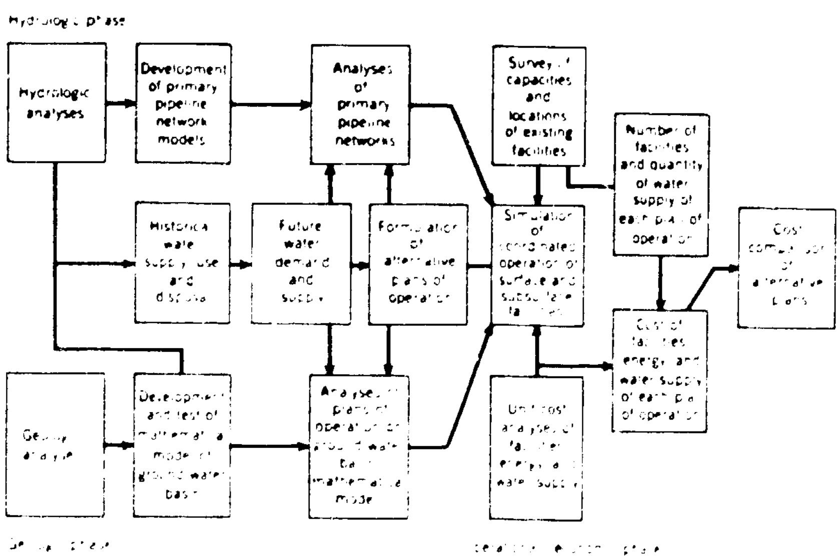


FIG. SIMPLIFIED FLOW CHART OF WATER RESOURCES MANAGEMENT STUDY OF THE SAN GABRIEL VALLEY GROUND WATER BASIN, CALIFORNIA

SOLAR PUMPING

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.

Over the past decade, photovoltaic technology has been the subject of quiet but but rapid evo;ution, starting with the development of cells base on crystaline Si wafers to provide power satellites. As an outer space technology, serious attention to its application back on Earth developed soon after the 1973 oil crisis and the rocketting rise in the cost of energy. But the cost of generating electricty with this new technology was still considerably greater than conventional electricity for which reason its application was largely limited to powering small power systems in remote, stand-alone locations.

More recently, further technological developments helped drive the cost of manufacturing cells sharply down to the extent that it began to compete with conventional energy applications in 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. These 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.

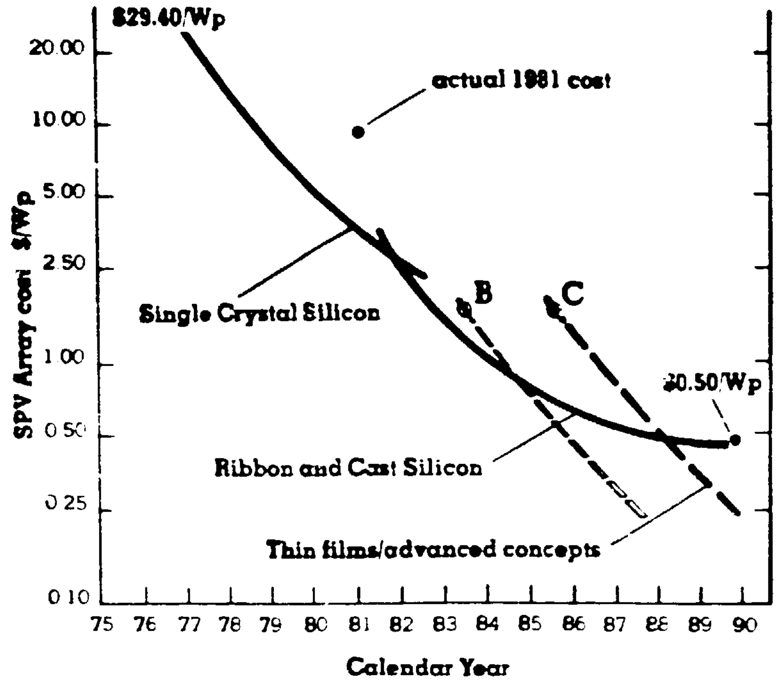
To calculate the cost of the more commonly used energy unit namely the kilo-watt-hour (KWH), the following formula is given for the conversion of cost/Wp to cost/KWH.

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

Assuming a 20 year life, 12% interest costs, linear amortization of principal, a 2000 hour peak sunlight equivalent per year, a phoyovoltaic array with a cost of US$10 per Wp (excluding balance of system cost) will generate electricity at $0.55/KWH.
Solar pump makers are offering complete pumping systems for lifting 48 cubic meters of water per day by 10 meters for $10000. In the following page Chronar's (a leading US firm) projections for cost of electricity based on its newly developed technology is given.

Figure

SPV PRICE HISTORY AND GOALS
(1980 $)

