100 - 120 lbs
45 - 60 kgs

RESEARCH REPORT

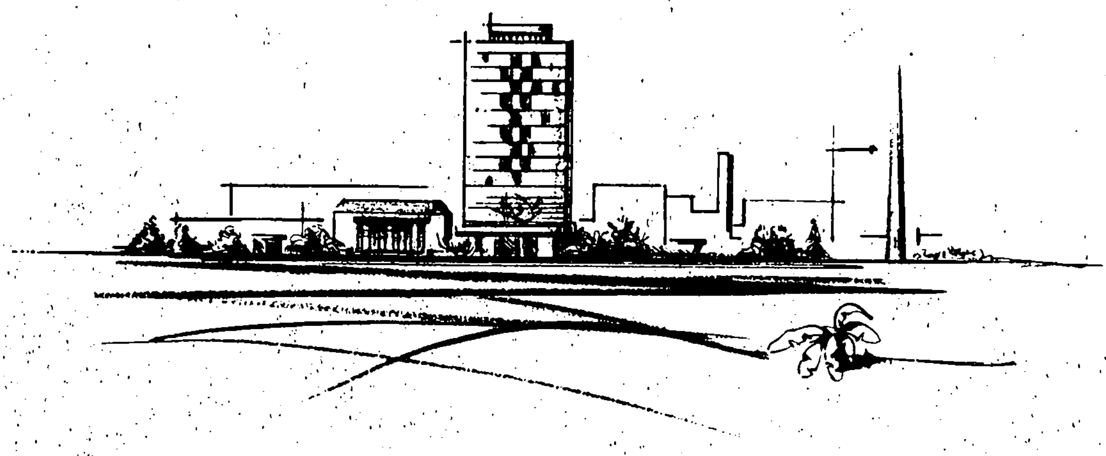
THE DEVELOPMENT OF A WATER PUMP FOR
UNDERDEVELOPED COUNTRIES

to

AGENCY FOR INTERNATIONAL DEVELOPMENT

Contract No. AID/csd-1434

September 29, 1967



BATTELLE MEMORIAL INSTITUTE

COLUMBUS LABORATORIES

FINAL REPORT

on

THE DEVELOPMENT OF A WATER PUMP FOR UNDERDEVELOPED COUNTRIES

to

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Contract No. AID/csd-1434

September 29, 1967

by

D. W. Frink and R. D. Fannon, Jr.

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ACKNOWLEDGMENTS

Grateful acknowledgment is given to the Agency for International Development and, in particular, to the Community Water Supply Section for the opportunity to participate in and contribute to such a worthwhile program.

Special acknowledgment and thanks are given to Mr. Arthur H. Holloway, Acting Chief of Community Water Supply Section, and to Dr. Charles D. Spangler, Water Supply Consultant for Pan American Health Organization, for their guidance, encouragement, and assistance during the program. Special thanks are also given to AID representatives Mr. Hugh Tolley in the Philippines, Mr. John Brandt in Thailand, Mr. James Cassanos in East Pakistan, Mr. Robert Harris in India, and Mr. George Bell in Jordan. Without their help much of the information obtained overseas would not have been possible. The Battelle staff considered working with them a privilege.

The contributions and support of the staff of Battelle-Columbus were also important to the success of this program. Appreciation is extended to Mr. Ronald Legue, Mr. Willard Slay, Mr. Lewis Nowacki, Mr. Robert Sharp, Mr. Donald Hackman, and Miss Dolores Landreman for their interest, assistance, and participation.

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D Ballance

Comments on Battle Pumps

Para 1.5. 1/8 US. Gal/cycle? 20' for shallow and 100' for deep wells.
See general comments.

Para 2.0. ASTM SPEC B146 - leaded yellow brass?

