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A Hand Pump and Well for Rural Areas of Developing Countries

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## A Hand Pump and Well for Rural Areas of Developing Countries

### The Problem and Proposed Solution

The World Health Organization has estimated that in 1975 only 20 percent of the world's rural population had access to safe water. To bring safe water to rural areas of developing countries, the World Bank recommends in a recent report<sup>1/</sup> that, wherever possible, shallow wells and hand pumps be used to raise groundwater. Groundwater, in contrast to surface water, needs little or no treatment to make it safe.

These hand pumps, the report advises, must be "rugged, designed for simple, trouble-free maintenance by local technicians." But this is exactly contrary to the nature of available wells and hand pumps. Costly and complicated, available wells and hand pumps require developed industries (such as foundries), parts machined to close tolerances, and skilled maintenance.

Available wells and hand pumps were designed for particular conditions -- for temperate climates, light use, and manufacture by developed industries. When these imported hand pumps and wells are installed in rural areas of developing countries, they soon break down and cannot be repaired by villagers. UNICEF indicated to a World Bank mission in 1975 that in India 70-80 percent of the hand pumps are out of order at any given time.

Wells and hand pumps must be redesigned for the conditions that actually obtain in rural areas. My purpose in this paper is to set out these conditions and to describe a design that meets them.

### Conditions for Rural Water Systems

Handpumped wells for rural areas should yield as much safe drinking water as a person is willing and able to carry away (seldom more than 20 liters at a time), for reasonable expenditure of energy (the less the better), in less than two or three minutes.

The pump must perform reliably under almost continuous use, and endure. Experience suggests that rural residents must maintain their water supply themselves: support from outside agencies will probably be inadequate. To meet these conditions of endurance and reliability under heavy use, the design for hand pump and well must:

1. Employ local materials as much as possible;
2. Be mechanically very simple; and
3. Lend itself to local, untrained maintenance.

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<sup>1/</sup> World Bank, "Village Water Supply," March 1976.

I propose a design which meets these conditions. It simplifies hand pumps mechanically, and substitutes plastic pipe for the traditional steel and cast iron. This simplification and substitution significantly reduces the cost of building hand pumps, as indicated in Table 1. All parts can be made in developing countries, and replacement parts can be improvised from local materials.

Pumps designed on this principle can be used both for drinking water and irrigation.

### Principal Features of the Design

The general design I propose (illustrated in Figure 1) consists of a plastic upper well-casing 3" in diameter that extends at least 12 feet below the minimum static water level. A reducer connects the upper well-casing to a plastic lower well-casing. The lower well-casing terminates in a slotted plastic well screen set in the aquifer. The principal features of this design are briefly summarized below.

1. Plastic pipe serves as the well casing and pump cylinder. In conventional designs, a metal pump is lowered into a steel well-casing. My design eliminates the need for this complicated, expensive metal pump and riser pipe. The well casing itself becomes the pump cylinder, as illustrated in Figure 1.

The casing is plastic, rather than steel. The walls are exceptionally smooth,<sup>1/</sup> and this reduces the coefficient of friction between the pipe and parts that contact it, thus saving wear on the piston cup seals.<sup>2/</sup>

Plastic pipe costs about one-fifth the price of metal pipe. Polyvinyl chloride (PVC),<sup>3/</sup> the plastic specified in this design, is extruded in many developing countries. It is lightweight and can easily be transported and installed. Installed, plastic pipe is inert and is not affected by aggressive ground or water conditions.

These characteristics support the substitution of PVC for metal pipe as well casing. Since the PVC pipe also acts as the pump cylinder, however, it is essential to establish the rate of wear of PVC as a function of the number of strokes, pressure head, and water quality. Annex 5 summarizes a controlled laboratory rate-of-wear experiment in progress: PVC pipe should be field-tested under conditions of actual use.

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<sup>1/</sup> An off-the-shelf polyvinyl chloride pipe selected at random from the stock of Preussag, A.G. and tested at the Technische Hochschule, Hannover, Germany, had a micro-finish of 2 microns. This is comparable to the finish of an extruded brass cylinder.

<sup>2/</sup> Battelle Memorial Institute established conclusively in 1967 that wear on the piston cup seals resulted from roughness of cylinder walls. (Frannon and Frink).

<sup>3/</sup> Although other plastics, e.g., ABS, could probably be substituted if readily available -- see Annex 4.

2. Submerged, interchangeable piston and check valve increase efficiency and reduce complexity. In this design, piston and check valve remain below the surface of water in the well. This arrangement results in increased hydraulic efficiency over surface-mounted piston pumps. Water is forced ahead of the piston, avoiding suction losses. Submerging the piston and check valve also keeps piston seals wet, minimizing wear and cracks.

The well is always ready for use, and need never be primed. The piston and check valve can be brought up for inspection and repair by pulling up the pump rod, which can be done by one person. In contrast, inspection and repair of available deep well hand pumps is a three-person job.

Both piston and check valve are made of the same interchangeable components: perforated plastic discs with flapper valves covering the holes. These are illustrated in Figure 2. I specify a light, almost indestructible nylon-reinforced neoprene for the flapper valves. Battelle Memorial Institute concluded from laboratory tests that flapper valves made of this material wear indefinitely.<sup>1/</sup> If the valves should ever need to be replaced, substitutes can easily be cut out of leather, rubber, or canvas.

These valves should last longer than conventional types: in the conventional design, cast-iron poppet valves or ball valves pound against the valve seat, and become distorted with heavy use.

3. Pump rod employs local materials. A pump rod connects the lever (handle) and piston. The pump rod should add no weight that would require additional energy to lift. We can approach this ideal weightlessness by neutralizing the pump-rod's weight in water. This can be accomplished by making the rod of buoyant material, such as locally available wood, or galvanized steel tubing with sealed air chambers. The wooden pump rod should be completely submerged to prevent rotting by aerobic bacteria. Bamboo might be used where plentiful, if adequate joints and couplings could be devised.

4. Pump-rod guides may not be necessary. The Battelle Memorial Institute reports that "Pumps are made the world over with oscillating unguided pump rods and with guided pump rods. Generally speaking, guided pump rods are used on the deeper wells. However, there is no data for the effectiveness of the guided pump rod in providing longer life for the cups. Apparently, the main reason for using guided pump rods is to provide a more stable pump rod for use with wind mills, pump jacks, force pumps, or heavy-duty equipment."<sup>2/</sup> I believe the only two conditions that would indicate a need for pump-rod guides in this design would be:

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<sup>1/</sup> Battelle Memorial Institute, Fannon and Frink, 1967.

<sup>2/</sup> Ibid.

1. If water is pumped to an overhead storage tank for subsequent distribution, or
2. If the cylinder is small ( $1\frac{1}{2}$ "  $\phi$ ).

In the first case, the space around the pump rod above the outlet would require sealing -- probably with a packing gland. The guides serve to restrict movement of the pump rod to the vertical axis of the well, so as to prevent excessive wear on the packing gland (as indicated in Figure 4)✓

In the second case, movement of the pump rod should be restricted to avoid rubbing against the cylinder walls. But these two conditions should only rarely obtain in rural areas of developing countries: overhead storage is seldom required, and using a pipe of sufficient diameter as both well casing and cylinder (as this design specifies) should provide ample room for an oscillating pump rod.

Nevertheless, some workers report that, if guides are not used, the flexing of the upper portion of the pump rod may cause it to uncouple. I recommend a heavy box and pin butt-joint pump-rod connector with parallel threads to prevent uncoupling (shown in Annex 2, p. 4).

Should rod guides prove to be needed, I believe the traditional arrangement of a brass or bronze bushing, through which the top of the rod reciprocates, should be replaced with plastic parts. The upper one or two joints of pump rod could be allowed to oscillate inside the 3" diameter well casing. The pump rod could be centered by a polyethylene sacrificial disc held in place between two joints. The inherent flexibility of the upper 12 to 14 feet of the pump rod will allow displacement as the end of the pump handle swings through its arc during pumping. Polyethylene is slightly softer than PVC, and can be expected to wear somewhat faster. But the interface of these two plastics, automatically lubricated by water, would wear far better than the typical unlubricated steel/brass rod guide.

5. Upper parts can be designed by the users. The users may determine the color, size, lever (length and height), outlet geometry, and arrangement of the capping slab to suit their own needs and preferences. The construction of the base slab and masonry or metal pillar that protects the upper part of the well casing requires some care. These must be stable to avoid shearing the casing at ground level, and correct dimensions between the lever support and the casing must be maintained to prevent the pump rod from chafing the casing. The upper part of the casing should be granted into the hole to prevent contamination of well water with surface water. The slab should be sufficiently large to keep the immediate area of the pump dry.

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1/ An early Roman design, shown in Figure 5, achieved overhead lift without guided pump rods. (Agricola, "De Re Metallica")

6. Local materials can be used to make pivot points. Conventional pivot points, which typically consist of a mild steel pin and cast-iron journal, wear badly. I suggest substituting a steel pipe shaft and a wooden journal impregnated with lubricant.

The earliest wooden pumps probably employed wooden shafts turning in wooden journals. These were succeeded by metal shafts turning in wooden journals, and finally by metal shafts in metal journals. But the last stage of development is the least adapted for survival in the rural areas of developing countries. Humidity corrodes the pins and journals, and both wear excessively with heavy use. I believe returning to a metal-wood interface will yield a more reliable pump.

Other alternatives, such as a mild steel pin in a bronze bushing, are expensive and difficult to replace. Bronze is frequently pilfered. A mild steel pin in a sealed bearing would perform acceptably in the short run, but would also be expensive and difficult for villagers to replace.

For the shaft-and-journal arrangement I recommend that the steel-pipe shaft should be an off-the-shelf item that can be cut and fit without special equipment.

Annex 6 describes a simple process for impregnating wood with lubricant. Wood has been used for bushings in farm equipment and draft vehicles for centuries, and can probably be made into a reliable bearing for hand pumps. But this assumption must be tested in the field. Lubricant-impregnated wooden bearings are already in use for conveyor rollers, but their performance in oscillatory shaft motion must be investigated.

7. Cup seals are made of leather. Leather absorbs water and becomes flexible, readily conforming to the walls of the cylinder. Leather piston cup seals have been used since early Roman times,<sup>1/</sup> as illustrated in Figure 3.

Cup seals of good quality leather have lasted up to a year in a PVC-lined well in Bangladesh.<sup>2/</sup> Rubber cups, available in Thailand and Korea, may also prove acceptable.

UNICEF determined in 1975 that PVC cups wear PVC cylinders.<sup>3/</sup> Oversized leather cups also abrade plastic from cylinder walls by overstressing

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<sup>1/</sup> In the Roman design, a conical leather pouch hangs point-downward. When the piston is pulled up, the large end presses against cylinder walls, making a water-tight seal. The pouch folds up on the downstroke, allowing water to pass.

<sup>2/</sup> A PVC-lined Battelle pump was installed in an urban slum in Dacca, Bangladesh in June 1975. One year later the cup was worn to a nub, but still made a hydraulic seal. The cylinder wear was negligible.

<sup>3/</sup> PVC cups, however, work well in cast-iron cylinders in Bangladesh: plastic hones the cast-iron cylinder walls smooth. PVC cups would not wear or crack from cyclical wetting and drying in a suction pump with a leaky check valve.



the surface. A loose fit of the assembled dry piston (up to 2 mm clearance) in the cylinder appears sufficient to prevent wear from leather cups.

Laboratory tests (described in Annex 5) indicate that in a properly developed well, wear between the piston cup seals and the cylinder is negligible. This finding should be tested in the field. Should wear occur faster than our evidence indicates, the pump rod can easily be shortened so that the cup seals bear on an upworn section of the PVC cylinder/casing.

### Well Development

Many wells fail because fine sand is drawn in through the well screen and rapidly fills up the screen. To avoid this, the well must be properly "developed" before it is brought into service.

By forcing water out through the screen and back in again at high velocity, and bailing out the screen, fine sand can be removed. Coarser particles remain in the area around the screen, acting as a filter against fine sand and increasing permeability. Once complete, this "development" stabilizes the aquifer permanently.

A development tool (surge plunger) can be improvised for this process using the pump rod and piston, with the flapper valve on the latter sandwiched between the discs rather than resting on top of them.

### Adaptation for Irrigation

Two changes in the design described above should enable rural residents to pump the greater volumes required for irrigation in dry seasons:

1. Enlarging the diameter of the upper well-casing to increase output per stroke, and
2. Incorporating a pendulum in the lever system to allow the pump to be operated for several hours at a time without excessive effort.

These changes are illustrated on page 8 of Annex 1.

The pendulum-lever system hangs in wooden bearings from an iron frame that also holds the four legs that support it. These legs may be wood or bamboo, and the counterweight sandbags or any other convenient material. To suit local preferences, the natural frequency of the lever may be adjusted by positioning the counterweight on the long lever arm.

Annex 1 gives more information on this modification, and appropriate applications.

### Differences between Proposed Design and Other Systems Using Plastic Pipe

Annex 7 describes three pumps and wells that also substitute plastic for metal pipe. Three important differences distinguish this proposed design from others employing PVC pipe:

1. Piston and check valve are always submerged below the static water level of the well.
2. Only bell flare and nipple joints are used in the 3" diameter upper well-casing. Furthermore, the bell flares (female ends) are oriented downwards. Separate socket fittings are not used. This allows the check valve to be easily withdrawn. The reverse orientation (nipple-ends downward -- the usual case) prevents the check valve from being pulled up for maintenance.
3. The last 15 cm of the bottom pipe of the upper well-casing taper, reducing in diameter about .5 cm over this length, or approximately 1°. Compression of the leather cup in the taper holds the check valve in place; building up several layers of solvent cement on the inside of the pipe end has the same effect.

### Limits of the Materials

1. Transport. PVC pipe may be handled successfully with minimum precautions. For example, it should not be stacked under heavy objects, and the ends of the pipe should be protected from mechanical abuse. Whenever possible, smaller pipe can be telescoped inside larger pipe.

2. Storage. PVC plastic is composed of long chains of polymers that chemically alter if exposed to direct sunlight for long periods. Exposure to sunlight causes the material to become brittle, interfering with solvent-cement welding.

PVC is rigid at ambient temperatures, but will gradually deform under moderate pressure; for example, from its own weight or that of a point load. It should always be stacked on a level, solid surface. The height of the stack should not exceed two meters, and the pipe should never be stacked on end for long periods of time.

3. Jointing. Only two methods of jointing PVC pipe are suitable for this application:

1. Solvent cementing, which fuses one pipe to the other, and
2. Threaded ends, alternately nipples and bell flares.

Problems may attend either method under field conditions, but each offers corresponding advantages:

1. Solvent cement has a limited shelf-life. The ends of the pipe must be clean and dry and reasonably round. But unthreaded pipe is usually cheaper, and any damage it may suffer easier to correct. Once the joint is made it is permanent and must be destroyed to separate the pipe.
2. Threaded joints may be unmade and remade as necessary without compromising the joint. PVC pipe threads, especially those on the nipple ends, should be protected with a PVC slip-on cap, but if damaged may be rethreaded with a standard pipe die if a dowel is driven into the pipe before threading is begun. Oval deformation of either male or female ends makes starting the threaded joint difficult, and if the threaded bell flare is broken, reflaring the pipe and cutting female threads under field conditions is difficult. Usually, solvent cement is used as a stand-by to join pipe when rethreading is too troublesome.

4. Limits of Plastic Casing. Small-diameter (1- $\frac{1}{2}$ " ) rigid PVC pipe has been used successfully in wells up to 200 meters deep in Germany and Japan. Tension breaks are not likely to occur when lowering PVC pipe into a borehole, especially one full of water, since the specific gravity of PVC (1.38) makes the weight of the pipe negligible when submerged.

Plastic pipe cannot be driven. An open borehole must be maintained into which the plastic pipe is lowered. The borehole must stand open naturally or must be induced to do so by hydrostatic pressure, drilling mud or steel-pipe casing.

As a general rule, casing can be avoided when drilling in alluvium with one of the various hydraulic techniques such as jetting, hydraulic rotary, or the "hollow rod" method.<sup>1/</sup> Where a borehole will not remain open during drilling (for example, in alternating consolidated and unconsolidated strata using the cable tool method), steel casing must be driven and PVC pipe lowered inside it. After installation of the PVC well, the steel pipe is pulled and recovered (if possible). This is, however, time-consuming and expensive.

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<sup>1/</sup> Known in Bangladesh as the "sludger" method.

PENDULUM PUMP

What is it?

A manually operated pump  
- incorporating a new principle (the pendulum) to conserve energy, and  
a new material (PVC) to minimize friction, corrosion and deterioration.

Why do we need it?

As a minimum cost, minimum maintenance, solution to the problem of lifting irrigation water from wells, and to avoid the social/organizational problems associated with shared irrigation supplies.