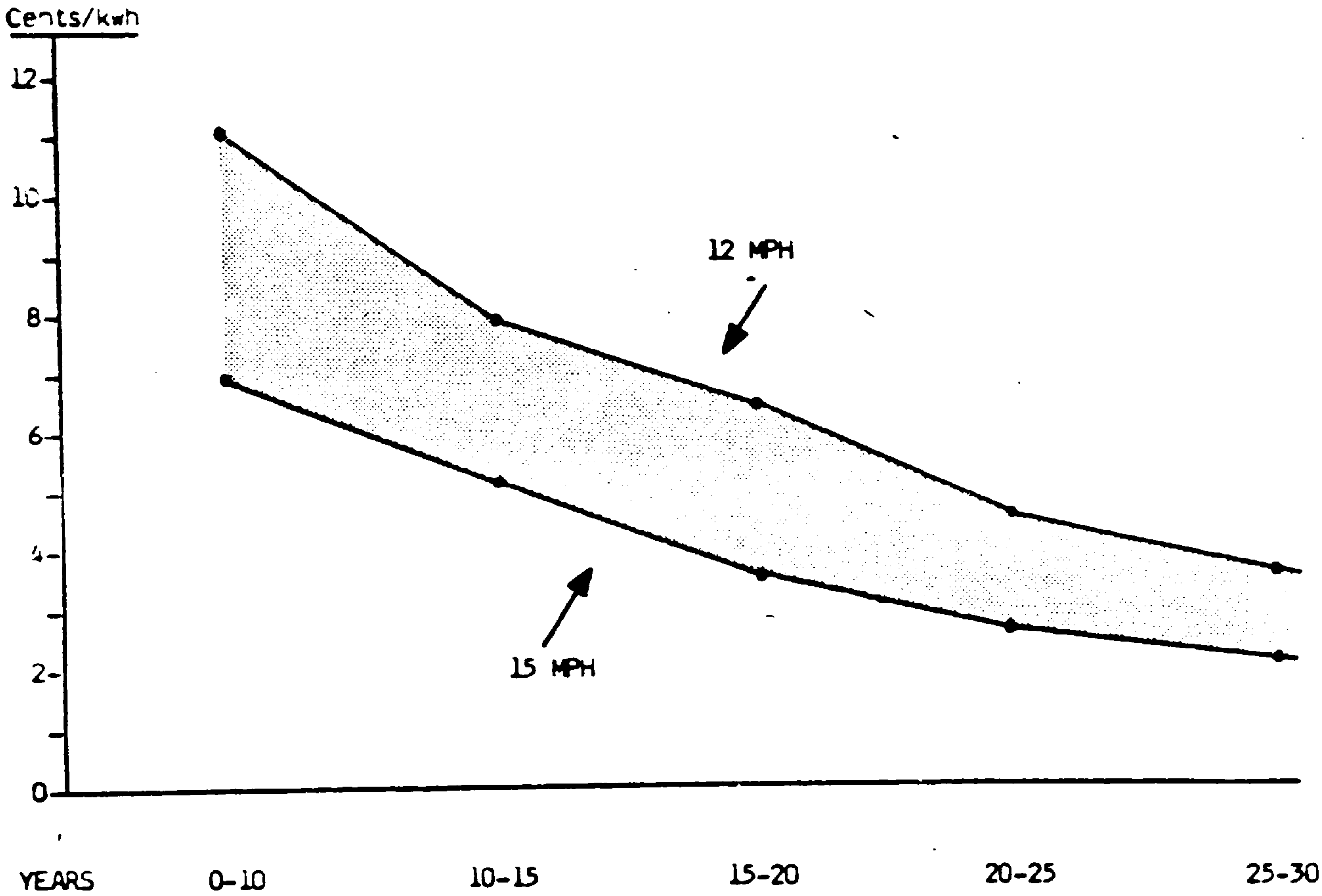


Key features of Figure .

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

SPV = Solar Photovoltaic

WIND GENERATION OF ELECTRICITY - COST PER KWH



WIND PUMPING

Wind energy has been in use for pumping water on 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 wing power in <u>suitable</u> locations where winds of 5 meters per second (11 miles per hour) or over blow some 5 hours per day is well established. On complementary basis with other forms of power generation wind generated electricity on a large scale is advocated by manufactureres 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 inverter AC/DC is recommended. Reports from the field also recommend replacement of mechanically driven reciprocal pumps with electrically driven turbomachines for greater efficiency.

In the chart above wind generation of electricity-cost per KWH is shown, Source: Energy Applications Corporation USA. The chart is based on 1980 prices of equipment using 12% interes and 10 year amortization.

Earlier in this report comparative costs of water pumping based on figures obtained in Somalia in 1987 were given showing very favourable results for wind pumping in comparison to diesel and solar. Somalia has excellent wind conditions.

#Pumps

Chapter III
PUMPS

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 principle of operation:

1-Turbomachinery

2-Positive-displacement machinery

Under the first category -Turbomachinery- fall the most widely used pumps by far; the centrifugal pump and axial flow pump and variations of both. 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 centrufugal 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.

-Radial Flow Pumps develop the pressue principally by rotating an impeller with an intake at the center and dischaging the water by centrifugal force into the casing surrounding the impeller. The pressure head developed by the pump

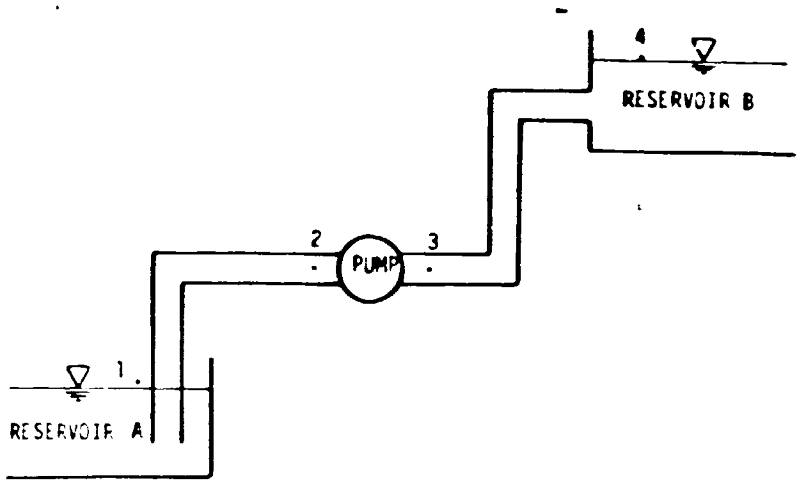


FIG. Schematic of generalized pumping conditions.

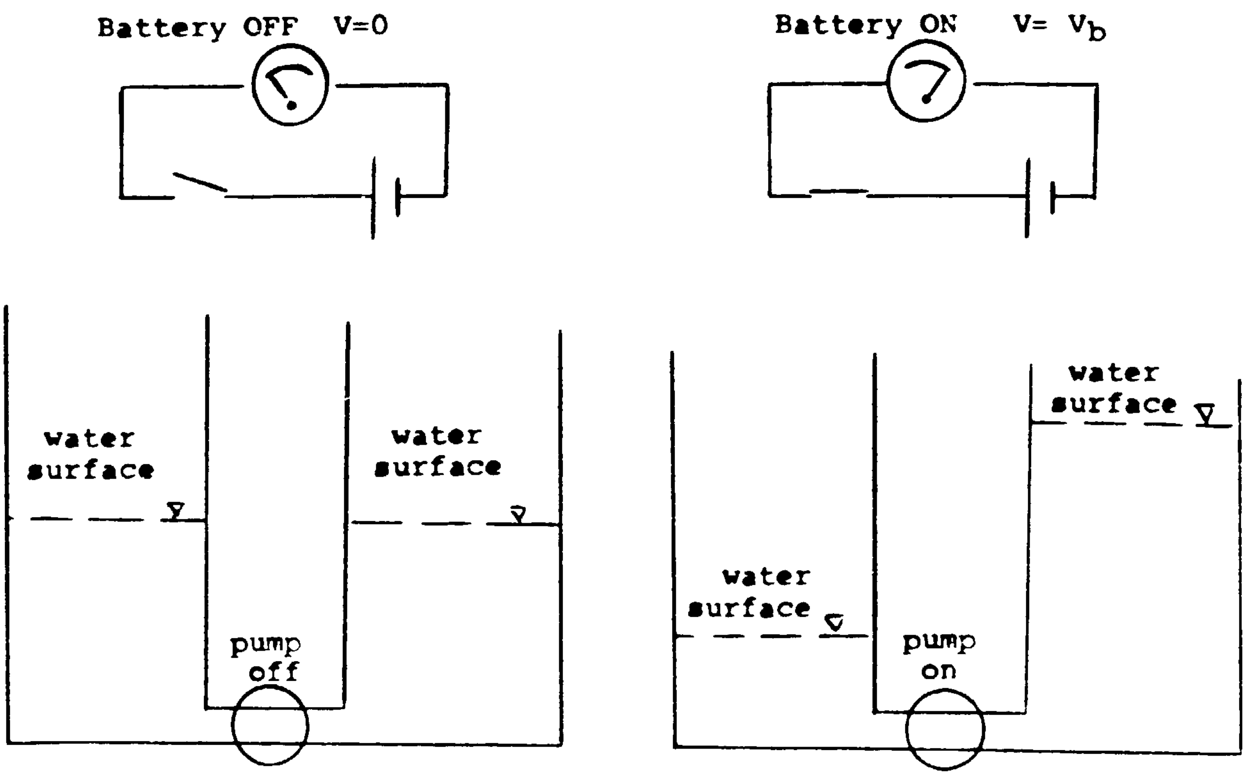
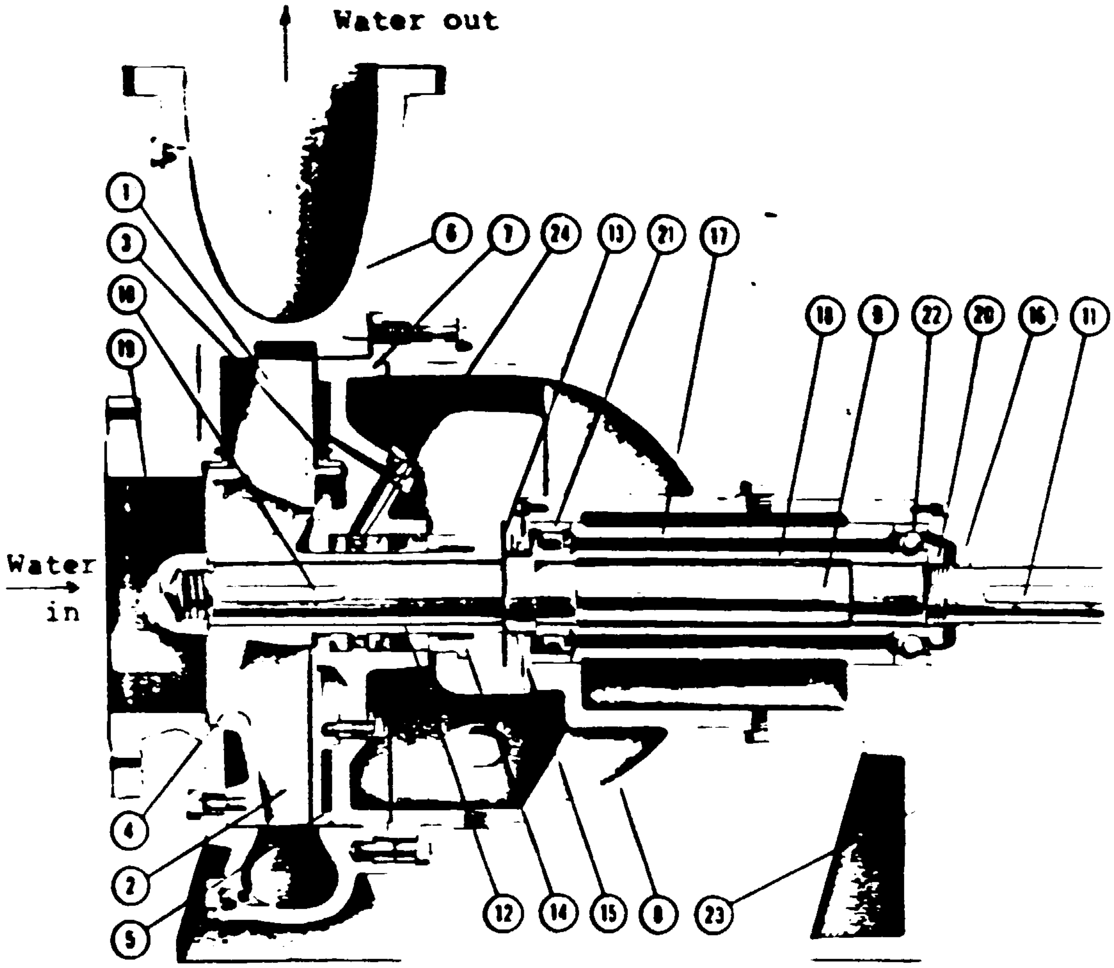