3.2.5. Oak tanned, second selection grade leather?
See general comments.

Deep Well

1. Point 22 - should have packing gland and nut, could also use a neoprene gland instead of conventional packing.
2. Spout with "hook" for hanging bucket is asking for trouble.
3. A wooden handle without elaborate linkage would be preferable, rod guide is unnecessary.
4. If suggestion 3 is adopted, I would suggest reduction of chamber in pump body.
5. It would be preferable to have a cylinder and drop pipe of 2" - 2 1/2" with 12" stroke so that maintenance is simplified to simply "gutting" the pump for repairs.
6. Foot valve or "lower check valve" assembly subject to easy wearing out. Suggest replacing with a foot valve assembly that can be removed without removing entire pump assembly.

Shallow Well Pump

Basically all previous comments apply with the added disadvantage of the necessity of priming.

General Comments

Where possible I would rather see some other material beside leather used in valves and cups.

The number of strokes needed to fill a 4 gallon tin at 1/8 Gal/cycle requires a great deal more patience than most villagers have plus fatigue effect on women and children who are the water carriers. Wherever possible cast metals should be discarded in favour of steel of GI piping.

CWS/EH
8.5.1969

LIST OF FIGURES
(Continued)

THE DEVELOPMENT OF A WATER PUMP FOR UNDERDEVELOPED COUNTRIES

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INTRODUCTION

This report describes the development of a hand-operated water pump suitable for both use and manufacture in developing countries. The program was organized in two phases: Phase I was a study to determine the requirements imposed upon hand-operated water pumps by various environments, to determine use patterns prevailing in less-developed countries, to identify the short-comings of standard pumps, and to develop detailed requirements for the design of a suitable pump. Case histories of pump failures and successes were obtained from both AID personnel and from Battelle personnel visiting the developing nations. A design study was directed toward evolving a new pump without the shortcomings of standard pumps and well suited for manufacture in developing countries.

Phase II included the design, construction, and evaluation of a production-model pump and formulation of a general plan for a typical small production facility based upon the design of the pump. The program was later modified to include specific critical tests to determine the functional characteristics of hand pumps currently manufactured and used not only in the developing nations but also in the United States.

Basic pump specifications were established at the beginning of the program and prevailed throughout the work. These specifications are:

(1) Low production cost

(2) Long life under severe conditions

(3) Easy to maintain with simple tools and unskilled labor

(4) Suitable for shallow- or deep-well installation with only minor changes (cylinder location)

(5) Capable of being manufactured in developing countries with a minimum of capital investment

(6) Easily operated by small people, including women and children

(7) Include design features which will discourage pilfering and vandalism.

A shallow-well pump is defined here as a pump in which the cylinder is attached to the pump body above the ground. A deep-well pump is defined as a pump in which the cylinder is separated from the pump body and submerged below the level of the water being pumped.

As a result of this program, a basic pump design was evolved. Figures 1 and 2 show two pumps constructed on this basic design. It is expected that these pumps will prove able to meet the original specifications and, in addition, to meet other requirements established during the program. Even though these pump have the specific configuration shown, manufacturers in developing countries should be encouraged to work out other configurations which are acceptable to them and their market but which incorporate the basic design principles outlined in this report. If this is done, the pump will be more readily acceptable to the local people.

Subtle aspects of consumer acceptance always vitally affect design success, and attention must be given to the potential acceptance problem when this pump design is introduced into the various developing countries. Appropriate educational programs must be devised.

Work following this program should include field evaluation of the pump and continued research to provide improved cups, valves, and cylinders.

Gratifying cooperation was received from AID personnel, from representatives of various other Government agencies, and from several United States manufacturers. A program to disseminate to them the information acquired during this program should be arranged.

A report of the trip made by Battelle personnel to selected developing nations can be found in Appendix A.

CONCLUSIONS

The following nine specific conclusions were drawn on the basis of the survey and the laboratory research conducted during this program:

(1) Battelle project team observations substantiate AID's conclusion that there is a serious need in the developing countries visited for hand water pumps, particularly in rural areas; if this need is comparable in other developing areas of the world of interest to AID, the challenge is tremendous and a major effort to alleviate the situation is indicated.

(2) The state of the art in foreign countries relative to pump design is minimal and technical improvement is required in almost every aspect, particularly in the areas of design and materials utilization.

(3) Imported pumps are quite often too expensive for a developing nation and generally do not meet local requirements.

(4) Better means for determining well sites and depths are needed.