Where will it work best?

Where high population densities and high water tables coincide, i.e. Northeastern India and Bangladesh, possibly the Nile-Delta, and some places in Indonesia.

Who will it work for?

The smallest farmers, who with even the limited cash and energy resources available to them, can use it to produce enough to feed themselves and their families.

What will it cost?

Less than \$100 (installed), with much of this being in labour and local materials contributed by the farmer, the rest locally manufactured.

How hard is it to work?

One man with this pump can lift 18 gpm, more or less steadily, from a depth of 12 feet. (Visualize carrying a gallon jug in each hand up a flight of stairs every 7 seconds!). There is no way to make this easy, regardless of the ingenuity of the machine employed, but if the alternative is going without food, that is not exactly easy either. In the course of a 120-day season, he may work, on the average, 5 hours per day, for a total of 600 hours.

What will he get for this effort?

From a half-acre of land he should get about 1200 lbs of rice, i.e. for each hour of work he gets about 2 lbs, or two days' food for a member of his family.

Mr. M. Yudelman

October 30, 1975

Stephen V. Allison

The Need for Improved Technology in Manual Pumping of Irrigation Water

Background and Statement of Problem

1. Over an area exceeding 40 million ha in monsoon Asia, intensive crop production is possible only with irrigation. Soils are good and temperatures are sufficient for year round cultivation. Because of high annual rainfall, water resources are generally adequate. The principal problem is the difficulty of getting the water from wherever it is (underground, or in streams and ponds) onto the land, where it is needed to support cropping activities.
2. This situation, of course, provided the justification for innumerable irrigation works which have been built over the centuries. A wide variety of constraints are now operating however to prevent the rate of construction of new facilities from equalling the rate of increase of demand for food. Additional solutions are thus required.
3. Manual pumping shows promise for this purpose because:
  - a) these are typically labor surplus regions;
  - b) the costs of other energy sources continue to rise sharply and there is a continuing shortage of fuel;
  - c) the capital costs of individually operated manual pumping units are sufficiently low to permit their purchase by even the smallest farmers;
  - d) the energy requirements for pumping can be provided from within the smallest farm family;
  - e) the water output of manual pumping units can meet the entire irrigation needs of the small blocks of land typically owned; and
  - f) because of the happy match between resources and requirements, these units can be installed and operated without the need for cooperation between farmers, which has proved to be a major stumbling block for most other types of irrigation facility.
4. Manual lifting of irrigation water has, of course, been practised in Asia for centuries. Except where lifts were very low (less than 1 m) it has however been found too costly in countries which had the possibility

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of one major rainfed crop per year; the economics of rainfed cropping kept food prices below the opportunity cost of the labour needed to produce more food by manual pumping. In more arid areas, where all cropping depended on irrigation, man/land ratios were lower and much irrigation was done by animal powered pumps. Where semi-arid conditions and high population densities coincide, as in China, manual pumping became and still is common.

5. The principal factor which has created the current need for manual pumping in South Asia in the course of the last few years is thus the population increase, which has:

- a) pushed the demand for food up faster than the supply, with the expected effect on food prices, and
- b) made more human labour available at costs which are lower relative to the cost of food.

6. One of the most important limitations of the manual pumping approach is the balance between the amount of energy available in a (not very well nourished) human body, and the large quantities of water required in the irrigation of any crop, particularly rice. The critical nature of this balance means that, for manual pumping to pay, absolutely minimal quantities of energy must be wasted overcoming friction or lifting water which is then permitted to slip back down the well. It is in this respect that most currently available handpumps are unsatisfactory. They were designed primarily for drinking water purposes and conservation of the human energy input was never an important consideration.

#### Description of Improved Technology

7. Under the pressure of rising food costs and severe unemployment attention is again being focussed on this problem. There is now reason to believe that ingenious mechanical design, coupled with the use of new materials, can minimize energy losses to make manual pumping for irrigation purposes a feasible and attractive proposition.

8. One such design is illustrated in Fig. 1. The distinctive features here are:

- a) elimination of the standard cast iron pump body, by expanding the upper 6 m of well casing to become the pump cylinder;
- b) setting of a simple piston below the water table in such a position that water will be lifted directly rather than by suction, and the piston gasket (pump leather) will remain moist at all times instead of passing through the wetting and drying cycles which cause deterioration of gaskets in surface mounted pumps which have their pistons above the water table;
- c) use of low cost PVC pipe with very smooth interior surfaces for all downwell components, eliminating the possibility of corrosion and minimizing energy losses due to friction. This pipe is easy

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to transport and may be installed without difficulty by local artisans;

- d) use of a ribbed and fine slotted PVC well screen, in which the ribs act to facilitate the development of a natural granular filter around the screen, and the slots are sized to pass the required fraction of fines -- and not more -- of the material from the surrounding aquifer;
- e) use of a simply supported pendulum above the well, to maximise mechanical advantage and conservation of the energy expended in pumping.

9. The pump has been designed to use energy at a rate which can be sustained up to 5 hours a day, by a small man working under tropical conditions (i.e. about 0.067 HP). The actual horizontal force which has to be applied to the push handle is between 7 and 10 kg, for lifts of 3 and 5 m respectively.

10. With this energy input, the pump will perform as summarized on Fig. 1. Hydraulic performance has been tested successfully under laboratory conditions but not, to date, in the field.

11. A pump of this design will cost about \$100 installed, as detailed in Annex 1.

#### Cost/Benefit Analysis

12. To obtain perspective on the economic merits of this design it may be compared with two principal alternatives: power-pumped shallow tubewells, and manually operated units using pump of designs currently in use. As all alternatives show economic returns well in excess of the opportunity cost of capital and range upwards, depending on the assumptions used, to well over 100%, a more relevant criterion for comparative purposes is the contribution of irrigation to the cost of the rice produced. The important variables and assumptions in this analysis are presented in Annex 1, and the results are summarized in Fig. 2.

13. Several conclusions can be drawn from Fig. 2. It appears that, except at very near zero wage rates, power pumping is substantially more attractive than manual pumping. This is certainly true from the engineering and economic viewpoints, but it is valid only within bounds defined by social and organizational constraints too complex to be neatly quantified. For a start the process of comparison implies that we have a choice, or must choose, between these technologies. The fact is that the power pumped wells are being installed throughout the region at a high rate and in fact about as fast as financial and organizational constraints permit. Under these circumstances what we would recommend is not that manual pumping installations should be supported instead of power pumps, but in addition to them.

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14. Secondly, electricity is simply not available in some areas, so power pumping implies the use of an internal combustion engine. For the necessary degree of reliability this means diesel engines and these are not made smaller than about 4.5 HP. If one is used it means either:

- a) producing enough water for 5 to 15 farmers, with associated requirements for organization or cooperation, or
- b) leaving a costly piece of equipment unused for between 50 and 90% of the time it could be working.

15. Finally, it has to be emphasized that, with the cost of a power pump installation being about \$1,300, only the larger farmers have the cash, or the influence necessary to get credit instead of cash. The manual pumping alternative, by contrast, is biased toward the smaller farmer because, from the farmers' perspective, this approach is considerably more attractive financially when labor internal to the farm family is used for pumping. A farmer with more than 3 ha of land would be incapable of having a family large enough to irrigate it all by manual pumping.

#### Potential for Development

16. It is clear that manual pumping, by any means, is a practical proposition for irrigation only when the static lift is less than 5 m. There are substantial areas (probably 4 to 5 million gross ha) in the most densely populated parts of the Indo-Gangetic plain, where the water table rises to near or above the surface during the rainy season and then falls to 4 m or less before the onset of the next monsoon. This condition is typically reached only in April or May, while the winter rice crop matures in March and may even benefit from drying out in April. During the important irrigation months, December to February, the average lift will thus be less than 3 m.

17. Irrigation from wells of any type will hasten the depletion of the water table as shown in the following table:

<u>Fraction of Area Irrigated (%)</u>	<u>Additional Depth of Water Table (m)</u>	
	<u>End December</u>	<u>End March</u>
10	0.26	0.85
25	0.66	2.12
50	1.32	4.24

18. This suggests that, in 4 million ha, manual wells should not be installed to serve more than about a million ha. This would still require 3 million wells -- scope enough for a major investment program.

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Next Steps

19. What is needed next is a series of tests, to ensure that the new pump functions as well in the field as it does in the workshop. Performance in terms of areas irrigated under different conditions, and the reactions of the farmers to the pendulum operating principle, need to be closely monitored through an entire irrigation season.

20. Only when this phase, which should, ideally, include 30 to 50 installations in differing areas, is complete will the concept be sufficiently proven to include in large quantities and major projects. At the present time we have several projects in the pipeline which may include manual pumping. Unless the pendulum principle is proven first, however, pumps of traditional design will be used, and project benefits will be significantly lower than if the human energy input was expended more efficiently.

SVallison:mam  
Encls.

cc: Messrs. Picciotto	Dunn/Gassner
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Weiss/Pak	O'Sullivan
Sud	Shipman

A. Detailed Cost Estimate

<u>Item</u>	<u>Quantity</u>	<u>Cost (\$)</u>		<u>Total</u>
		<u>Local</u>	<u>Foreign</u>	
Upper well casing (120 mm dia.)	6 m	-	18.00	18.00
Lower well casing (37.5 mm dia.)	11 m	-	22.00	22.00
Well screen (37.5 mm dia.)	5.5 m	-	11.00	11.00
Pump		12.00	12.00	24.00
Installation		15.00	-	15.00
		27.00	63.00	90.00
Contingencies		3.00	7.00	10.00
		30.00	70.00	100.00

B. Variables and Assumptions in Cost/Benefit Analysis

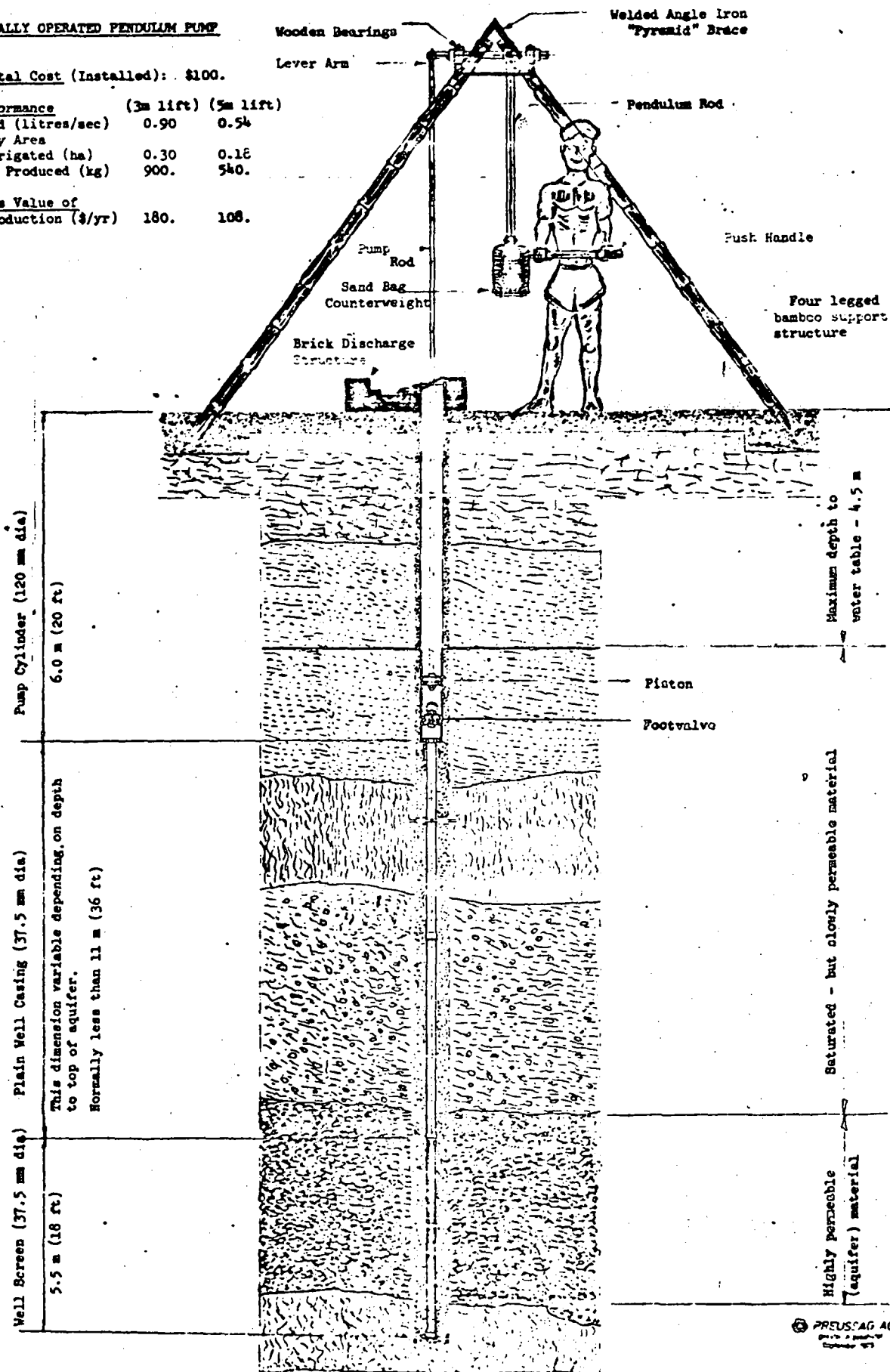
	<u>Power Pumped Shallow Well</u>	<u>Manually Pumped</u>	
		<u>Present Design</u>	<u>New Design</u>
Capital Cost (\$)	1,300	70.00	100.00
Area Irrigated (ha)	6	0.13	0.25
Incremental Rice Production (tons/crop)	15	0.45	0.825
GVP at \$200/ton	3,000	90.00	165.00
GVP/Capital Investment	2.3	1.28	1.65
Pumping Energy Use			
Power (gals diesel)	134	-	-
Manual (kg rice)	-	30.00	-
Value of Energy Consumed			
Diesel price range (0.40 - 1.00/gal)	53.60-134.00	-	-
Rice price (20 ¢ /kg)	-	6.00	-
Operating Labor Requirements (man/days/crop)	12	120	-
Labor Costs (\$/crop) (Range \$0.10 - 1.00/day)	1.20-12.00	12.00-120.00	-