Fig. Electrical analogy of a Turbopump (schematic) is entirely the result of the velocity imparted to the water by the rotating impeller and is NOT due to any impact or displacement. A centrifugal pump which admits water on only one side of the impeller is called a single suction pump; if it admits water 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.: (volute pumps), and(b) diffuser or turbine pumps. In the former the impeller is surrounded by a spiral case, the outer bindary of which may be a curve called a volute. In the latter 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.

-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 rduce 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 as well where the propeller pitch is adjustable to flow requirements (volume of discharge and head).



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	Flange	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	Lantern ring

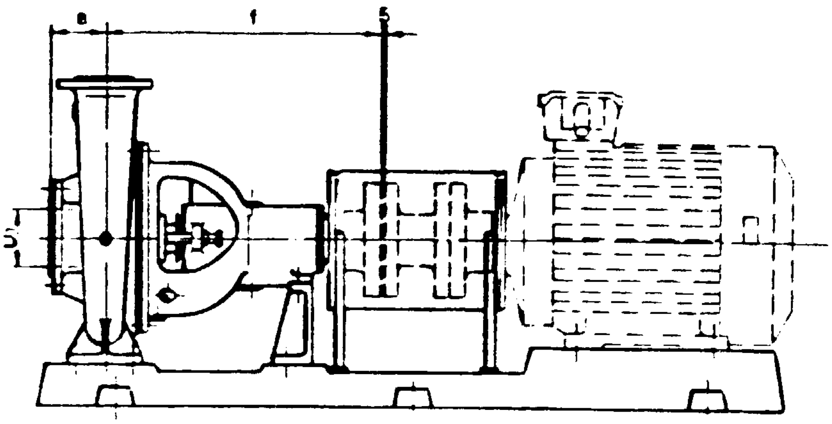


Fig. Centifugal pump - single suction
Above: cross-sectional view and list of parts
Below : View of pump and motor assembly

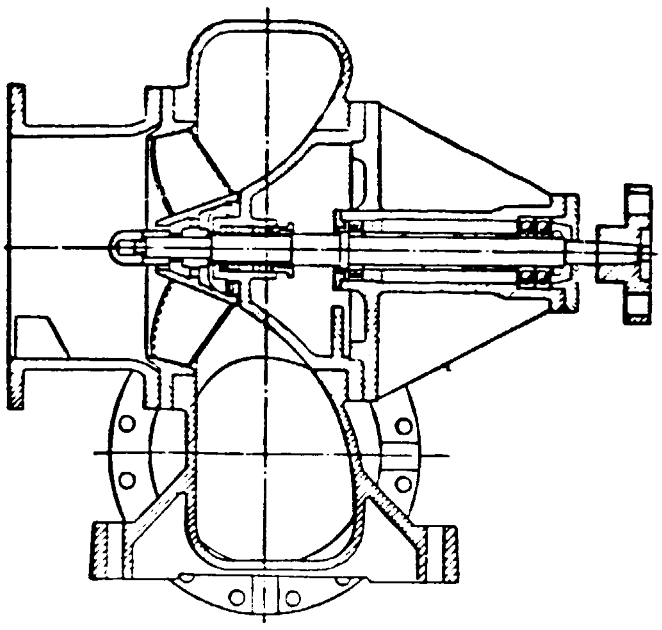


FIG. Worthington mixed-flow pump.

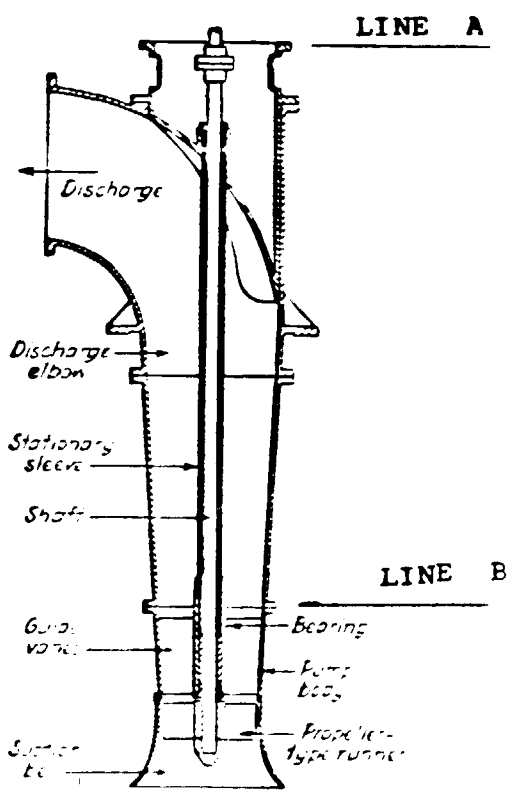


FIG. Vertical propeller pump

In the axial-flow propeller pump shown in Fig. 14 (left), all parts except the shaft and bearing can be omitted, and their functions taken over by concrete works.