(5) Maintenance programs are very poor:

- (a) Needed skills are not available
- (b) Responsibility for maintenance is not defined and maintenance records are not kept

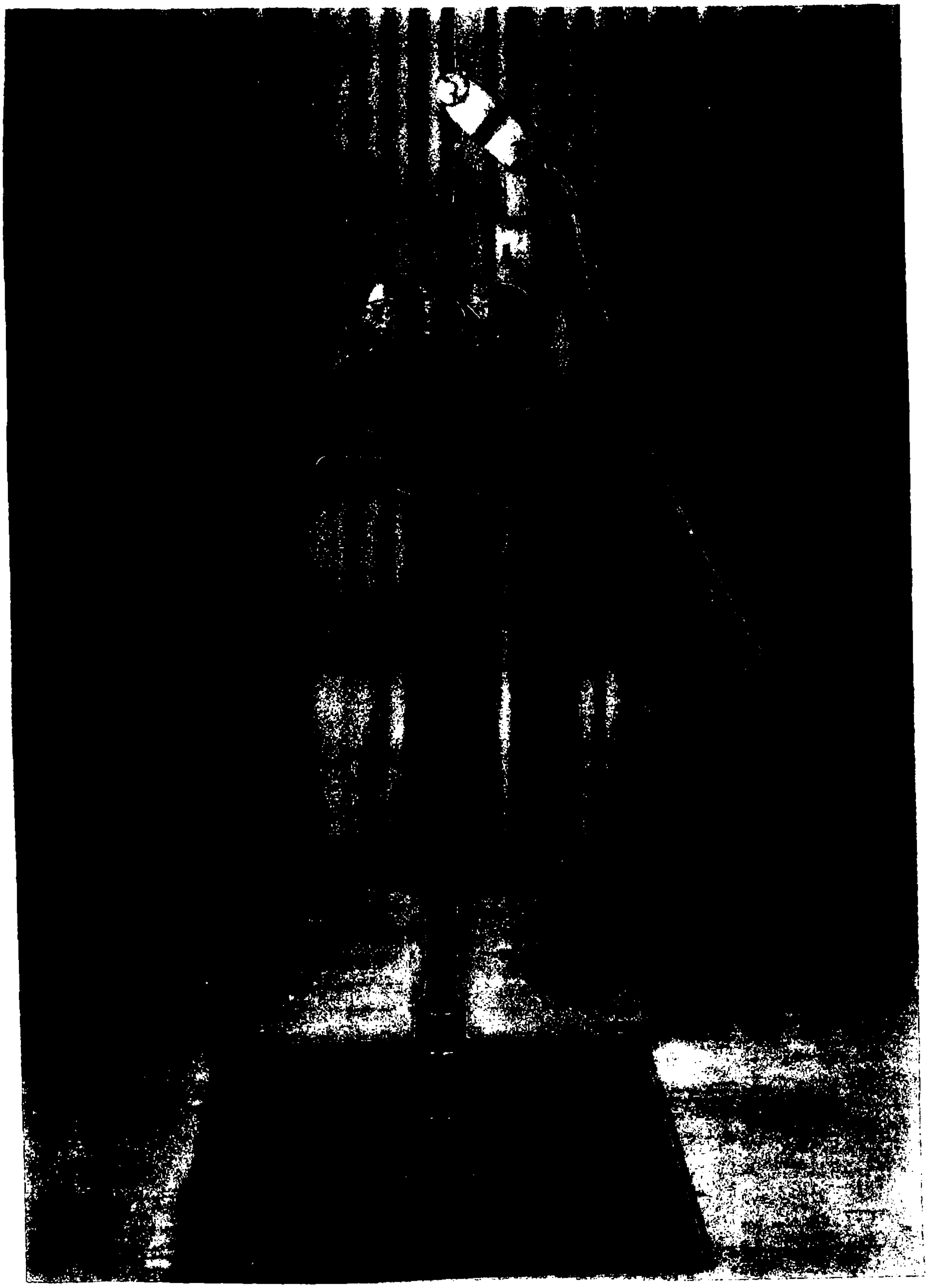

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FIGURE 1. SHALLOW-WELL VERSION OF AID PUMP