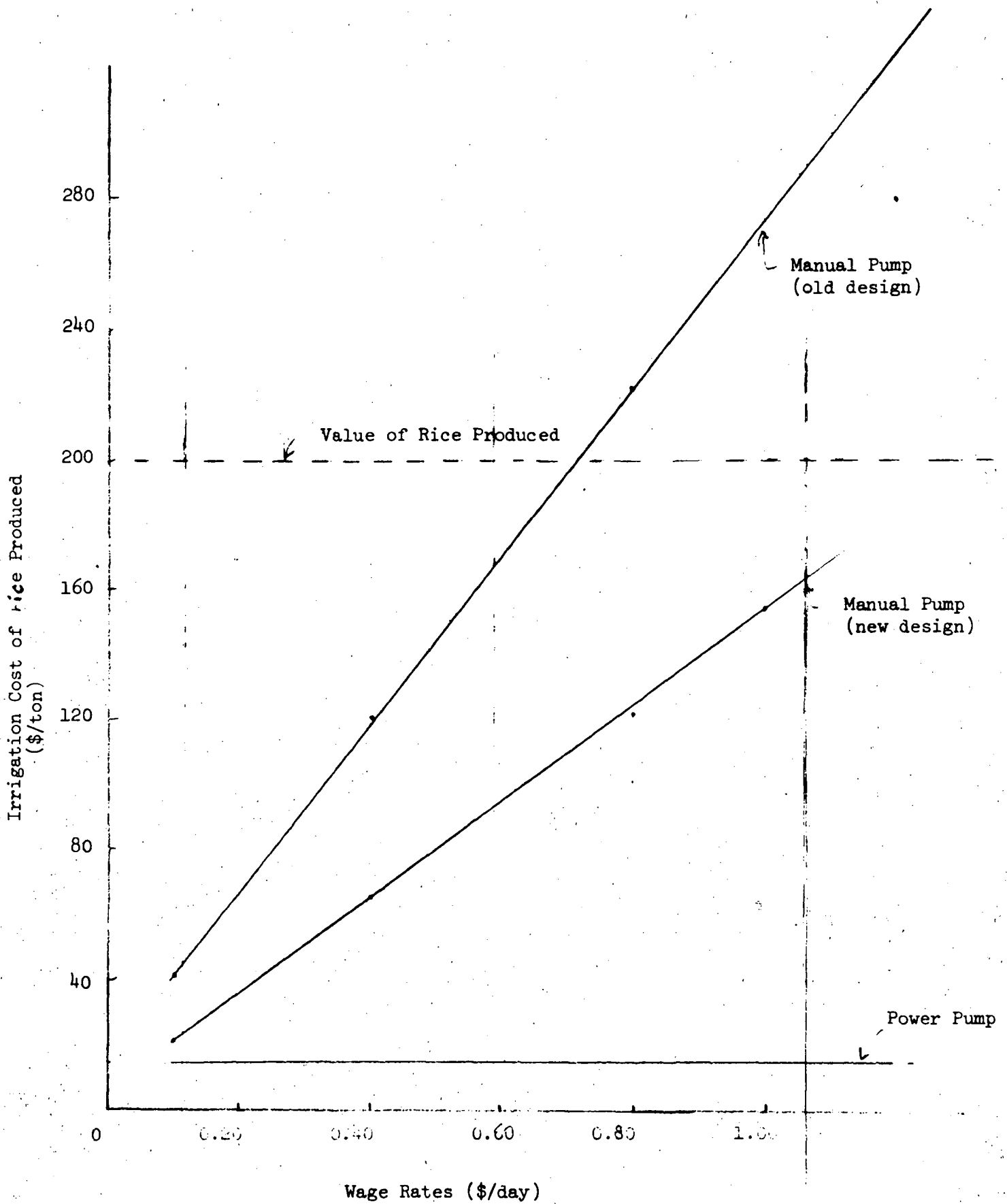
**MANUALLY OPERATED PENDULUM PUMP**

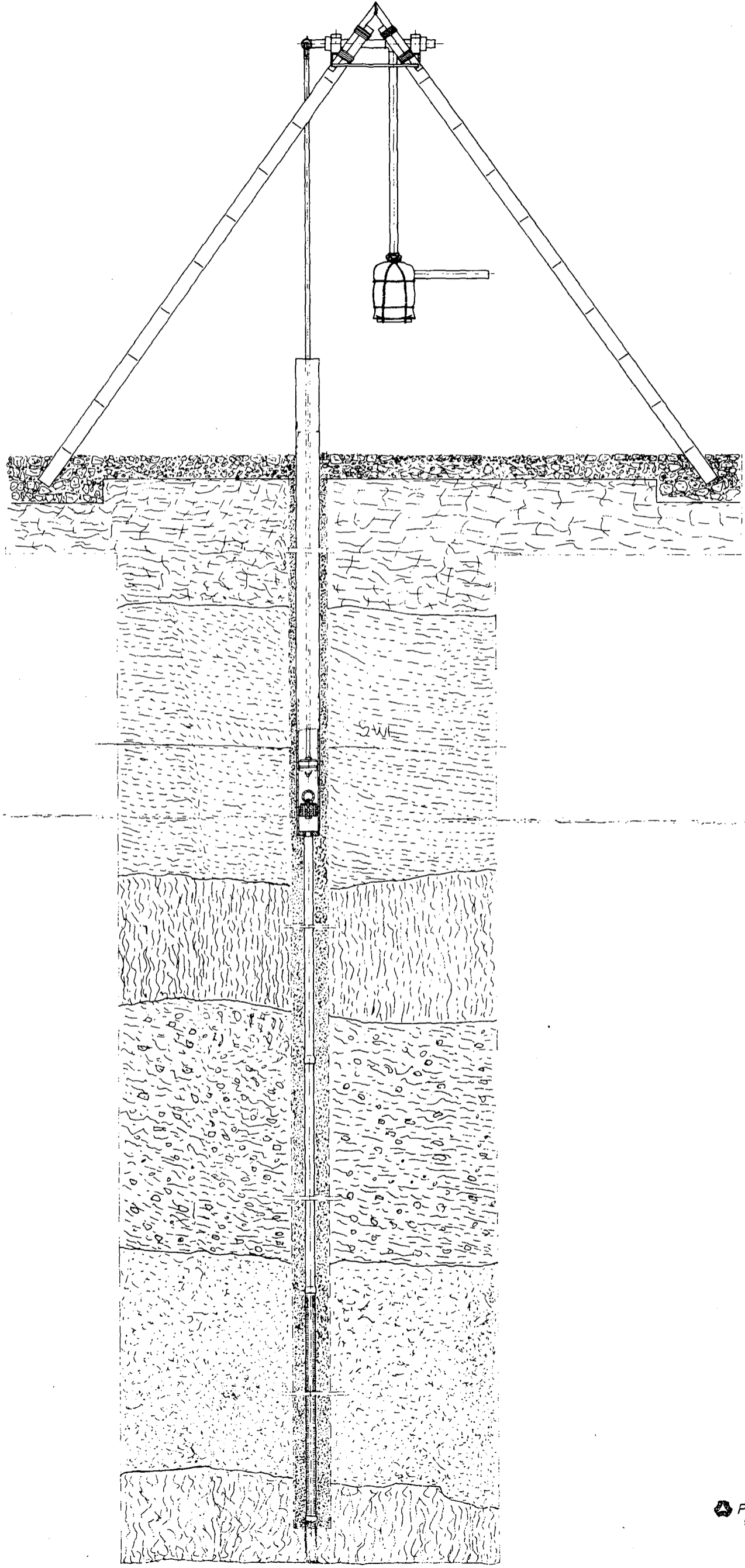
Capital Cost (Installed): \$100.

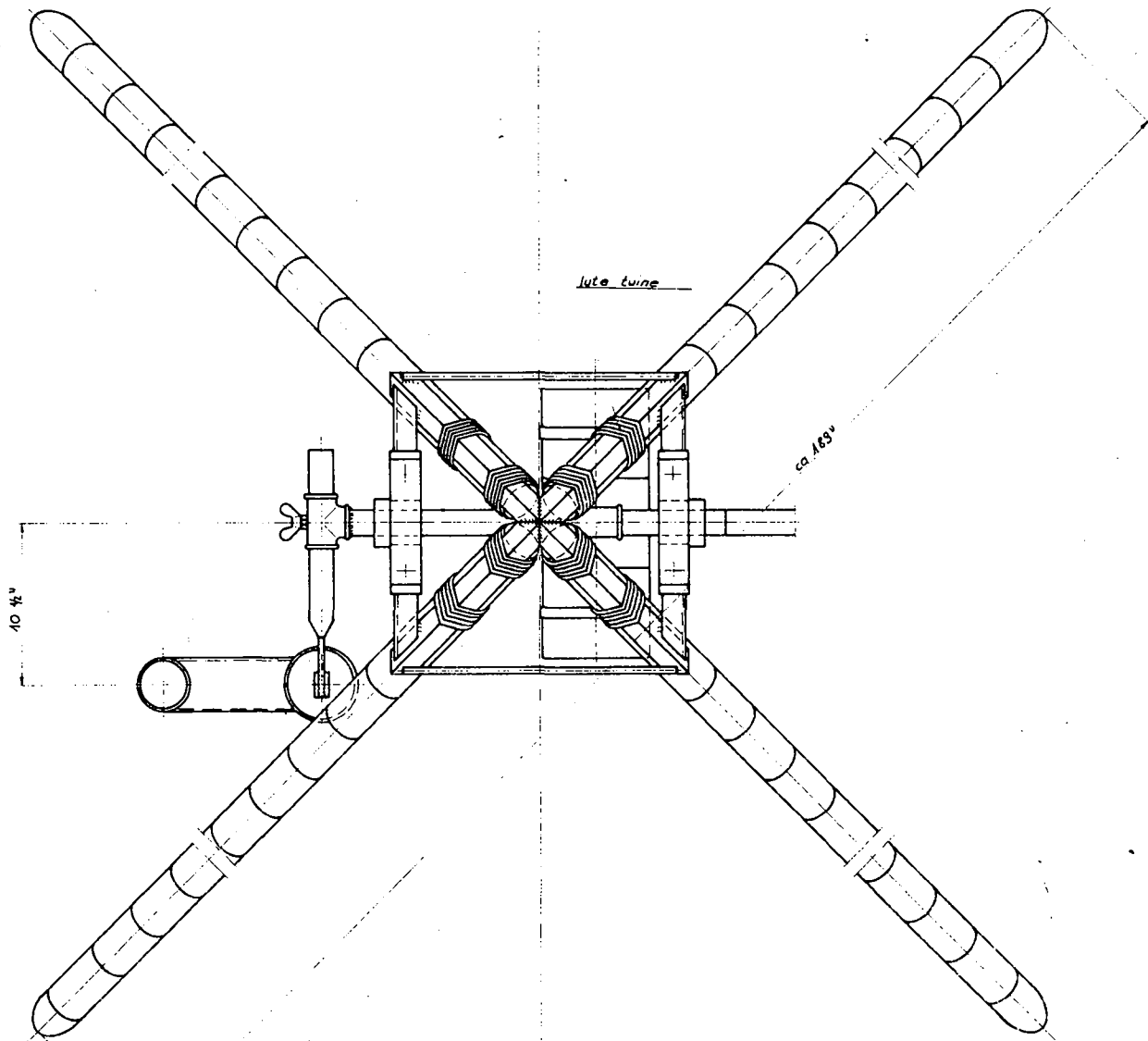
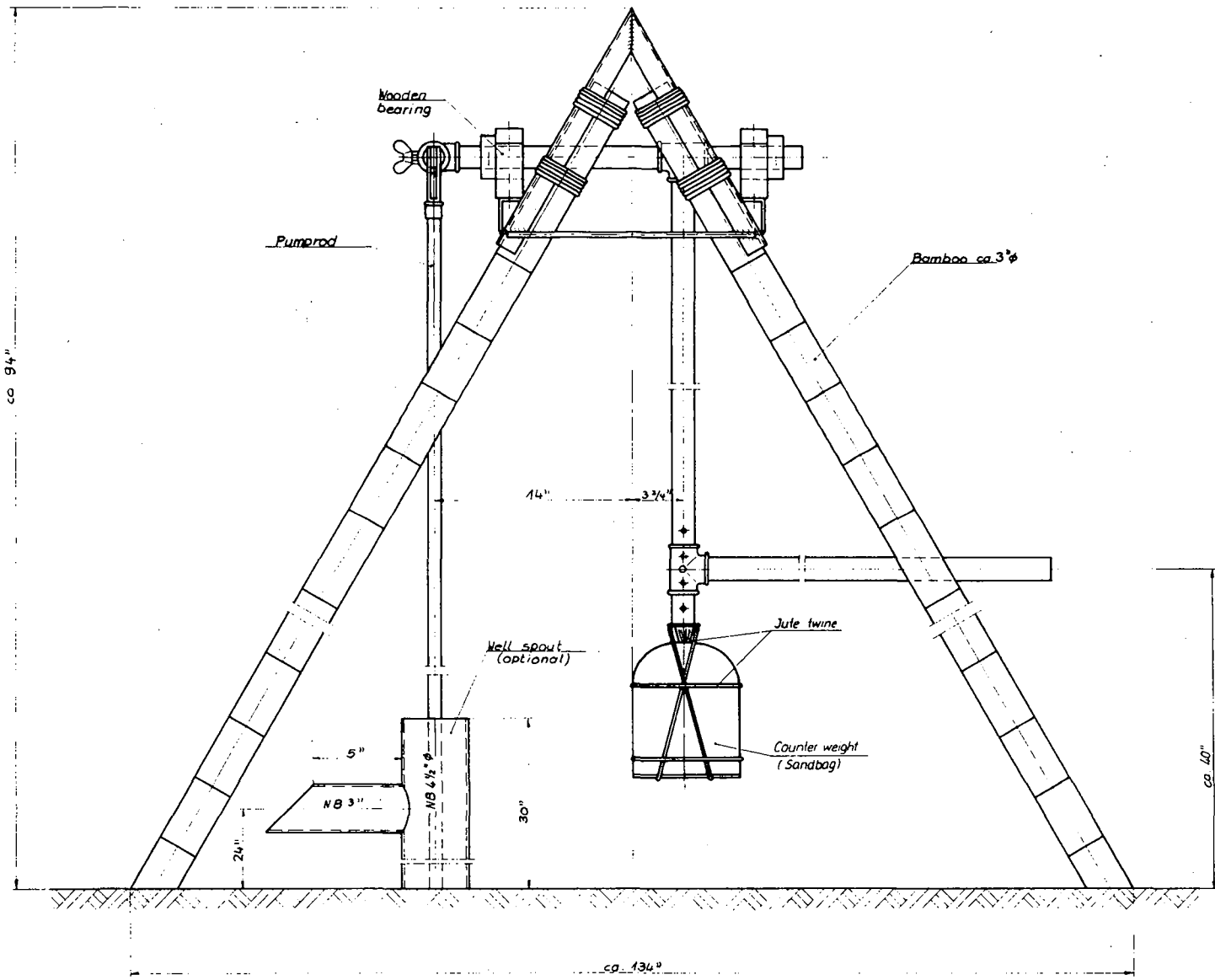
Performance	(3m lift)	(5m lift)
Yield (litres/sec)	0.90	0.54
Paddy Area Irrigated (ha)	0.30	0.18
Rice Produced (kg)	900.	540.

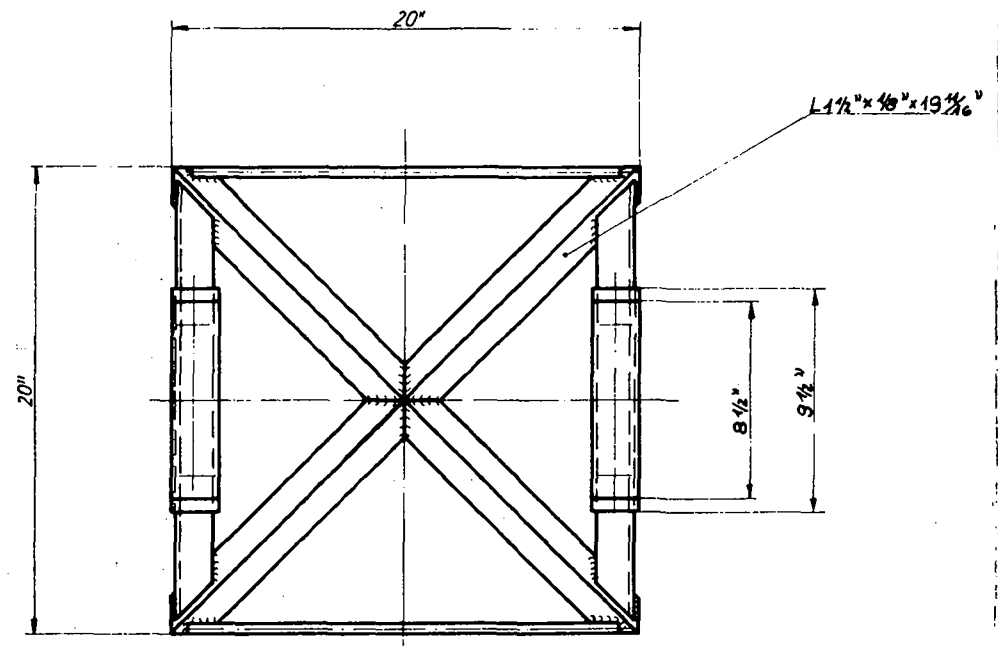
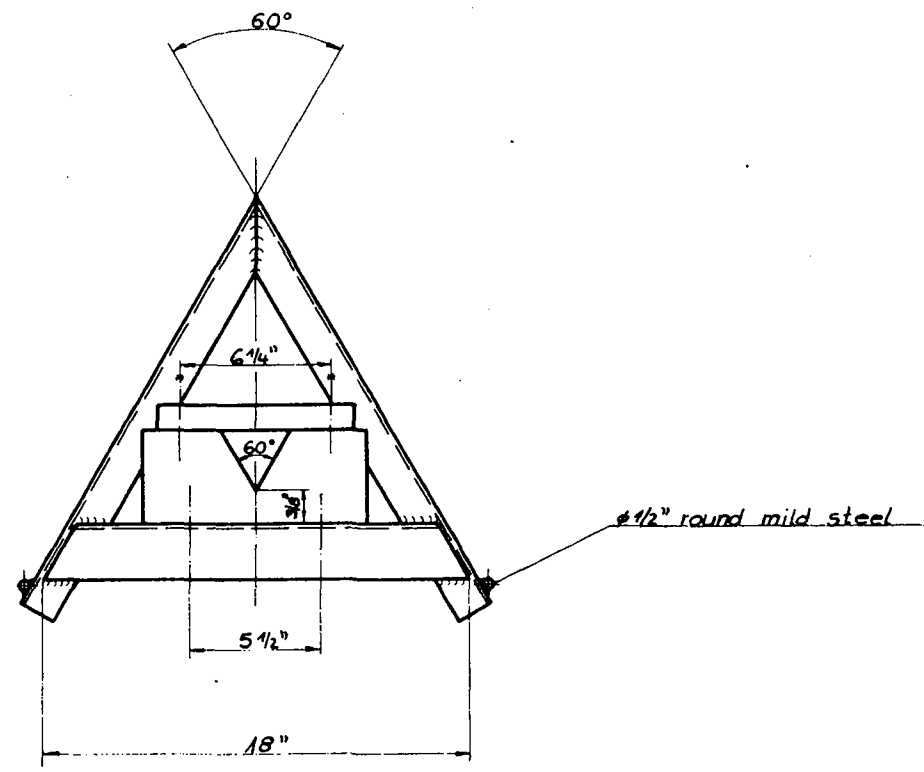
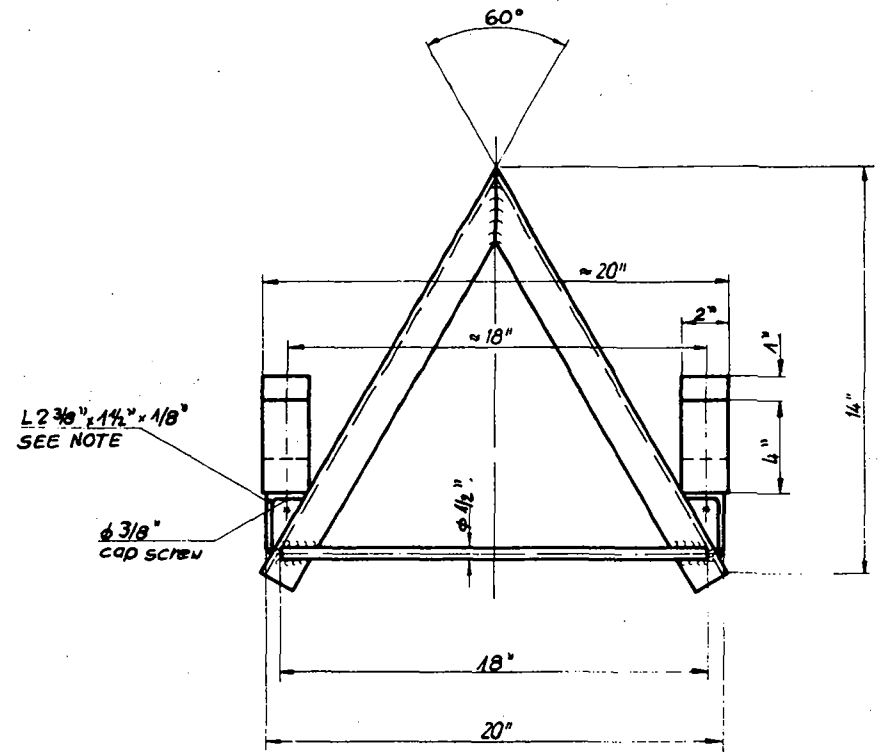
Gross Value of Production (\$/yr)	180.	108.
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Note:  $2 \frac{3}{8}'' \times 1 \frac{1}{2}'' \times \frac{1}{8}''$  angle iron is an odd size which would have to be specially made. For the purposes of a pilot project  $2'' \times 2'' \times \frac{1}{8}''$  will be sufficient after trimming to provide a level platform for the bearings.