This principle was successfully 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.

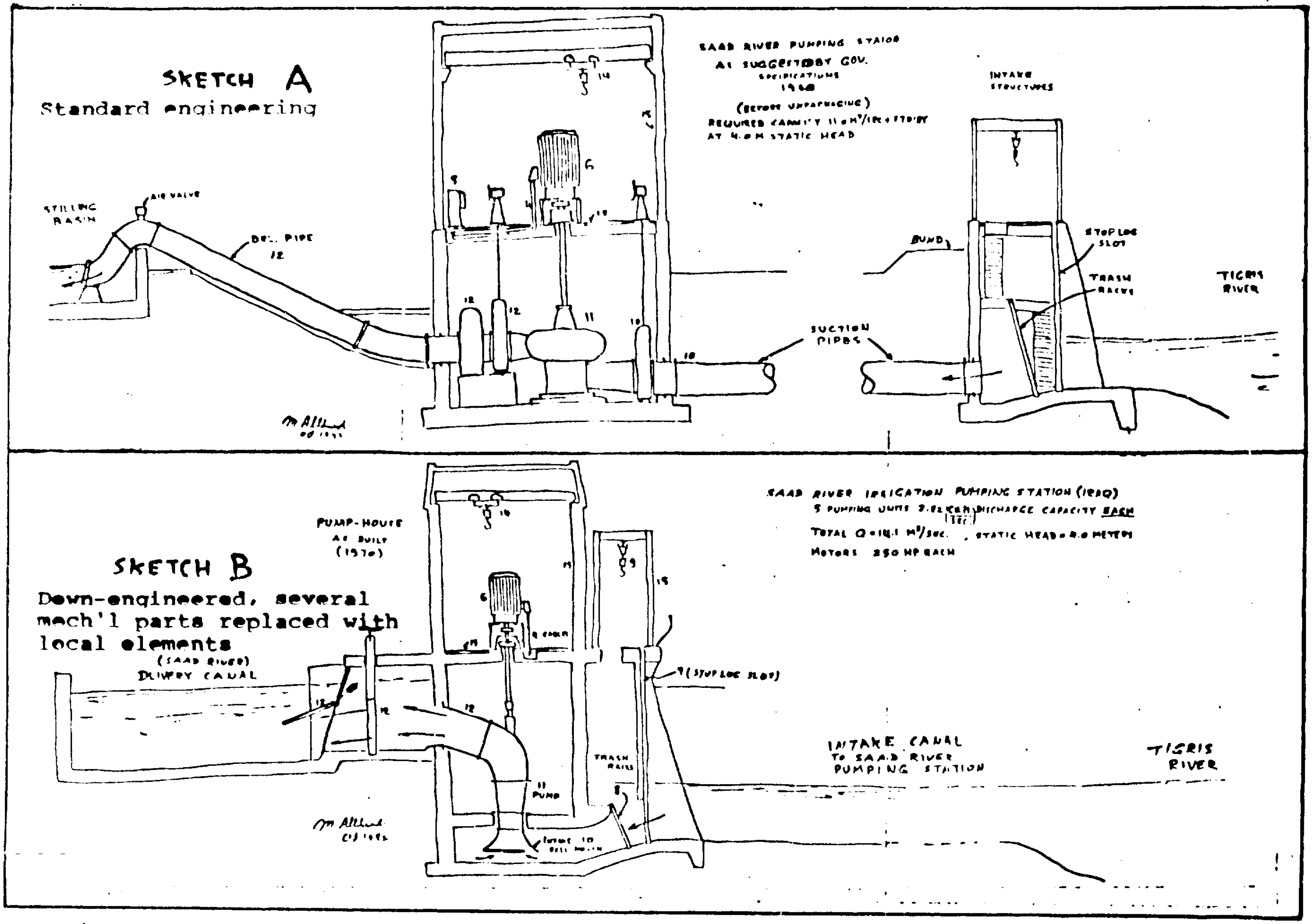


Fig. Saad River pumping station (Iraq). Sketch A standard engineered. Sketch B, same station as built after unpackaging and down engineering by consultant. Saving to gov. 50 percent.

-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 managable by the simpler axial flow or pure propeller pumps.

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 solid body displacing the fluid. They fall again under two subcategories;

-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.

-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 .

TABLE . Mechanization levels for pumps
Choices for different farm sizes

TECHNOLOGY LEVEL I	II	III	IV
Lever-type hand pump	Hydraulic ram	Engin-driven pump(over 6hp)	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 6hp)		Measuring device
Hand-operated diaphram pump			Head gates

<---Water from well, borehole, stream--><-Water from stream, river, catch->
canal or channel -ment 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

Centifugal Pump Analysis

The principal adavantages of centrifugal pumps are smooth and even flow, a decrease in pressure head when water level at the source is high for instance, increases the capacity and the power consumption, and an increase in the head, reduces t' capacity and power consumption. the effect of closing the valve on the pump discharge is to increase the pressure head approximately 15 30% and reduce power 50% to 60% from those values at the most efficient operating point.
These characteristics make a centrifugal pump a very easy load for any driver. The torque required to start the pump is . ry small, suitable for direct coupling even to squirrelcage AC motors, while the operating load is smooth and free from shock.

Pump characteristics.

The pump characteristic c. ves, also referred to as"performance curves", show the relashionship 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 of the characteristic curves with the discharge rate as the abscissa as shown in