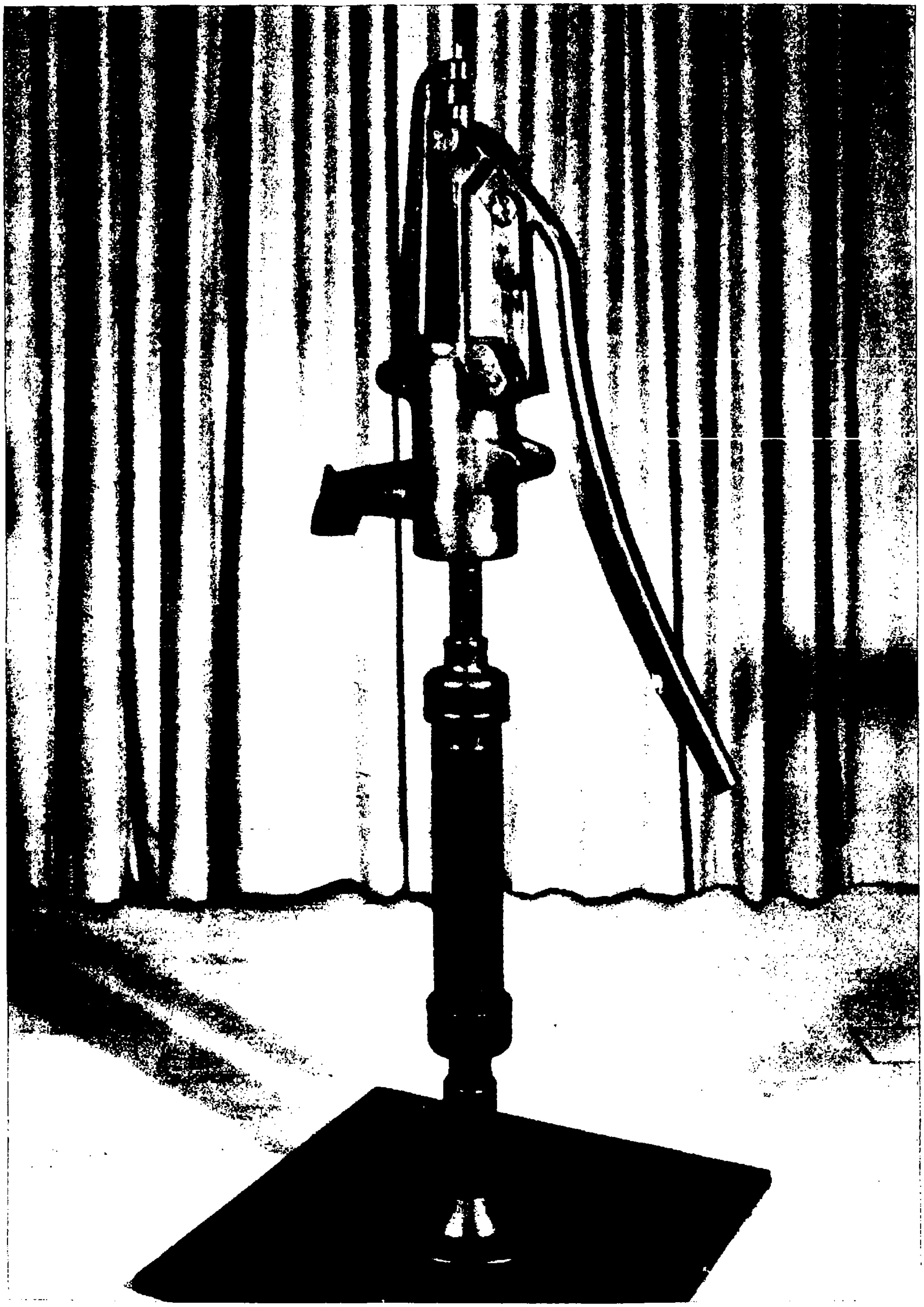

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FIGURE 2. DEEP-WELL VERSION OF AID PUMP

(c) Adequate inventories of good replacement parts are not readily accessible

(d) Cooperative, communal attitudes do not prevail in many villages that need pumps.