# CLAYTON MARK & COMPANY

EVANSTON, ILL. U.S.A.

## WATER WELL SUPPLIES

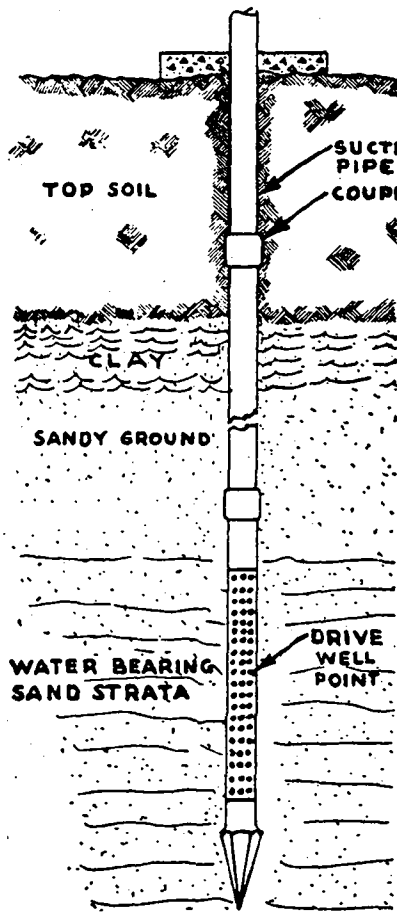
### Common Types of Wells

The illustrations shown represent common types of well constructions; namely, the driven well, tubular well, and cased well.

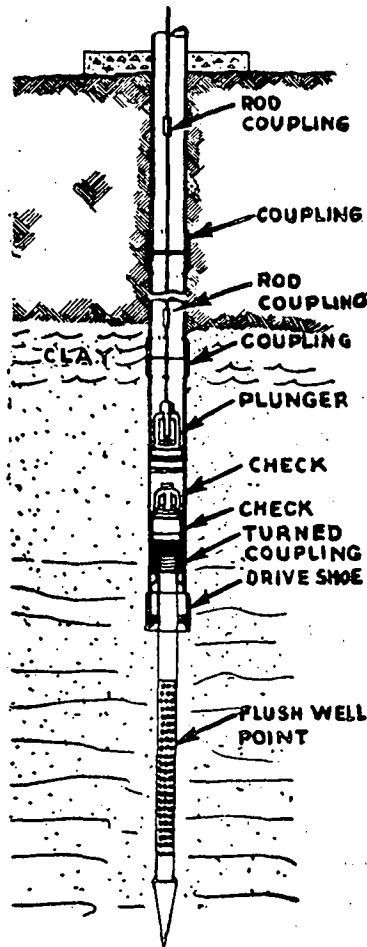
**DRIVEN WELLS** are more sanitary than the old type open well by the prevention of surface contamination and seepage. They are limited as to their capacity by the size and the volume of water available at shallow depths, but will provide sufficient water for the average family need. Driven wells vary in depth from 15 to 50 feet, depending upon the locality and nature of soil below the surface. They are constructed by using Drive Well Points with short lengths of pipe.

**TUBULAR WELLS** are sanitary. The casing extends from base of pump to the source of water supply, thereby preventing any outside contamination. They are constructed by drilling and then driving casing, with drive shoe attached, to water bearing strata. Then Flush Well Point is set in sand; valve is then placed and sealed to wall of casing. Plunger works in tubular well cylinder or pipe.

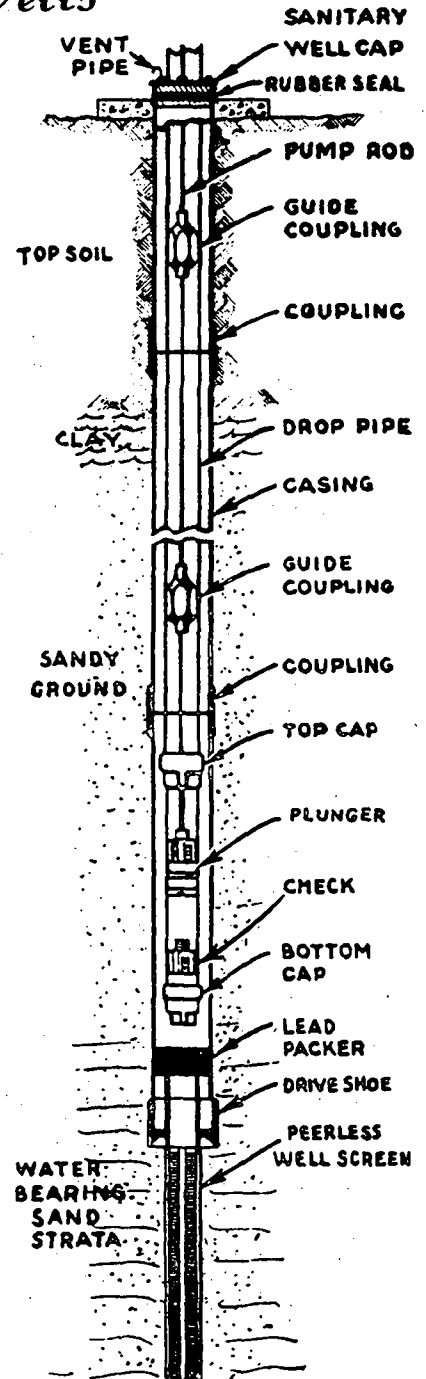
**DRILLED WELLS** are used when a greater depth of well is necessary to obtain the required amount of water. Casing is driven down as well is drilled and extends to rock or water bearing sand. If well is finished in sand, a sand screen is set through casing to the water bearing sand, then casing is raised to expose the screen which is sealed at top to casing with lead packer. Cylinder is then set on end of drop pipe inside the casing.



DRIVEN WELL



TUBULAR WELL



DRILLED WELL





# CLAYTON MARK & COMPANY

EVANSTON, ILL. U.S.A.



## All-Brass Cylinders

Gum Packer Type

Numbers 651, 653, 653-B and 655



Number 655



Number 651



Number 653-B



Number 653

**No. 655:** This cylinder is fitted with the same heavy valves as used in No. 448 and No. 654 Cylinders, illustrated on pages 53 and 49.

**No. 651** is fitted with the same valves as used in No. 650 Cylinder, illustrated on page 50.

**No. 653** is fitted with the same valves as used in No. 449 and No. 652 Cylinders, illustrated on pages 54 and 48.

**Directions for Installing Gum Packer Type Cylinders:**

Install No. 495 Well Packer (page 71) by inserting No. 451 Seating Tool (page 29) in slot provided; attach pump rod or drill rod to seating tool and lower the packer to the desired depth; seal the packer to sidewall of well casing by turning rod to the right, which will expand rubber packer making a tight joint; withdraw rod and seating tool from well.

**To Set No. 653 and No. 655 Cylinders:**

Screw the check into bottom of plunger about three turns and force the check into the taper at bottom of cylinder; take gum packer No. 496 (page 71) and insert tapered end of cylinder into same until gum packer expands to size of well. Attach pump rod to plunger and insert cylinder in well and lower same with pump rod to well packer; drive firmly into gum packer and unscrew plunger from check and attach pump rod to pump.

**Cylinder No. 651** is installed in the same manner, except that the No. 995 Hook is used on bale of check valve to lower the cylinder; plunger being inserted in cylinder after same is fastened in well.



# CLAYTON MARK & COMPANY

EVANSTON, ILL. U.S.A.



## All-Brass Closed Type Pump Cylinder

With Outside Brass Caps  
Numbers A-20 and A-20-L

The barrel is heavy seamless brass tubing with all brass outside caps.  
Plunger is all brass and fitted with two Waterproof Frictionless cup leathers. Regularly furnished with brass poppet type check valve.

Cylinder with leather flapper type check furnished if desired.

Strokes listed allow a clearance of two inches or more.

Order by Trade Number, Stating Inside Diameter and Length of Stroke.

### PRICE LIST

Inside Diameter and Stroke Inches	Length of Shell Inches	Length Overall Inches	Caps Tapped Pipe Size Inches	Size Rod in Plunger Inches	Smallest Well Cylinder Will Enter Inches	Approx. Net Weight Each Pounds	Capacity Per Stroke Gallons	Price Each No. A-20	Price Each No. A-20-L
2 x 6	12	15	1 1/4	7/16	3 1/2	6.7	.082	\$ 9.00	\$ 8.60
2 x 8	14	17	1 1/4	7/16	3 1/2	7.2	.109	9.70	9.30
2 x 10	16	19	1 1/4	7/16	3 1/2	7.7	.136	10.40	10.00
2 x 12	18	21	1 1/4	7/16	3 1/2	8.2	.163	11.10	10.70
2 x 14	20	23	1 1/4	7/16	3 1/2	8.6	.190	11.80	11.40
2 1/4 x 6	12	15	1 1/4	7/16	4	7.2	.103	9.20	8.80
2 1/4 x 8	14	17	1 1/4	7/16	4	7.7	.136	9.95	9.55
2 1/4 x 10	16	19	1 1/4	7/16	4	8.2	.171	10.70	10.30
2 1/4 x 12	18	21	1 1/4	7/16	4	8.8	.205	11.45	11.05
2 1/4 x 14	20	23	1 1/4	7/16	4	9.3	.240	12.20	11.80
2 1/2 x 6	12	15 1/2	1 1/4	7/16	4	8.1	.128	10.20	9.75
2 1/2 x 8	14	17 1/2	1 1/4	7/16	4	8.7	.170	10.95	10.70
2 1/2 x 10	16	19 1/2	1 1/4	7/16	4	9.3	.213	11.70	11.45
2 1/2 x 12	18	21 1/2	1 1/4	7/16	4	9.9	.256	12.45	12.20
2 1/2 x 14	20	23 1/2	1 1/4	7/16	4	10.5	.298	13.20	12.95
2 3/4 x 6	12	16	1 1/4	7/16	4	9.6	.154	10.65	10.00
2 3/4 x 8	14	18	1 1/4	7/16	4	10.2	.206	11.40	10.75
2 3/4 x 10	16	20	1 1/4	7/16	4	10.8	.257	12.15	11.50
2 3/4 x 12	18	22	1 1/4	7/16	4	11.4	.308	12.90	12.25
2 3/4 x 14	20	24	1 1/4	7/16	4	12.0	.360	13.65	13.00
3 x 6	12	16	1 1/4	7/16	4 1/2	11.0	.184	11.20	10.70
3 x 8	14	18	1 1/4	7/16	4 1/2	11.7	.245	11.95	11.45
3 x 10	16	20	1 1/4	7/16	4 1/2	12.4	.306	12.70	12.30
3 x 12	18	22	1 1/4	7/16	4 1/2	13.1	.367	13.45	13.05
3 x 14	20	24	1 1/4	7/16	4 1/2	13.8	.428	14.20	13.80
3 1/4 x 6	12	16	1 1/4	7/16	4 1/2	12.0	.196	14.00	13.40
3 1/4 x 8	14	18	1 1/4	7/16	4 1/2	12.7	.288	15.00	14.40
3 1/4 x 10	16	20	1 1/4	7/16	4 1/2	13.4	.360	16.00	15.40
3 1/4 x 12	18	22	1 1/4	7/16	4 1/2	14.1	.432	17.00	16.40
3 1/4 x 14	20	24	1 1/4	7/16	4 1/2	14.8	.504	18.00	17.40
3 1/2 x 6	12	16	1 1/2	7/16	5	13.2	.250	14.00	13.40
3 1/2 x 8	14	18	1 1/2	7/16	5	14.0	.332	15.00	14.40
3 1/2 x 10	16	20	1 1/2	7/16	5	14.8	.415	16.00	15.40
3 1/2 x 12	18	22	1 1/2	7/16	5	15.6	.498	17.00	16.40
3 1/2 x 14	20	24	1 1/2	7/16	5	16.4	.581	18.00	17.40
4 x 6	12	16	2	7/16	6	21.4	.326	18.15	17.20
4 x 8	14	18	2	7/16	6	22.3	.435	19.40	18.45
4 x 10	16	20	2	7/16	6	23.2	.544	20.65	19.70
4 x 12	18	22	2	7/16	6	24.0	.652	21.90	20.95
4 x 14	20	24	2	7/16	6	24.9	.762	23.15	22.20



Number A-20-L



Number A-20

Can furnish 4 1/2", 5", 6" and 8" sizes—price and delivery on application.  
Repair parts listed on page 88.



# CLAYTON MARK & COMPANY

EVANSTON, ILL. U.S.A.



## Octagon Ash Wood Pump Rods



For All-Depth Wells

### Number 927 Type

Made of first quality ash wood with square ends and furnished in random lengths 12 feet to 22 feet; exact lengths made to order at special prices. Couplings (No. 908 pattern) are steel painted black, or galvanized, after fabrication; box and pin parts are of solid hexagon steel with wrench-grip section; box is recessed to permit butt joint; threads cut sharp and true are same size as, and interchangeable with, oil well couplings.

Order by Trade Number, Stating Size, Whether Blank, with Black Couplings, or with Galvanized Couplings.

#### PRICE LIST

Wood Rod Size Inches	Box and Pin		Number Rivet Holes Per Blade	Used in Pipe Size Inches	Approximate Weight Per 100 Feet, Pounds		Price Per 100 Feet		
	Size Inches	Threads Per Inch			Blank	With Couplings	Not Tapered Blank	With Black Couplings	With Galvanized Couplings
1 1/8	5/8	12	4	2	35	45	\$10.60	\$17.75	\$19.65
1 3/8	7/8	10	6	2 1/2	45	75	15.35	25.40	28.20
1 5/8	7/8	10	6	3	70	100	18.90	29.55	32.85

List Prices for This Type Coupling on Page 63.