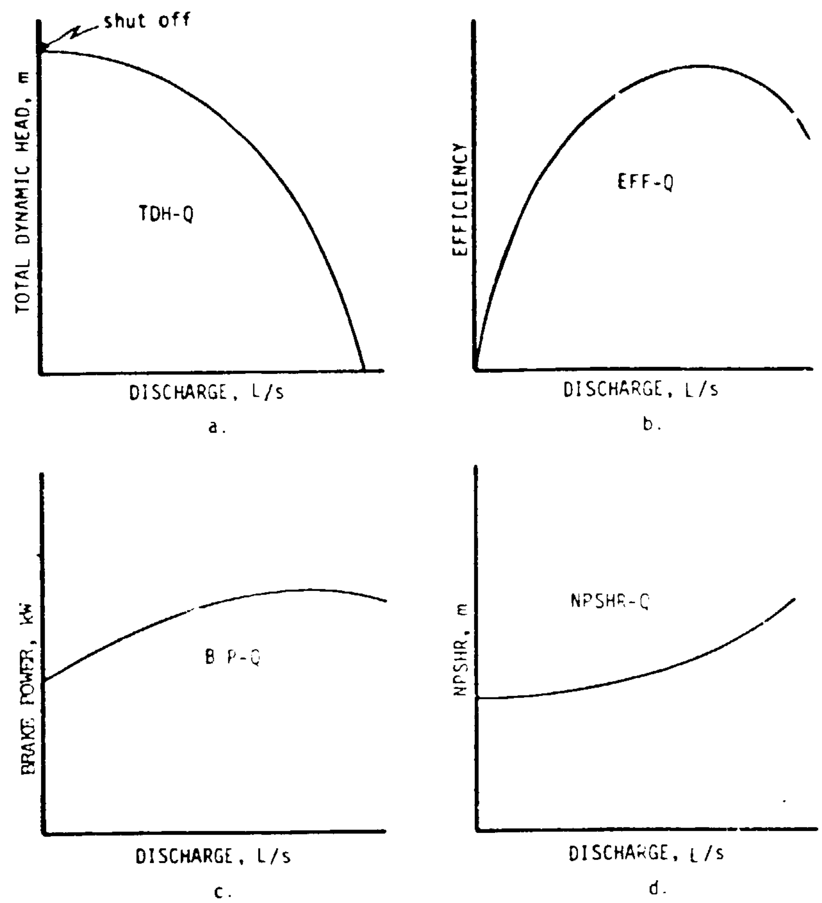
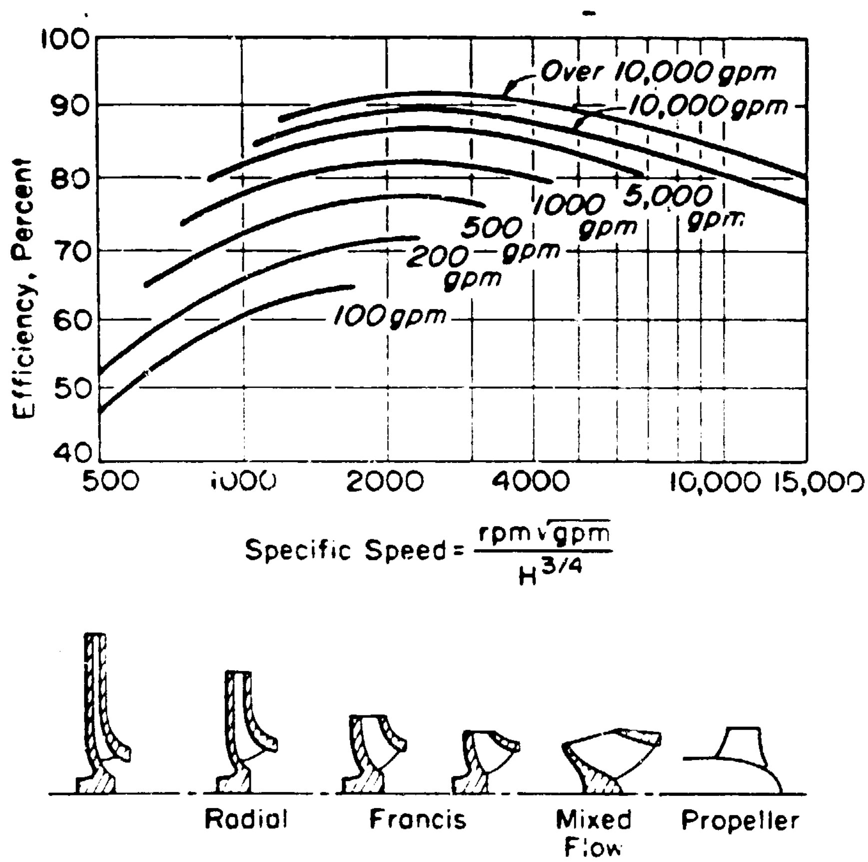


FIG. Typical characteristic curves for a pump.

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 wea is excessive. This best determined by carrying out firld 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 the report.



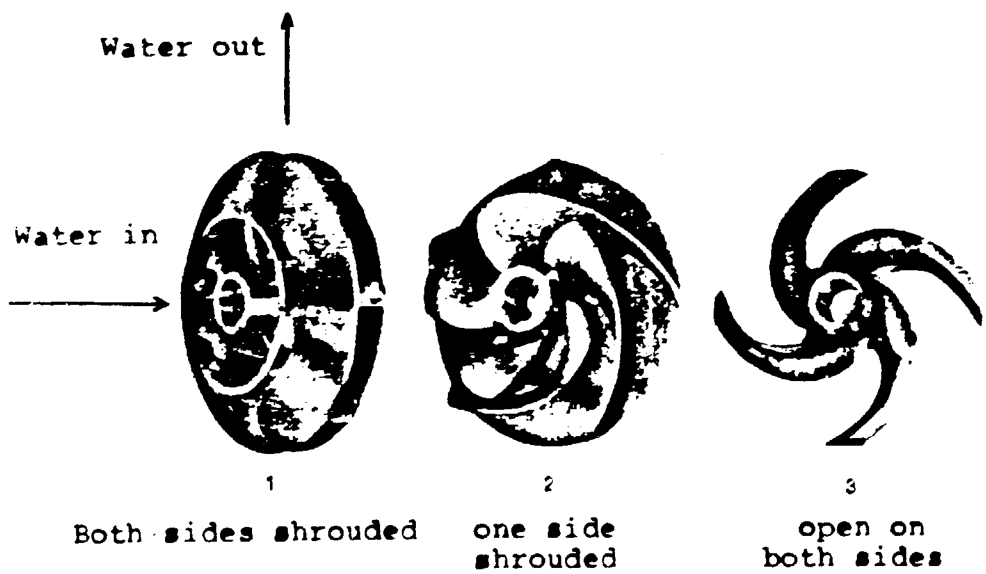


Fig. Shrouded and open propellers for radial flow centifugal pumps

Figure . 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 test 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 the size, speed, and the design of a particular pump.

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 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. From Figure , the shutoff head is 180 ft (55 meters).

PUMP RATING AND EFFICIENCY

Pumps are usually rated at a certain capacity in gallons per minute (gpm),liters per second or cubic metrs 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).

Pump efficiency is a direct measure of itd hydraulic and mechanical performance and is defined as the ration of energy output of the pump to the energy input applied to the pump shaft by the driver (motor/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).

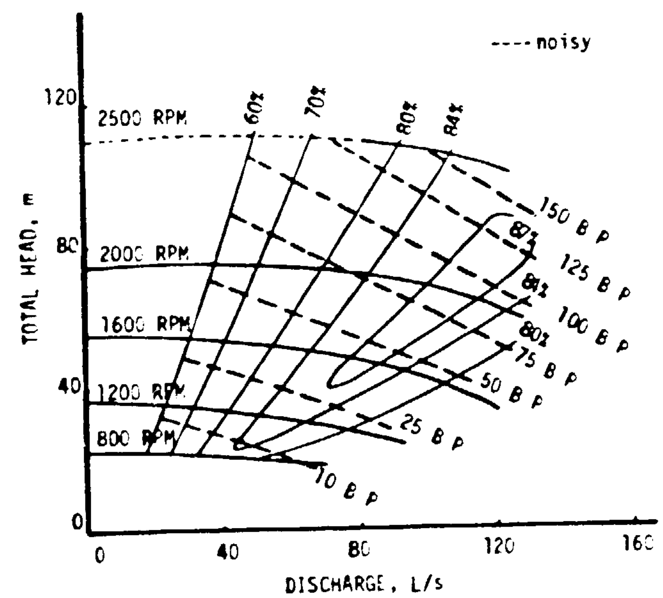


FIG. Characteristic performance curves of a single stage pump for several operating speeds

OVERALL PUMPING EFFICIENCY

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 electicity 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=3600000 joules).