## Octagon Ash Wood Pump Rods

For Medium Depth and Shallow Wells



### Number 935 Type

Made of first quality ash wood and furnished in random lengths 12 feet to 16 feet. Couplings (No. 437 pattern) are steel black, or galvanized after fabrication. Threads are standard pipe size, cut sharp and true for straight joint.

Order by Trade Number, Stating Size, Whether with Black or Galvanized Couplings.

#### PRICE LIST

Wood Rod Size Inches	Threads Pipe Size Inches	Number Rivet Holes Per Blade	Used in Pipe Size Inches	Approx. Weight Per 100 Feet Pounds	Price Per 100 Feet	
					With Black Couplings	With Galv. Couplings
1 1/8	3/8	2	2	42	\$16.28	\$17.20
1 1/8	3/8	3	2	45	17.20	18.10
1 3/8	1/2	3	2 1/2	70	22.70	26.00

List Prices for This Type Coupling on Page 62.

## Octagon Ash Wood Pump Rods



For All-Depth Wells

Made of first quality ash wood with tapered ends and furnished in random lengths of from 14 feet to 22 feet. Couplings (No. 408 pattern) are forged steel and furnished black, or galvanized after fabrication.

Order by Trade Number, Stating Size, Whether Blank, with Black Couplings, or with Galvanized Couplings.

#### PRICE LIST

Wood Rod Size Inches	Box and Pin		Number Rivet Holes Per Blade	Used in Pipe Size Inches	Approximate Weight Per 100 Feet, Pounds		Price Per 100 Feet		
	Size Inches	Threads Per Inch			Blank	With Couplings	Tapered Blank	With Black Couplings	With Galvanized Couplings
1 1/8	5/8	12	4	2	35	45	\$10.60	\$18.80	\$20.90
1 3/8	7/8	10	6	2 1/2	45	75	15.35	27.00	30.00
1 5/8	7/8	10	6	3	70	100	18.90	31.40	34.90
1 7/8	1	10	6	3 1/2	100	150	24.75	42.65	47.45
2 1/4	1 1/8	8	6	4 to 5	125	200	55.45	87.90	97.68
2 1/2	1 1/8	8	6	6	165	240	66.00	100.45	111.60
3 1/2	1 1/2	8	7	8 to 10	325	450	112.15	188.35	209.30

List Prices for This Type Coupling on Page 63.



# CLAYTON MARK & COMPANY

EVANSTON, ILL. U.S.A.



## Airtite Steel Pump Rod Galvanized



Suitable for Single and Double Acting Cylinder Service in All-Depth Wells.

Much stronger and more durable in any service than corresponding size wood sucker rod; can be installed with tools same as used with wood sucker rod.

Made of standard steel pipe with couplings welded to pipe, making each section a sealed air chamber.

Couplings are solid steel with square shoulders; box is recessed to permit butt joints; threads cut sharp, true, and treated to prevent corrosion, are same size as, and may be used with, wood sucker rod or oil well couplings.

Airtite steel pump rod in ten feet lengths with No. 660 guide couplings (see page 69) will not swerve or whip on down-stroke and is the best for double acting cylinder operation.

Order by Trade Number, Stating Length.

### PRICE LIST

Trade Number	Pipe Size Inches	Corresponding Wood Rod Size Inches	Box and Pin		Approximate Weight Random per 100 Feet Pounds	Price Per 100 Feet			
			Size Inches	Threads Per Inch		5-Foot Lengths	10-Foot Lengths	15-Foot Lengths	Random 15 to 20 ft. Lgths.
1	3/8	1 1/8	5/8	12	60	\$ 29.00	\$ 22.00	\$ 20.00	\$18.00
2 1/2	3/4	1 1/8	5/8	12	122	42.50	32.50	28.00	26.00
2	3/4	1 3/8 or 1 1/8	7/8	10	122	42.50	32.50	28.00	26.00
3	1	1 3/8	1	10	180	61.00	47.00	44.00	40.00
4	1 1/4	2 1/4	1 1/8	8	250	82.00	66.00	62.00	56.00
5	2	3 or 3 1/2	1 1/2	8	420	137.00	112.00	102.00	90.00

## Polished Galvanized Steel Pump Rods

Plain Ends, Threaded, and Threaded and Coupled

Rod has heavy galvanized coating, smooth outside surface and is rigid and easy to thread.

All rods are uniformly straight and cut to exact lengths.

Stocked in sizes—

3/8" and 7/16" in 18', 20' and 22' lengths.

1/2" in 18' or 20' lengths.

5/8" in 20' lengths only.

All Rod Bundled, as follows:

Size Inches	No. of Pieces	Length	Approx. Weight per Bundle Pounds
3/8	15	18 ft.	105
3/8	14	20 ft.	108
7/16	11	18 ft.	106
7/16	10	20 ft.	106
1/2	9	18 ft.	111
1/2	8	20 ft.	109
5/8	5	20 ft.	105

For prices on Pump Rod—see Special Sheet.

## Pipe Drift

Number 621

Made of solid steel bar, tempered, with sharp cutting edge.

Thread is standard pipe size.

Used for drifting pipe for tubular wells.

Order by Trade Number, Stating Pipe Size.

### PRICE LIST

For Pipe Size Inches	Threaded Pipe Size Inches	Approx. Weight Each Pounds	Price Each
2	1	2 1/4	\$ 8.00
2 1/2	1 1/4	4 1/4	11.20
3	1 1/2	7 1/2	16.00



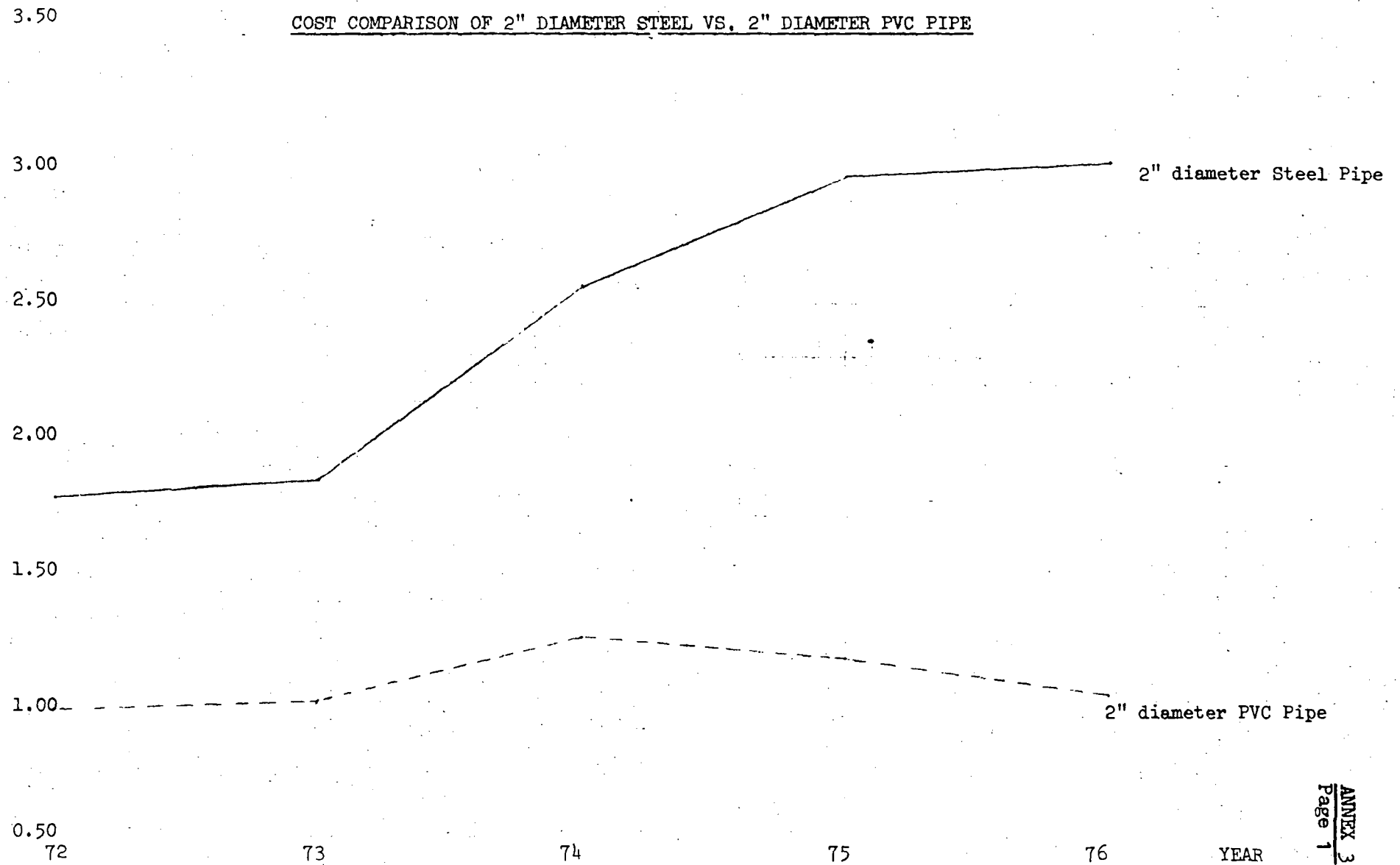
Number 621



\$/meter

PVC-STEEL COSTS

COST COMPARISON OF 2" DIAMETER STEEL VS. 2" DIAMETER PVC PIPE



Source: U.S. Bureau of Labor Statistics.

QUANTITY OF PIPE OBTAINABLE FROM VARIOUS MATERIALS

Material	Unit (Mtons)	Length of Pipe (meters)				
		1 1/2" dia.	2" dia.	3" dia.	4" dia.	6" dia.
Steel	1	246	183	88	62	35
PVC	1	2,667	1,869	1,111	784	421
ABS	1	3,448	2,439	1,439	1,020	546

April 1976 pipe prices: Steel \$545/ton; PVC \$957/ton, ABS \$1,144/ton

Nominal Diameter		Cost/meter		
(in)	(mm)	*PVC	*ABS	**Steel
1 1/4	35	0.72	0.67	1.90
1 1/2	40	0.86	0.72	2.25
2	50	1.24	1.12	3.04
3	80	2.08	1.90	5.98
4	100	2.94	2.68	8.83
6	150	5.47	5.00	15.57

\* Based on April 1976 production and raw material costs plus a profit margin of 20% to approximate an F.O.B. price.

\*\* Quote from Bethlehem Steel Corporation, F.O.B., Baltimore, April 1976.

Relative Merits of Acrylonitrile Butadiene Styrene (ABS) vs. Polyvinyl Chloride (PVC) in Tubewell Construction

Discussions with Borg-Warner, a manufacturer of ABS indicate that the two thermoplastics are very similar in physical properties and equally chemically inert in the ground. ABS has been used for years as drain pipe. Specifications for ABS well casing are being prepared now for approval by ASTM in July 1976. The manufacturer expects that ABS will compete successfully with PVC in groundwater applications because of its slight advantages:

- volumetrically less expensive;
- extrusion is somewhat simpler; less build upon dies;
- higher distortion temperature (180°F vs. 170°F);
- may be solvent welded;
- resists abrasion at least as well as PVC.

The most prominent difference between ABS and PVC is that ABS has only half the internal pressure rating as PVC.

RATE OF WEAR OF PVC PUMP CYLINDERS

(Conducted by Prussag, Kunststoffe u. Armaturen, Hannover, Germany)

Lengths of (3"  $\phi$ ) sized PVC pipe are being tested for application as the working barrel of piston pump. The object of the test is to measure the wear (loss of material from the walls) of the pipe. Two test benches were built each with sixteen cylinders mounted as individual units with a gate valve and a manometer.

The system is driven through a transmission (at 30 cycles/minute) which alternatively lifts and depresses two transverse bars to which the piston push rods are connected.

Each piston consists of four PVC plastic discs with four 16 mm diameter holes at 90° around a center hole (occupied by the 40 cm long push rod); the holes are covered by a 2 mm thick flapper of nylon reinforced neoprene. Two leather cups make a seal against the cylinder walls.

The 30 cm long PVC cylinders were cut from randomly selected production pipe. The wall thickness was measured at selected points in the middle of the cylinders and each point was marked. The cylinders were installed in the test benches, the water tanks were placed under them and filled with water.

When the piston ascends water is lifted from the tank and pushed through the discharge pipe in which the gate valve is located. The gate valve is adjusted to provide an impedance to the egress of the water, thereby creating a pressure which is measured by the manometer. The water is then recirculated in the tank.



The water tanks are open topped, allowing atmospheric dust and foreign matter to enter the water. Periodically water is added to the tanks to compensate for evaporation.

The test benches simulate pressure heads ranging from 0.5 to 2.0 atmospheres (pumping depths of 15 to 200 feet).

The PVC cylinders were removed after 340,000 cycles and measured for wear at the marked positions. A maximum decrease in wall thickness of 0.10 mm was recorded. Pumping pressure was observed to remain constant.

After 500,000 cycles the cylinders were again measured for wear. A maximum decrease in wall thickness 0.15 mm was observed also with an unchanged pressure reading. The experiment continues.

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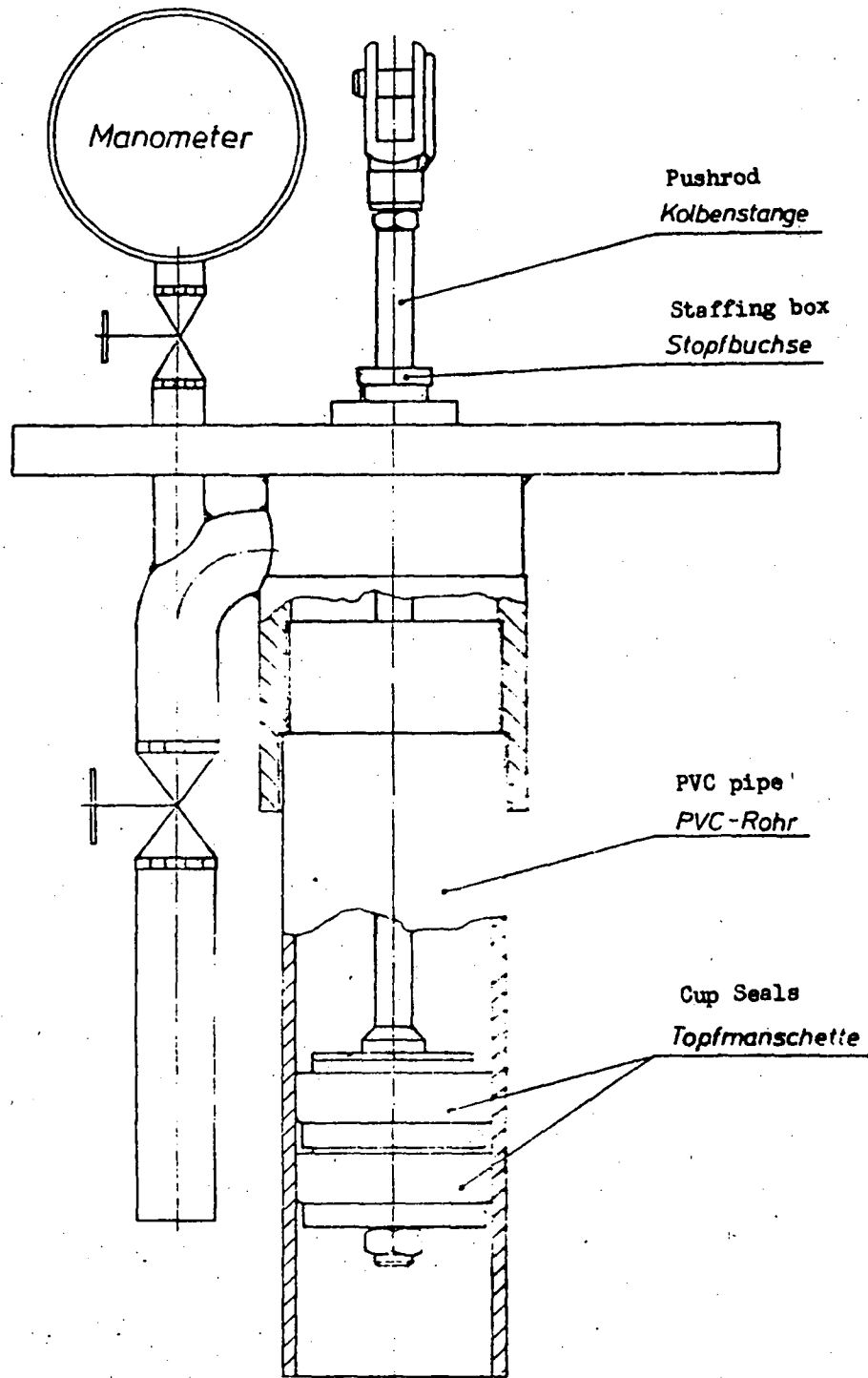
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The water tanks are open topped, allowing atmospheric dust and foreign matter to enter the water. Periodically water is added to the tanks to compensate for evaporation.

The test benches simulate pressure heads ranging from 0.5 to 2.0 atmospheres (pumping depths of 15 to 200 feet).

The PVC cylinders were removed after 340,000 cycles and measured for wear at the marked positions. A maximum decrease in wall thickness of 0.10 mm was recorded. Pumping pressure was observed to remain constant.

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Test Stand for Rate-of-Wear Experiment

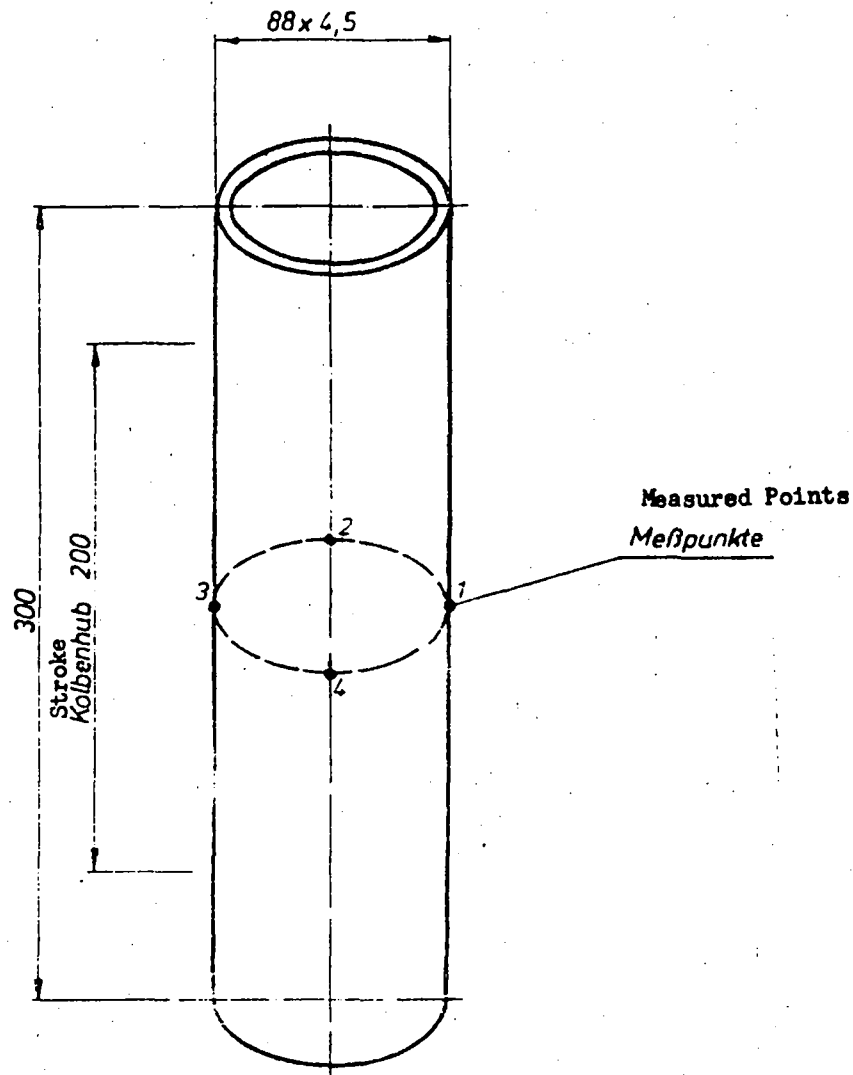
Prüfstand für Verschleißprüfung

gez.: 10. 2.76 *Klass*



**PREUSSAG AG**  
Kunststoffe u. Armaturen  
Werk Siederdorf





Location of the Measured Points along the Walls of 3" diameter for Pipe

Anordnung der Meßpunkte für Rohr  $\Phi 88 \times 4,5 / 300$  mm lg.

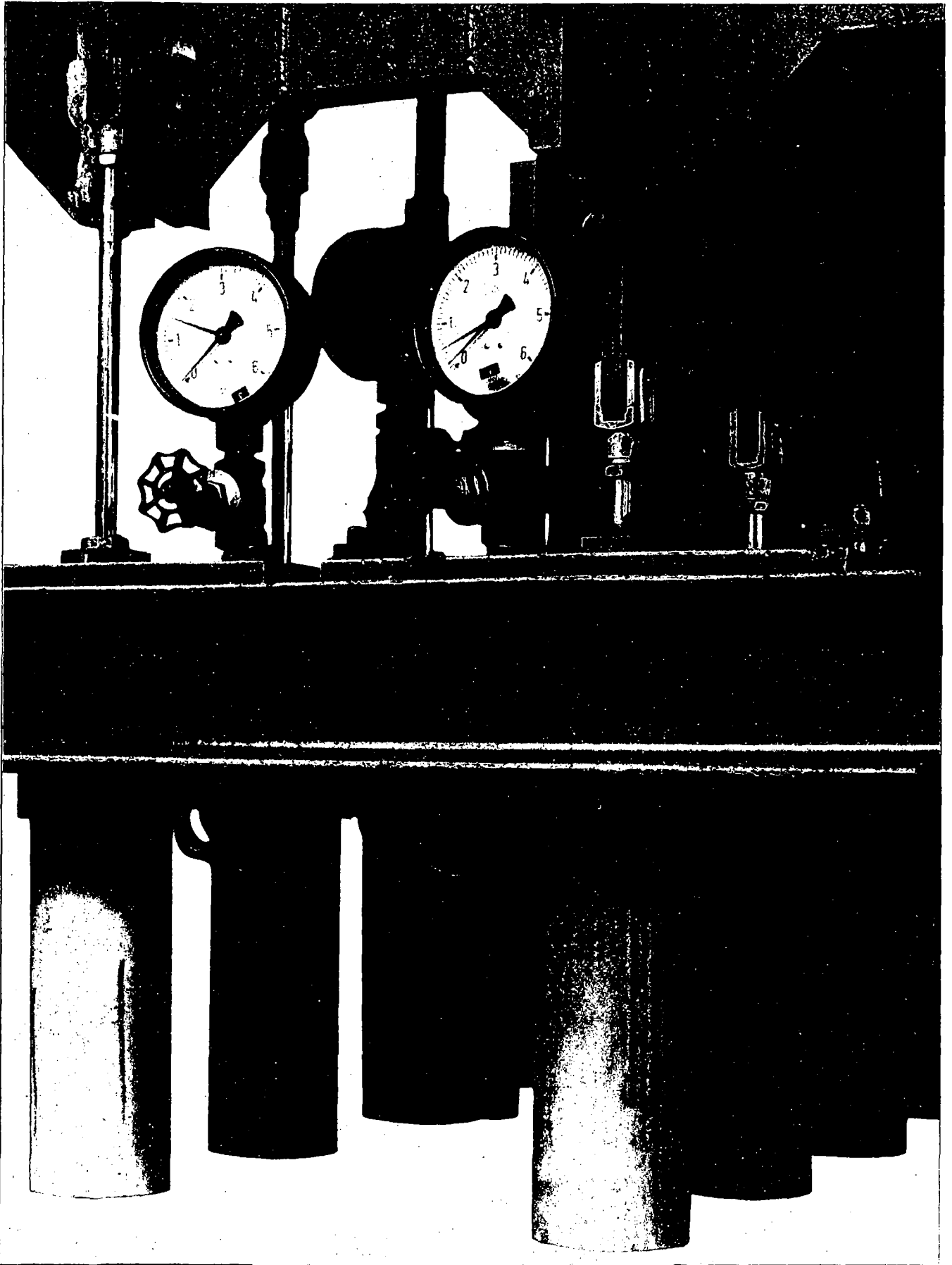
Anlage zum Prüfbericht vom 11.2.76

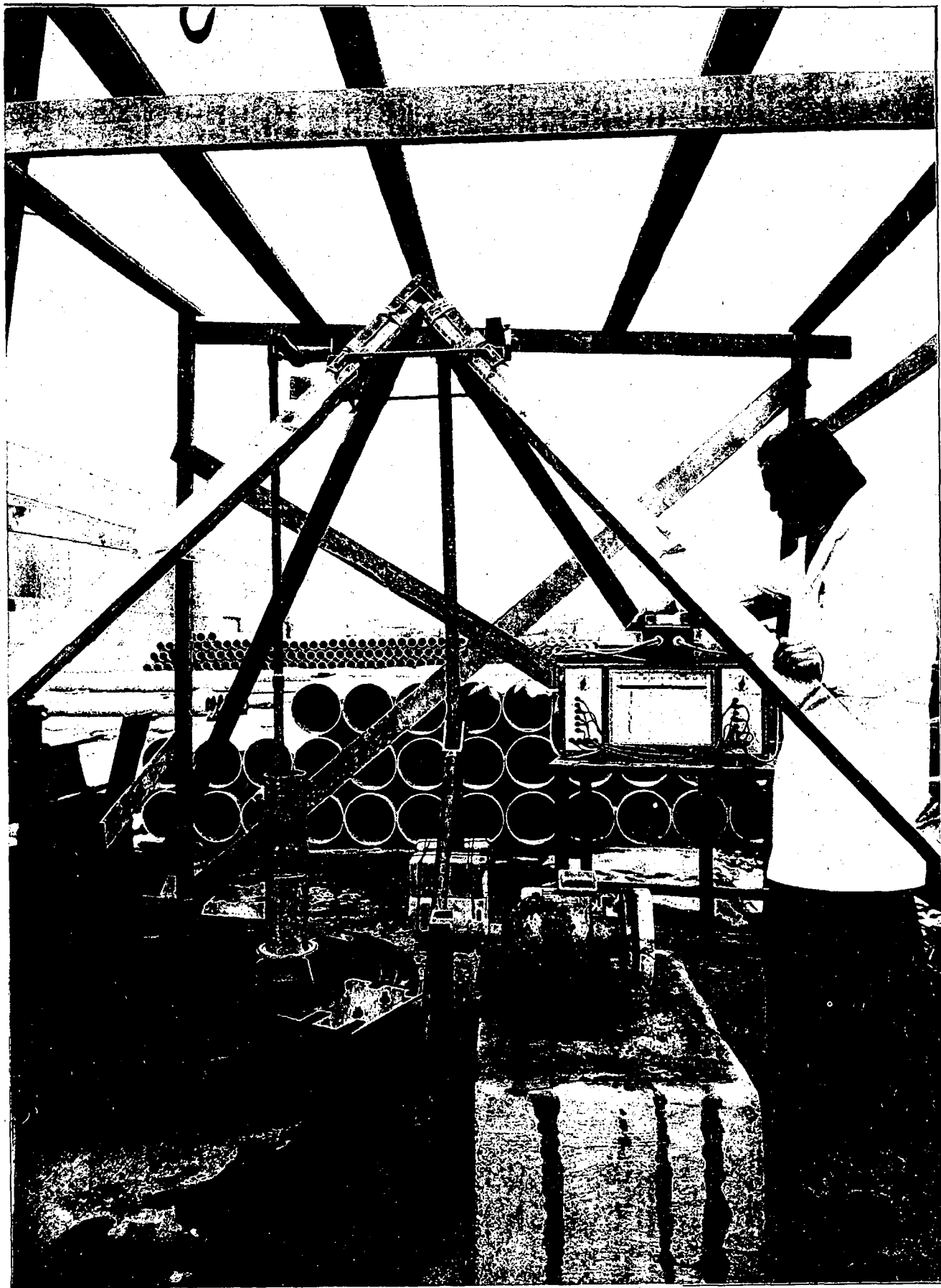
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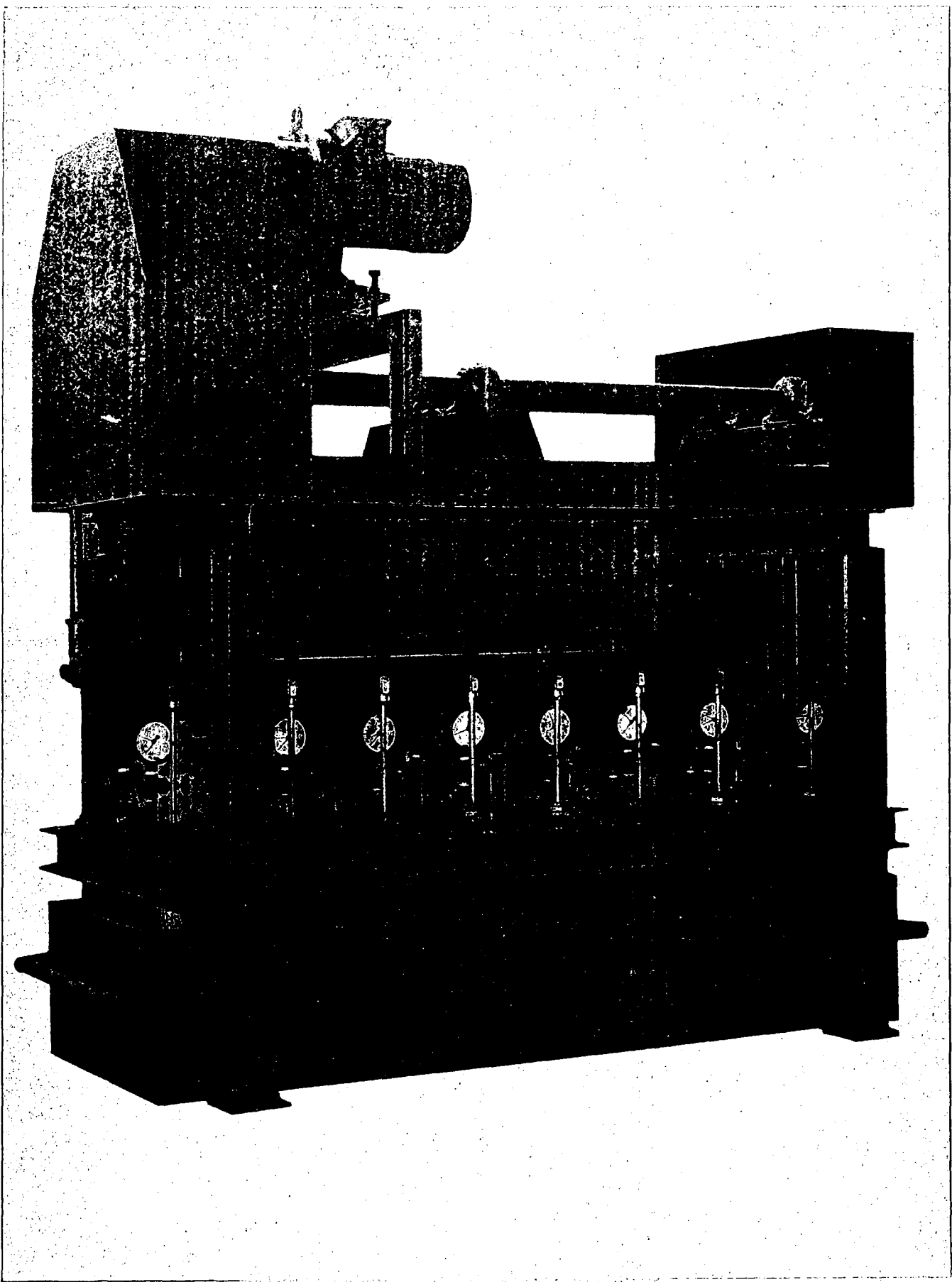


**PREUSSAG AG**  
Kunststoffe u. Armaturen  
Werk Stederdorf











# Oil Soaked Bearings: How to Make Them

Compiled by John Collett, ITDG Project Officer, National College of Agricultural Engineering, Silsoe, Beds. from designs by H. Pearson

The purpose of this article is to provide some background information for both constructors and designers who wish to use wood bearings. The type of wood to use, its treatment, lubrication and expected performance are included.

## Advantages

Some of the advantages of oil-soaked wood bearings are obvious. They can be made from available materials by local craftsmen with woodworking skills. They are easily assembled, do not require lubrication or maintenance, and operate under dirty conditions. They can be quickly repaired or replaced and provide a temporary means of repairing a more sophisticated production bearing. They also require low tolerance on both the shafts and the housings.

One of the essential characteristics to look for in the choice of wood is hardness. Because the harder the bearing surface, the less the deformation and the smaller the coefficient of friction and the lower the rate of wear. It is also unlikely to break down prematurely, singe or ultimately burn. It is also worth noting that, generally, the harder the wood, the greater its weight and the more difficult it is to work

The oiliness of the wood is a particularly important consideration when the bearings are unlikely (or not intended) to receive lubrication during their service. Practical indicators that assist the identification of timbers which may have good self-lubricating properties are: they are easily polished, do not react with acids, are difficult to impregnate with preservatives and glue does not easily stick to them.