Overall efficiency= product of efficiencies of all components .

Properly selected pumps run at efficiencies between 65 and 80 percent. Electric motors loaded between 75% and 125% of their nominal power ratings should run at near their peak efficiencies of 80% to 92%. Diesel engines' efficiencies for calculations of fuel consumption are realistically considered to be 22% to 25%.

Other usefull efficiency figures are;

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

The maximum theoretically possible values for overall efficiency is 72 to 77 percent (electric drive). In reality, as shown in the table below, average values obtained from field tests in the U.S.A. are considerably lower; 45-55% for electric driven and 13-15% for diesel.

TYPICAL VALUES OF OVERALL EFFICIENCY

FOR REPRESENTATIVE PUMPING PLANTS,

EXPRESSED AS PERCENT

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 effiencies 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 15% 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.

PUMPING AT OTHER THAN B.E.P.

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 valus. 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 the best efficiency point. The result would ofcourse be far from catastrophic. Since this lower efficiency performance represent a controversial issue in official attitudes towards the quality of industrialization, it deserves a brief analysis which will follow.

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 two bad after all and in fact it is normal. An ordinary centrifugal pump whose characteristic curve (Fig.), shows its best efficiency point as when pumping against 145 ft head, efficiency being at 72%.

When this pump operates against 125 ft head, only 20 ft less than for best efficiency head, the drop in efficiency is 10% e.g. from 72% to 62%, an accepted reality in irrigation pumping, since such fluctuation in water head is normal. And make the case more general, an axial flow pump used in irrigation for low lifts is considered. Its characteristic curve (Fig.) shows its best efficiency point as when pumping against a total head of 4.76 meters, efficiency

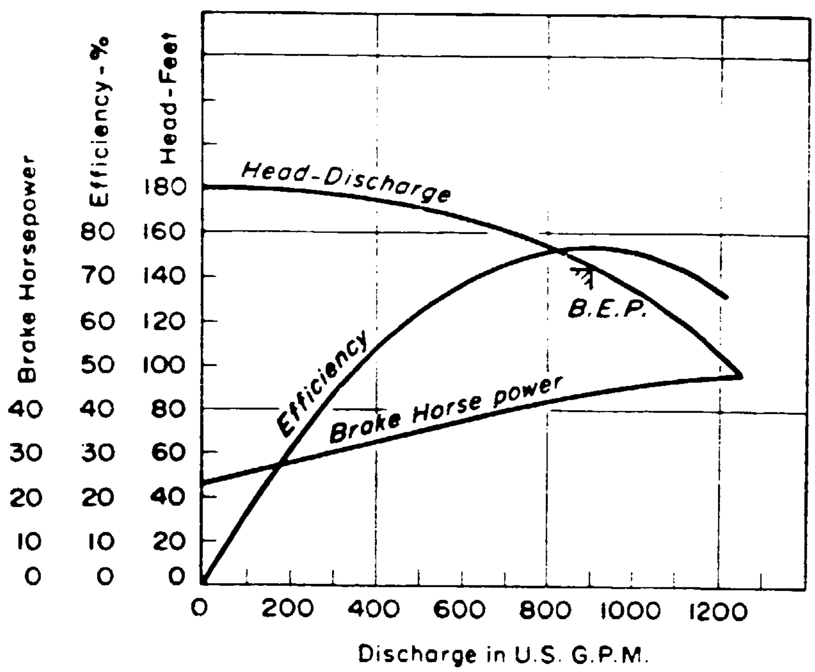


FIGURE
TYPICAL CENTRIFUGAL PUMP CHARACTERISTIC CURVES

At Best Efficiency Point (B.E.P.),
Efficiency = 72 % ,head=145 ft.

At 10 % lower 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.

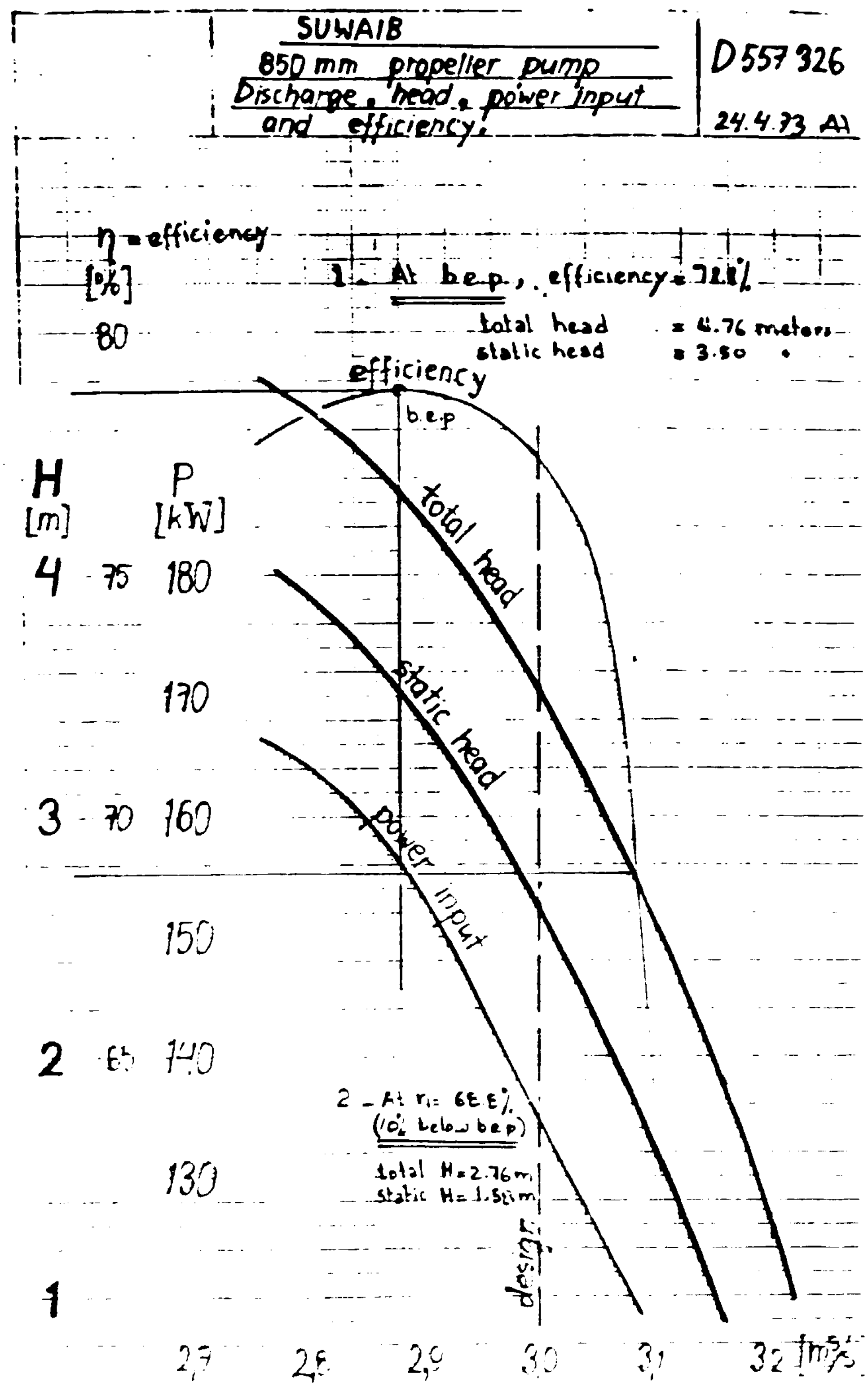

SUWAIB
850 mm propeller pump
Discharge, head, power input and efficiency.
D557 326
24.4.73 AI
η = efficiency
[%]
80
1. At b.e.p.
total head
= 4.76 meters
static head
= 3.50
efficiency
b.e.p
H
[m]
P
[kW]
180
170
160
150
140
130
total head
static head
power input
(10% below bep)
total H = 2.76m
design
2,7
2,8
2,9
3,0
3,1
3,2

Fig.

being 78.8% 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%, e.g. from 78.8% to 68.8%, once more proving the case.