## Other considerations

High moisture content causes a reduction in hardness and results in greater wear. For most applications low moisture content is preferred and excess moisture must be removed to prevent subsequent shrinkage, especially if the bearing is to be used as a bush.

The hardest wood is to be found in the main trunk just below the first branch.

Grain direction should be considered, and if possible advantage taken of the close grain to provide hardness at the wearing surface.

The piece of timber selected for the bearing should be free from cracks. Some suitable timbers are listed below:

"Greasy" woods	Lignum vitae	(Guaiacum officinale)
	Tallowood	(Eucaliptus microcorys)
	Teak	(Tectona grandis)
	Blackbutt	(Eucaliptus pilularis)
Other woods	Poon	(Calophyllum tomentosum)
	Hornbeam	(Carpinus botulus)

Degame	(Calycophyllum carididissimum)
Boxwood	(Phyllostylon brasiliense)
Pear	(Pyrrus communis)
Oak	(Quercus robur)
Camphorwood	(Dryobalanops aromatica)

If the timber is not of the self-lubricating variety (or of doubtful self-lubricating characteristics) it can be soaked in oil to minimize the need for subsequent lubrication. It is important to have dry wood to assist maximum absorption of oil.

## Construction

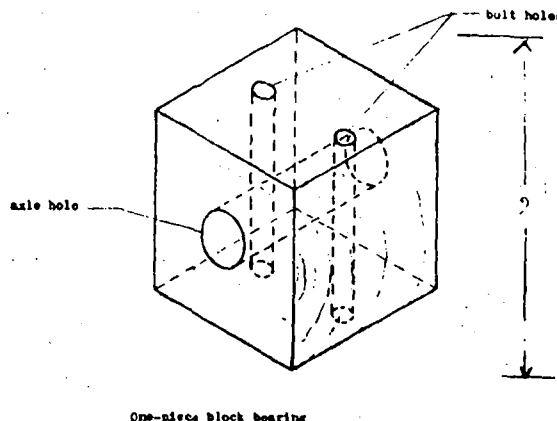
The following notes relate to experience gained in the "field" manufacture and testing of three types of wood bearing – the bush bearing, the split-block bearing and the one-piece block bearing. All are of the oil-soaked variety. H.S. Pearson has suggested that as a general rule-of-thumb guide to the size of timber needed for the bearing, the axial length of the bearing should be at least twice the shaft diameter. For example, for a 25mm diameter axle, the bearing should be at least 50mm long.

In the case of the block bearings, the thickness of bearing material at any point should not be less than the shaft diameter.

The drilling of radial holes for lubrication purposes is only recommended by Pearson for the bush type of bearing. He found that if lubricated holes were drilled in block bearings not only were the bearings weakened but also the holes acted as dirt traps.

Whenever possible the bearings should be located in a position where falling dirt will not directly enter the bearing. For example, if the axle is carried in bearings mounted under the floor of a cart instead of a fixed axle with bearings at the hub of the wheel, then dirt falling from the rim of the wheel will not fall directly onto the bearing.

If the bearing is expected to take side-thrust, large flat washers must be used, the one at the end of the bearing being free to rotate on the shaft.



The bearing surface of the shaft should be perfectly round and smooth and polished in appearance.

### How to make the bearings

Available timber often has rather doubtful self-lubricating properties and high moisture content. In this instance, a simple procedure for making an oil-soaked bush bearing has been devised by the Industrial Development Centre, Zaria, Nigeria. Excess water is removed and subsequent shrinkage prevented.

First, reduce the timber to a square cross section and bore a hole through the centre the same diameter as the journal on which the bearing will be working.

Place the blocks into a metal container of commercial groundnut oil and keep them submerged by placing a brick on top. Raise the temperature of the oil until the water in the wood is turned into steam — this will give the oil the appearance of boiling vigorously. Maintain the temperature until only single streams of small pin-size bubbles are rising to the surface of the oil. This may take anything from 30 minutes to 2 hours depending on the moisture content of the wood.

Remove the heat source and leave the blocks in oil to cool overnight if possible. During this stage the wood will absorb oil. *Be very careful if you need to handle the container whilst it is full of hot oil.* If the temperature of the oil is allowed to get too high after the bubbles have ceased to appear, the wood will change to charcoal and the bearings will be ruined.

Rebore the centre hole to compensate for any shrinkage that might have taken place.

Place on a mandrel or lathe and turn the outside diameter to the required measurement that will give the bush a press fit into the hub.

Bore four equally spaced holes through the wall of the bush at its mid-point and fill with lubricant — in general terms, the harder the lubricant the better, so animal fat, soap or tallow are preferable although grease is an excellent alternative. Finally press the bush into the hub.

The forty bush bearings made and tested at Zaria were 2½" long by 1.550" outside diameter with a 0.855" bore. They were pressed into 1½" seamless black iron Class C pipe, and turned on a ½" pipe journal. The wood used was mahogany (being the most readily available) and rig tests with a loading of 100 lbs and a speed of 100 - 200 rev/min indicated sufficient lubrication. These test conditions were chosen to simulate the working force on a 7" gauge wheel of an ox-drawn plough. Tests performed on bush bearings without the four radial lubrication holes again indicated sufficient lubrication.

On heavy equipment such as ox-carts or where it is not possible to push the axle through a bush-bearing, the split-block bearing provides a more practical solution.

It is simple to fit and replace, and if wear takes place the two halves can be changed around. After further wear, the life of the bearings can be extended by removing a small

amount of material from the matching faces.

A simple procedure was devised by the GRZ/ITDG project at the Magoye Regional Research Station in Zambia for the production of such a bearing, again using an oil soaking technique. The timber in this case was teak, and used engine oil provided a satisfactory alternative to groundnut oil.

Reduce the timber to a square cross-section and cut lengthwise into two halves.

The two halves of the bearing must be clamped firmly together for the drilling operation. It is most important that the hole for the axle is bored exactly square through the blocks. For the best results an electric powered pillar-drill should be used although a hand powered pillar-drill would be quite satisfactory. If neither of these is available, a jig would have to be made to keep the drill bit in line. After drilling, the two halves should be tied together to keep them in pairs.

For soaking in oil an old 20 litre (5 gal.) drum is needed. Fill it three-quarters full with used engine-oil and bring to the boil over an open fire. *Great care is needed when handling the drum of hot oil.* Lift the drum off the fire and carefully place the pairs of bearings into the hot oil. Put a brick on top of the last pair to stop them floating, and leave the drum and contents to cool slowly overnight.

The split-block bearings measured 150mm x 150mm x 75mm with a 38mm diameter bore. They were field tested for reliability by installing them on ox-carts fitted with iron or pneumatic wheels and carrying loads of up to 2 tons.

A radial clearance on one of these assemblies of about 1mm was found to be essential. If carefully run in at low speeds (ox draft) the clearance is increased to 1.5 - 2.0mm and the bearing surface attained a highly polished glass-like appearance. Having reached this condition it was found capable of withstanding journeys of a few kilometers at higher speeds (Land Rover towing).

A soft pine-wood oil-soaked bearing was tested as an alternative to the hardwood bearing, and this also gave satisfactory performance but might have a shorter life.

For lower load, lower speed applications such as the seed-drive mechanism on a small planter, a smaller one-piece oil-soaked block bearing was used measuring 50mm x 50mm x 50mm with a 16mm diameter bore, and this gave satisfactory results although tests were not extensive.

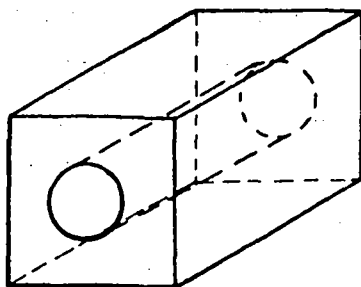
The possibility of boring the axle hole using hot irons was not investigated but there should be no serious objection to this alternative.

### Bibliography

*The characteristics of bearings when employed in slow running machinery.* D.A. Atkinson. University of Manchester Institute of Science (UMIST), 1972.

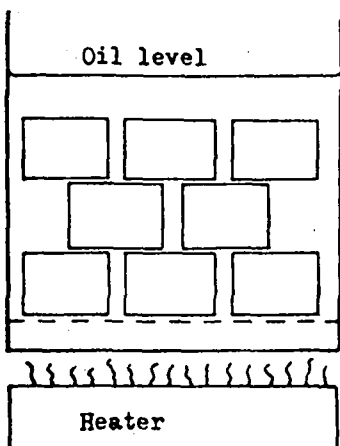
*Carts* Intermediate Technology Publications, 1975.

*The wood bearing: how to make it* Shambaugh, T.J., Pearson, H.S. & Jibril, Center, Zaria, Nigeria, Dec. 1969.



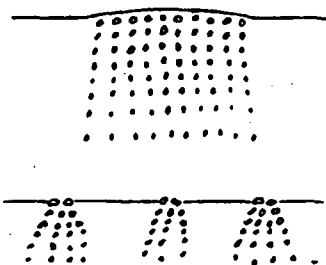
**INITIAL PREPARATION.**

Saw timber into shape of an oblong block somewhat larger than the O.D. of the finished bearing to allow for shrinkage and bore being off centre. Bore hole through centre of block the size of the journal.

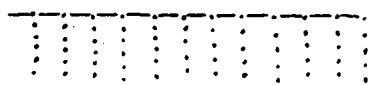


**DEHYDRATION**

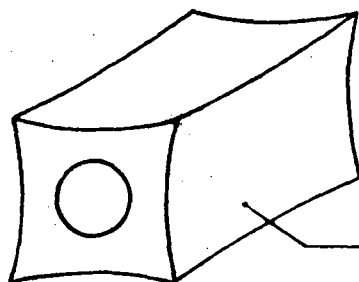
Soon after submerging the bearing blocks in hot groundnut oil, many surface bubbles 1" in diameter, made from a multitude of smaller bubbles, will appear on the surface.



As the moisture content of blocks is reduced, the surface bubbles will become smaller in size.

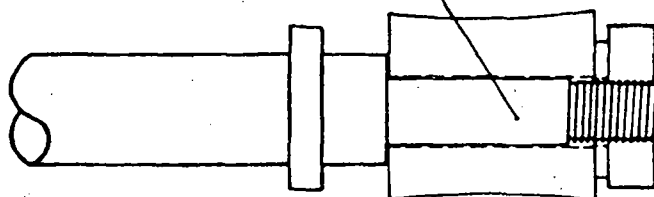


When the surface bubbles are formed from single streams of pin-size bubbles, the dehydration process has gone far enough. Stop heating, and let blocks cool in the oil overnight.



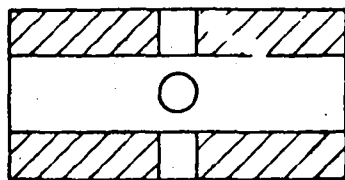
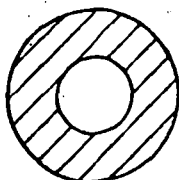
Shrunken block

Mandrel



**FINISHING**

Re-drill centre hole and place shrunken oil-soaked bearing block on mandrel and turn to the desired size.



Cross section of the finished oil-soaked wood bearing showing grease reservoir holes.

\* Oil soaked Wood Bearings: How to make them and how they perform, available from IT Publications price 25p net; £0.35 U.K. postpaid; £0.50 airmail and £0.35 surface mail.

SIMPLE PVC HANDPUMPS - TRIAL

Installations in Thailand

The following details were received from Mr. C.D. Spangler, who has recently retired from the IBRD's South Asia Water Supply Projects Division and was instrumental in introducing these pumps into Thailand.

"Cast iron has become increasingly expensive, and in the deep well pump the heavy cylinder suspended on a galvanized iron discharge pipe with the rod inside is difficult for the villager to remove and repair.

If a Governmental agency establishes mobile repair crews, as more wells are installed with handpumps the maintenance cost increases rapidly. For many years it will not be feasible or economic in most countries to put small piped systems in villages of less than 500 people. There is a great need for low-cost, dependable, easily-repaired handpump. Such a pump is now available using PVC pipe as the cylinder. This pump was described in a VITA publication and two prototypes shallow well suction pumps have been fabricated and tested by the Thailand Department of Agriculture. The test pump was shown on the cover of their monthly journal, with a report on its performance.

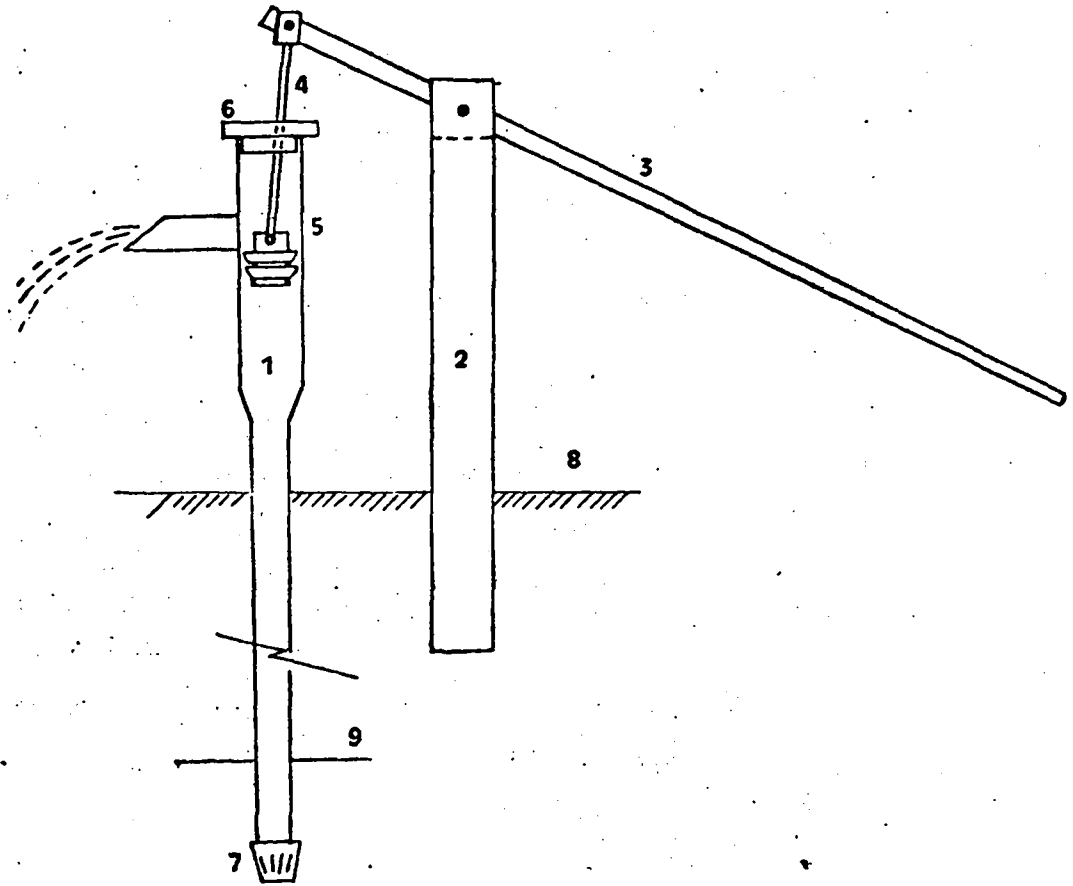
The cylinder was a section of 3" dia. PVC pipe above the platform with a 1 1/2" dia. suction pipe extending into the well. The pump rod was 3/8" dia. steel with a small yoke at the top to fit on both sides of the wooden handle. A standard piston with poppet valve was attached to the lower end of the rod. A foot valve was placed on the bottom of the 1 1/2" dia. suction pipe. The handle was supported by a 5" x 5" wood post set firmly into the ground. The handle was of hard wood 2" x 1 1/2" x 70" long. A round, flat cover of wood with a small slot to permit free movement of the

rod was used to close the top of the 3" dia. PVC pipe (see illustration). The pump had a maximum lift of 23 feet and the discharge was between 10 and 15 gallons a minute with an 8-10 inch stroke, depending upon the suction lift. The cost was about US\$20.00. However, the PVC foot valve alone was US\$5.00; using a simpler lower valve and making the pump in quantity, the cost could be reduced to about US\$15.00, compared to US\$100.00 - 150.00 for a cast iron pump.