ESTIMATED USEFUL LIFE OF VARIOUS

PUMP COMPONENTS(YEARS)

	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	25	25	25	25
Engine foundation	25	25	25	25
Electric motors	25	25	25	25
Electric controls and wiring	25	25	25	25

Note: Above values are for U.S.A 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 are reduced 7 years while in the remote rural areas are assumed to be 2-3 years only

*Depreciation Guidelines for Irrigation Systems Components

Component	Depreciation (hours)	Period yr	Annual Maintenance and repairs(% 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	32000-50000	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		20-40	0.5-1.0
Pipe,asbestos-cement and PVC (buried)		40	0.25-0.75
Pipe,aluminum,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,aluminum,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		12-16	5-8
Continuously moving sprinkles		10-15	5-8

Source:Design and Operation of Farm Irrigation Systems
The American Society of Agrricultural Engineers;Dec.1980

Specific Speed (Ns)

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 behavior of one pump based on tests of similar but different sized-pumps. Properly designed and constructed pumps show that the efficiency is a function of the dpecific speed. The specific speed for a single suctio pump is usually expressed as:

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

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 would be operated to produce a discharge of one gallon per minute against a head of one foot.

Cavitation

Pump impellers/propellers act as battreies 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 vapor bubbles and their eventual collapse. The repetition of this bubble formation and their collapse cause pulsation producing sounds as if stones are 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)

Certain portion of 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 the 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 - vapor pressure

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

Affinity Law

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

$$Q1/Q2 = RPM1/RPM2$$

$$H1/H2 = (RPM1/RPM2)^2$$

$$\frac{BP1}{BP2} = (RPM1/RPM2)^3$$

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

This concludes a very brief description of most relevant pump characteristics for simple pumping on single pump - single stage basis.

An Economic Consideration of
<u>downengineered-low efficiency pumps</u>

Rigid standards and efficiency requirements may constitute unsurmountable difficulties to entrepreneurs who plan to start an industry small scale in particular. They are often individuals with limited capital and technical knowledge but a lot of courage and vision. Government planners, economists and decission makers in developing countries, those with high training abroad often oevremphasize 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 embrionic stage, or where government licencing 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 arguement which is quoted from a formally submitted document.

"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 develpoed by IRRI and produced now by thousands per year in the Philippines, Thailand and Indonesia, need 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."

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 percent may result in improving overall efficiency of a diesel driven pump by probably a mere 2 percent since the overall efficiency for such pumps measured in developed countries is not over 18 percent(please see fig.).
3-Using figure from the quotation above, the saving per year would be about US$20 at best and total for 10 years is 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 annum, is found from table in fig.) 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.

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

n= number of years
i= interest rate

Table

DISCOUNT FACTORS - CALCULATION OF THE PRESENT VALUE OF A FUTURE COST OR BENEFIT IN YEAR n

Year	5%	6%	7%	8%	9%	10%	12%	15%	20%
1	.952	.943	.935	.926	.917	.909	.893	.870	.833
2	.907	.890	.873	.857	.842	.826	.797	.756	.694
3	.864	.840	.816	.794	.772	.751	.712	.658	.579
4	.823	.792	.763	.735	.708	.683	.636	.572	.482
5	.784	.747	.713	.681	.650	.621	.567	.497	.402
6	.746	.705	.666	.630	.596	.561	.507	.432	.335
7	.711	.665	.623	.583	.547	.513	.452	.376	.279
8	.677	.627	.582	.540	.502	.467	.404	.327	.233
9	.645	.592	.544	.500	.460	.424	.360	.284	.194
10	.614	.558	.508	.463	.422	.388	.322	.247	.162
11	.585	.527	.475	.429	.388	.350	.287	.215	.135
12	.557	.497	.444	.397	.356	.319	.257	.187	.112
13	530	.469	.415	.368	.326	.290	.229	.163	.093
14	.505	.442	.388	.340	.299	.263	.205	.141	.078
15	.481	.417	.362	.315	.275	.239	.183	.123	.065

Table

DISCOUNT FACTORS - CALCULATION OF THE PRESENT VALUE OF A FUTURE CONSTANT ANNUAL COST OR BENEFIT IN YEARS 1 TO n INCLUSIVE

Year	5%	6%	7%	8%	9%	10%	12%	15%	20%
1	0.95	0.94	0.93	0.93	0.92	0.91	0.89	0.87	0.83
2	1.85	1.83	1.80	1.78	1.76	1.74	1.69	1.63	1.53
3	2.72	2.67	2.62	2.58	2.53	2.49	2.40	2.28	2.11
4	3.54	3.46	3.38	3.31	3.24	3.17	3.04	2.85	2.59
5	4.32	2.21	4.10	3.99	3.89	3.79	3.61	3.35	2.99
6	5.07	4.91	4.76	4.62	4.49	4.30	4.11	3.73	3.33
7	5.78	5.58	5.38	5.21	5.03	4.87	4.56	4.16	3.60
8	6.46	6.20	5.97	5.75	5.53	5.33	4.97	4.49	3.34
9	7.10	6.80	6.51	6.25	6.00	5.76	5.33	4.77	4.03
10	7.72	7.36	7.02	6.71	6.42	6.14	5.65	5.02	4.19
12	8.86	8.38	7.94	7.54	7.16	6.81	6.19	5.42	4.43
15	10.88	9.91	9.11	8.56	8.0[illegible]	7.61	6.81	5.85	4.68
20	12.46	11.47	10.59	9.82	9.1[illegible]	8.51	7.47	6.26	4.87

Chapter IV

RECOMMENDATIONS

Pumps in the Multipurpose Approach

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 acknowledeged 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 multipurpose Approach to the manufacture of agricultural machinery.

Mechanical Workshops

Mechanical workshops are at the core of Multipurpose 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.

Recommended Action

A- On Government level:

1-Accord workshops in both public and private sectors the same privileges and protection accorded to young industries. With the advent of multipurpose 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 extentions needed for existing plants, based on technology unpackaging, reverse engineering and down-engineering as explained earlier.

4-Allocate sufficient part of R & D capabilities in universities, research centers etc. to solving problems associated with the 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 which the claims may be legitimate requiring apprporiate 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 with the following:

-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 progrssively.

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 multipurpose manufacturing approach of agricultural machinery within the framework of international cooperation. More information is needed on the subject. Such information can be gathered by means of surveys, seminars etc. The following informations are 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-On 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 cooperate in implementing a plan of action derived from the suggested common remedies. Other countries may find opportunities for cooperation on individual and collective basis. The informations 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.