The deep well version is based upon the use of PVC pipe as the well casing in small diameter driven, jetted or drilled wells. The PVC casing becomes the cylinder and the casing is extended above the platform to act as the channel for the water. The handle and support post is similar to the suction pump. If the casing is considered part of the cost of the well, the pump cost only includes the handle, support post, pump rod, piston and lower valve. The lower valve seat can be fixed in a length of PVC casing at the shop. The PVC pipe should be supported from the bottom as it is lowered into the well with a trip to release the support when the casing is in place. The deep well pump has not yet been field tested. The suction pump has been run 200-300 hours with only very slight wear on the leather "bucket". The handle should be of such a length that the end of the handle attached to the rod will, in sweeping a small arc, pass through the vertical position for the rod. This will minimize wear of the leather "bucket". A rubber bucket is used in Korea and should give a superior performance when used in a PVC pipe cylinder.

This dependable, low cost, easily repaired pump should make wide spread use of handpump wells feasible and economic."

It will be seen that the "deep well" pump is essentially the same as the one proposed in this report, whereas the "shallow well" pump is a suction pump. It would be interesting to compare performances of the two types in actual field trials.



### Installations in Bangladesh

The two experimental pumps described below were built in early 1974 in Bangladesh while this writer was a member of the UNICEF Water Section. Both pumps shared the following features:

- a) suction lift
- b) fulcrum pivot point supported independently of the pump body on a steel pipe post
- c) all-PVC poppet type check valve
- d) cylinder housing and outlet made of jute reinforced polyester resin.

The principal difference in the two (see photographs) was that pump No. 1 was anchored directly into the concrete slab while pump No. 2 had a conventional separable base.

### Results of testing

Pump No. 1 failed shortly after installation in an urban slum when the cast iron clevis, which was screwed onto a 1 $\frac{1}{2}$ " steel pipe post, sheared off as a result of fatiguing the steel pipe threads (notch effect). The failure may not be attributed to the plastic, however.

Pump No. 2 was installed in April 1974 and corrected the oversight in supporting the fulcrum point by employing an interference fit of the clevis on the post. As of 20 May 1976 the pump is still in daily use by about 40 families in Aliganj (a village near Dacca) at the CARE workshop. Three leather cups were worn out during the two year period. The cylinder was moderately scored, presumably by the metal follower plate of the piston as the cup became too thin to fend the plate off the walls. These gouges, however, did not appreciably affect the hydraulic seal. The PVC poppet valve was observed to still hold a seal overnight and did not show noticeable wear. The fiber reinforced plastic pump housing, while dirty did not show damage of any sort. The steel pins in the cast iron journals showed typical wear (both on the cast iron parts and the pins) and needed replacement. Most significant, however, was the fact that little wear was noticeable on the PVC pumping cylinder (estimated by the writer to be 1-2 mm increase in diameter).



Plastic Body Pump No. 1



Pump No. 1 Installed



All PVC Poppet Valve





Plastic Body Pump No. 2



3"Ø PVC Cylinder after two years



All PVC Poppet Valve

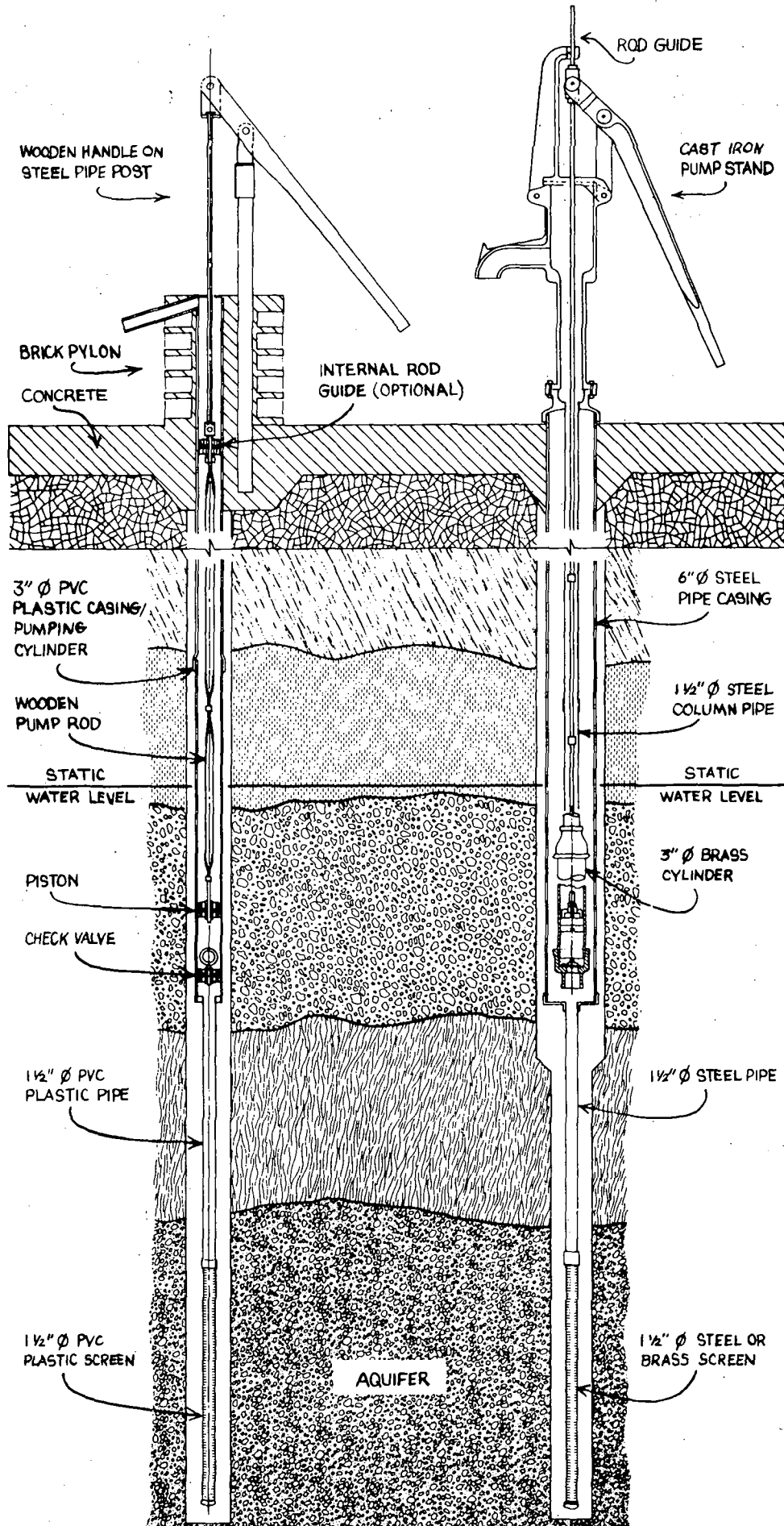
Table 1

Cost Comparison between Handpump Tubewells of Traditional Design and Those Using PVC Extensively

----- TUBEWELL A -----					----- TUBEWELL B -----					----- TUBEWELL C -----				
Steel pipe, cast iron pump stand, brass cylinder					PVC pipe, cast iron pump stand, brass cylinder					PVC pipe, local materials pump stand, PVC cylinder				
Item	Unit	No.	Cost/Unit	Sum	Item	Unit	No.	Cost/Unit	Sum	Item	Unit	No.	Cost/Unit	Sum
4" $\phi$ G.I. pipe	m	15	8.83	132	4" $\phi$ PVC pipe	m	15	2.94	44	3" $\phi$ PVC pipe	m	15	2.08	31
4" x 1 1/2" G.I. reducer	-	1	6.00	6	4" x 1 1/2" PVC reducer	-	1	4.00	4	3" x 1 1/2" PVC reducer	-	1	4.00	4
1 1/2" $\phi$ G.I. pipe	m	30	2.25	68	1 1/2" $\phi$ PVC pipe	m	30	0.86	26	1 1/2" $\phi$ PVC pipe	m	30	0.86	26
1 1/2" $\phi$ Stainless Steel well screen	m	3	49.29	148	1 1/2" $\phi$ PVC well screen	m	3	13.43	40	1 1/2" $\phi$ PVC well screen	m	3	13.43	40
			<u>Sub-Total:</u>	354				<u>Sub-Total:</u>	114				<u>Sub-Total:</u>	101
Cast iron pump stand	-	1	90.00 <sup>1/</sup>	90	Cast iron pump stand	-	1	90.00 <sup>1/</sup>	90	Piston/check	-	2	4.00	8
3" $\phi$ brass cylinder and valves	-	1	116.10	116	3" $\phi$ brass cylinder and valves	-	1	116.10	116	Wooden handle	-	1	6.00	6
"Airtite" steel pump rods (3/8" $\phi$ )	m	15	5.60	84	"Airtite" steel pump rods (3/8" $\phi$ )	m	15	5.60	84	Wooden bearings	-	2	3.00	6
1 1/2" $\phi$ G.I. pipe	m	15	2.25	34	1 1/2" $\phi$ G.I. pipe	m	15	2.25	34	1 1/2" $\phi$ G.I. pipe shaft	m	0.4	2.25	1
			<u>Sub-Total:</u>	324				<u>Sub-Total:</u>	324	Bricks	-	50	0.02	1
Aggregate	cu. ft.	9	0.50	5	Aggregate	cu. ft.	9	0.50	5	Cement	100 lb.	1	2.00	2
Cement	100 lb. sack	2	2.00	4	Cement	100 lb. sack	2	2.00	4	Labor	man-day	1	5.00	5
Labor	man-day	2	5.00	10	Labor	man-day	2	5.00	10	"Airtite" 3/8" $\phi$ G.I. pump rods	m	15	5.60	84
			<u>Sub-Total:</u>	19				<u>Sub-Total:</u>	19				<u>Sub-Total:</u>	113
			<u>Total:</u>	697				<u>Total:</u>	457				<u>Total:</u>	233

<sup>1/</sup> UNICEF average purchase price for a Dempster deep well pump stand; other pump components priced from "Clayton Mark" catalogue, April 1976.

Figure 1



MULTIFUNCTION COMPONENTS

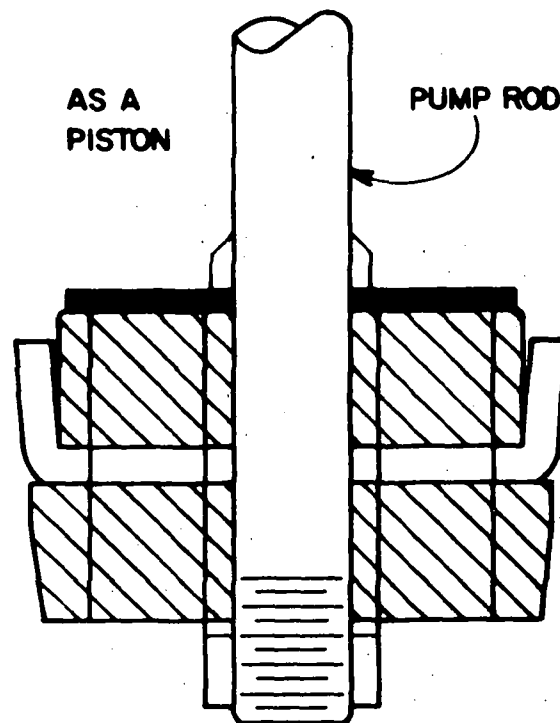
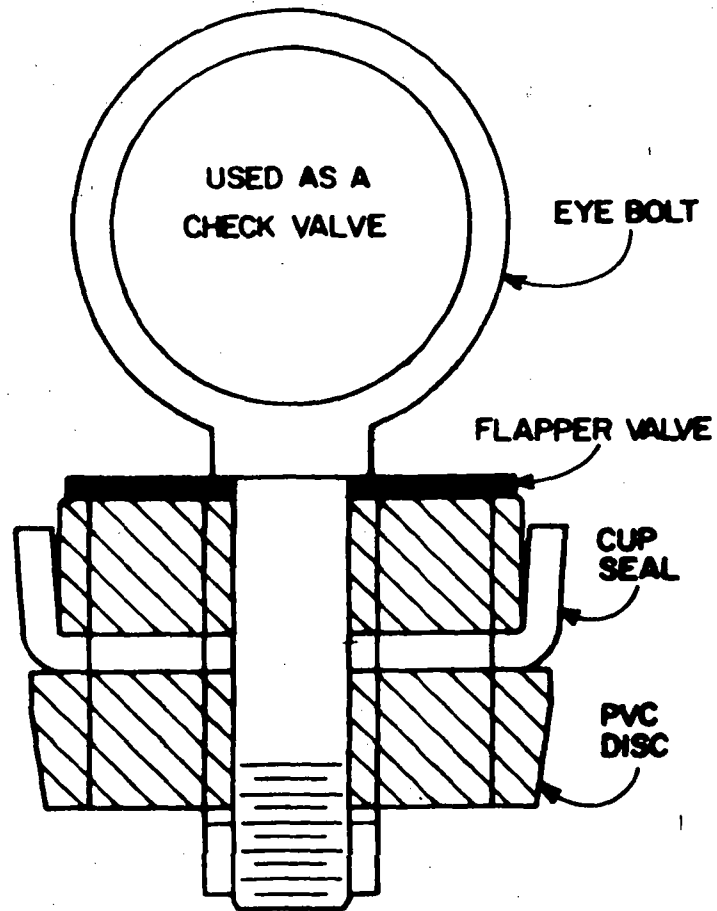


Figure 3

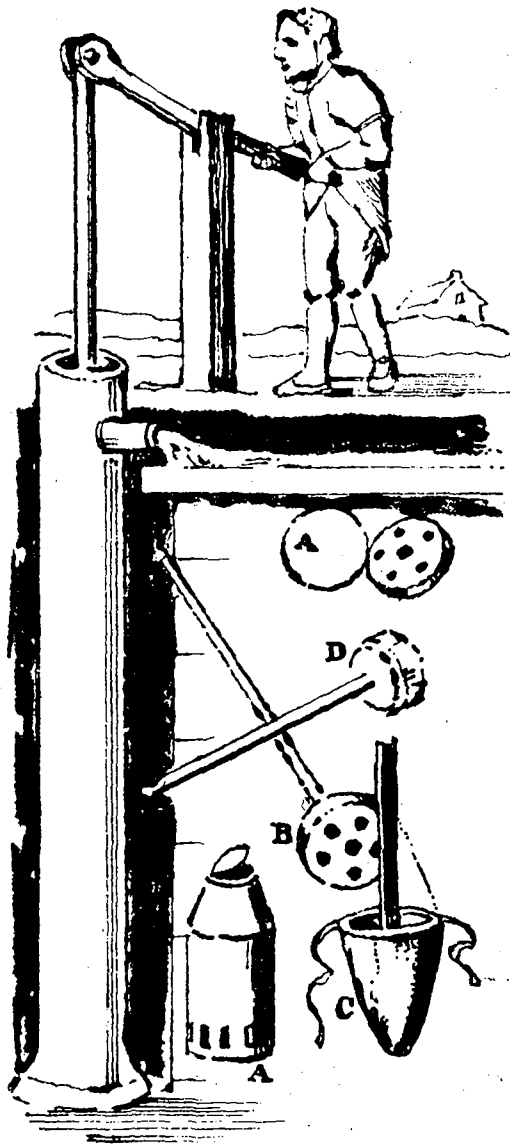


Figure 4

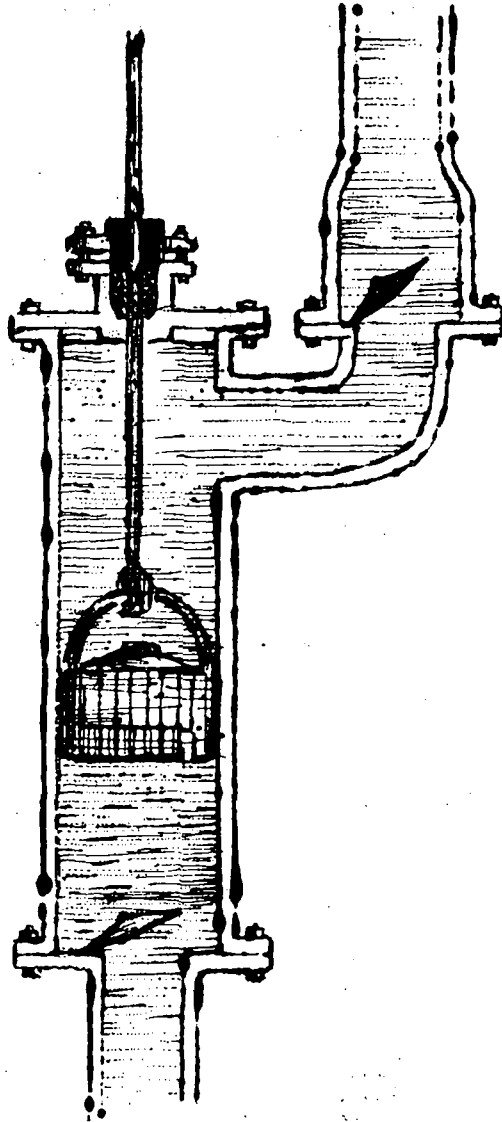


Figure 5