Annex I

Mission Report

Visit to FAO 29-31 Nov. 1985
to obtain performance data on irrigation pumping
Munir Allahwerdi (consultant)

The mission was arranged by the Negotiations Branch of UNIDO as part of the tasks assigned to the consultant with the purpose of obtaining feedback data from the field on latest developments in pumped irrigation , pump performance, efficiency, life-span, etc. with the locally manufactured pumping units in particular. The mission was accomplished successfully thanks to the kind cooperation of Mr. von Hoelst, chief, Agricultural Engineering Service-FAO who acted as focal point for the mission.

The following FAO staff members were consulted:

Mr. H.von Hoelst
Chief Agricultural Engineering Service

Mr. Akram Al-Jaff, Chief, Near East, North Africa and Europe Service, Agricultural Operations Division.

Ms.A.R.Teramo de Ravenel, Liaison officer, office for Inter-Agency Affairs

Mr. L. Vermeiren, Senior officer, Irrigation science

Mr. D.J. Waterman, Senior officer, Operations Information and analysis Unit

Mr. Abdullah Arar, Senior Land and Water Development Officer

There was general agreement that the pump was indeed the most valued piece of agriculiural machinery to the farmer who depended on irrigation. Mr. Arar explained at length the benefits of even supplementary irrigation to farmers of rain-fed lands where it has been found on average that each cubic meter of water applied on supplementary basis increased the yield of wheat by 1.5 kgs.

Mr. von Hoelst's remarks were striking in particular for his long experience in the field, specially in India. He asserted that mechanical power has become essential even to the poorest farmers as the intolerablly hard physical work required on the farm makes life seem more attractive in the city and would compel him to abandon farming. His estimate is that 5-10 horsepower diesels, for instance, would make his life more tolerable. As to pumping, Mr. von Hoelst gave a precise reason, <u>THE PUMP PUTS THE FARMER IN CHARGE.</u> The farmer felt insecure when the lifeblood of his crop is controlled by others.

With such unanimity on the importance of pumping, field data would need to be more complete and in a compiled form. Unfortunately this was not found to be the case. Some work is beeing done on solar pumping , and the Intermediate Technology Group has been commissioned by FAO to produce a study on small scale pumping for irrigation and drainage which is due to be completed in early 1986. Otherwise there have been evaluation missions to selected locations, mostly in French speaking Africa. Selected relevant aspects of this report shall be reflected in the consultants final report. FAO is sending a participant to the Regional Workshop on Water Lifting Devices which is to take place in Hanjzou, China 21 April-5 May 1986.

FAO is clearly a biology biased organization. To it, irrigation engineering and with that pumping are matters subordinated to the broader field of Land and water Resources Management. With this observation, it seems that between the three major UN Agencies dealing with pumping, namely, FAO, WHO and UNICEF, a relative vacuum exists in the way of providing UNIDO with guidance on the development of this vital item of AGRICULTURAL MACHINERY AS CAPITAL GOODS.

Annex II

Lists of Obstacles & Remedies

List of Causes or Obstacles

A list of obstacles to the transfer of technology or causes of the dependency status should be compiled for use with the forms illustrated earlier for determination of the degree of dependency. A sample of such causes or obstacles is given below for illustration. Each cause is given a number for identification to simplify reference to it in the forms.

1-lack of coherent and integrated science and technology policy planning.

-

-

7-Foreign aid and capital flow constraints including trans-national practices.

10-Uneasy process of social transformation: culture, tradition, religion, and the political setting etc.

11-Inappropriate technical managers lacking the needed broad experience and information base. Or lack of multidisciplinary expertise.

12-Lack of institutional infrastructures: Engineering design, construction and manufacturing enterprises.

-

27-Lack of incentives to scientists, engineers and technicians.

28-Lack of engineers in the industrial disciplines.

29-Lack of skilled workers including machinists, tool makers, operators and welders.

30-Lack of workshops for metal fabrication.

31-Malutilization of existing mechanics.

32-Malutilization of existing workshops.

In determining the causes and obstacles for the list, generalization should be avoided. Each cause should be as narrow as possible in order to find a remedy for it which/is easily handled. Reference to wholesale obstacles may make the remedies also wholesale and unmanageable.

The Remedies

When the factors contributing to the state of dependency or the 'obstacles' have been identified they readily become a guide to the remedies required. While in some cases the remedy can be a direct derivative of the obstacle as in the case of obstacle No. 18 concerning lack of access to information contained in expired patent documents where an obvious remedy would be establishment of the necessary patent information dissemination network or linkage to existing such networks, in other cases the remedy can be of more complex nature as in the case of obstacle No. 9 (population increase) or obstacle No. 10 dealing with social, cultural, religious and political factors. The LIST however, is only an illustration of possible remedies consolidated from existing literature to which a country analyst can add his own to choose from.

List of Remedies:

1. Establishment of science and technology policy planning body linked to the highest executive bureau in the government, to set up guidelines and oversee technology transfer and development.
2. Legislation of laws regulating and governing the process of technology transfer in consultation with policy planning body.
3. Re-examination of curricula of schools at all levels especially engineering and technical colleges and institutes for inclusion of country specific technical courses and for educating general engineers and technologists.
4. Measures for the stimulation of discussions and debates on S & T issues by holding more seminars, work-shops and meetings with allocation of incentives such as travel and other forms of compensation) national, regional and international.

5. Establishment of technical documentation centers to preserve and disseminate existing technical data and reports used by government and other organizations particularly project reports and documents including blueprints and maps.

6. Computerized linkage of national scientific research councils with patent and other information and documentation centers.

7. Establishment of Regn'l Science and Technology Fund to finance and co-ordinate the remedies and measures taken collectively and individually by countries lacking the needed financial resources.

8. Establishment of Natn'l Information Bank with the necessary linkage facilities with emphasis on existing S & T capacities, production and services.

9. Enrichment of academic and professional engineering libraries with the internationally available non-proprietary information documents containing design procedures and criteria for engineering works especially in the fields of civil engineering, and agriculture as those published by United States Bureau of Reclamation and the Corps of Engineers.

10. Establishment of and strengthening existing technological institutes specialized in training instrumentation and laboratory testing technologists in all scientific branches: medical - chemical - eletrical - nuclear - mechanical , etc.

11. Special programmes using existing large government technical establishments including factories and engineering bureaus for the training of individuals and small businesses from the private sector.

12. Establishments of special national funds to assist small industries, individual artisans and small architectural and engineering firms up-grade their operations, services and products.

Summary of the most Persisting Obstacles and their Remedies

When the dependency evaluation charts have been completed for sufficient number of projects or sectors to reflect the true dependency picture in the country, the following table can be derived:

Table of the most persisting obstacles and remedies.

The obstacle to which reference occured the greatest number of times as totalled from all the charts is listed first followed by the other obstacles according to descending order of their respective occurences. This table as well as the charts will be referred to in the process of finding the most appropriate remedies. Now the obstacles are numbered with 1 for the most persistent on top then 2 onwards for the less persistent ones. The percentage of the occurence of each obstacle is given in the 4th. column.

A remedy for each obstacle can be chosen from the list of the most persistently referred to remedies.

The remedies most persistently referred to in the charts are also listed according to their descending order of occurences they clearly reflect priorities. Against each remedy the appropriate level for action - country - bilateral - subregional - regional or UN is accordingly indicated. This way priorities on various levels are indicated.