(6) The basic pump design devised during this program will meet the needs identified.

(7) Some additional work is advisable:

(a) Dissemination of information to interested agencies and organizations

(b) Field evaluation of proposed pump design

(c) Further research in cups, valves, and cylinders

(d) Development and implementation of educational programs

(8) The manner in which the proposed pump design is introduced will have extensive implications for the success of the pump and the field trials; the production and installation programs must take this into consideration to be successful.

(9) Adequate facilities and skills are available in most of the countries visited for local manufacture of pumps designed on the principles outlined in this report.

RECOMMENDATIONS

The following recommendations are based on the conclusions drawn as a result of the program.

(1) AID should arrange a meeting to provide a specific opportunity for AID and Battelle personnel to disseminate results of this program to all interested agencies and organizations.

(2) Field trials should be conducted with approximately 20 pumps of the proposed design in selected areas under technically controlled conditions to determine:

(a) Whether the present design will perform as anticipated under field conditions

(b) The effectiveness of guided pump rods and flapper valves at various well depths.

(3) Research should be continued relative to cup and valve improvement but leather cups should be used until a more suitable material is found. Additional work might also be done simultaneously in formulating cylinder coatings that may be more acceptable under various conditions.

(4) Specifically structured educational programs should be designed for introduction of the pump design to various countries.

(5) Possibilities for AID stimulation of metallurgical improvements should be explored.

(6) Possibilities for AID stimulation of improvement of production practices should be explored.

PROGRAM APPROACH

The program followed a natural sequence of events. First, the Battelle staff had a series of meetings with AID personnel and with interested personnel from other Government agencies. Much was learned from these meetings in that the conditions that exist in many of the developing nations were discussed and the most important things to be accomplished during the program were established.

Next, a literature search and a patent search were made to uncover as many facts as possible concerning modern, hand-pumping methods. Simultaneously, a state-of-the-art search was made. Then a Battelle team made a tour of five selected areas of the world which are representative of conditions that can be found in developing countries. It was on this tour that the project team began to truly understand the problems of developing nations as described by AID personnel. The team was strongly impressed by the needs of these countries in terms of time and money required for technological development to improve conditions of everyday living.

Following the tour of the selected nations, American manufacturers were asked to supply information regarding the technological development of pumps in the United States. An analysis made of all the data collected revealed that supplementary testing would be needed before a design program could be started. Results of the supplementary tests that were conducted can be found in a later section.

During the second phase of the program, basic principles were established and a simple and flexible design was developed and evaluated in the laboratory. In addition, consideration was given to facilities required to manufacture a limited number of such pumps. Finally, a number of areas were identified in which further work is required. The area of education falls outside the scope of Battelle's responsibility, but, nevertheless, the Battelle staff believes that if this program is to be successful, the pump design must be introduced properly and confidently in developing countries with a carefully planned educational program.

ANALYSIS OF UNITED STATES SURVEYS AND OBSERVATIONS

Both before and after the foreign surveys made by the project staff, much information was obtained from various sources in the United States. The following sections summarize what was learned.

Meetings with AID

Meetings with AID personnel were very effective in establishing the scope of the program and providing an insight into the problems facing the people of developing nations. Representative developing countries were selected for observation by the Battelle team and the philosophies and characteristics of these nations were discussed to provide a basis for an effective visit.

Literature Search

Unfortunately, it was found that there are no recent development in hand pumps described in the literature. Also, there is no information published on related subjects associated with developing nations.

Patent Survey

Again, little help was obtained from this survey. Most of the patents examined describe pumps of a more complex nature than could be used effectively in developing nations.

Manufacturer Contacts

Contacting United States manufacturers was one of the most important aspects of the program. It was through these manufacturers that the basis for American pump design was learned. Present hand-pump configurations are based on considerations of cost and on past "experience". However, plastic cylinders are being introduced and cushioned poppet valves are becoming more prevelant. Production techniques provide for use of good materials and interchangeable parts.

Pump guides are used extensively in conjunction with windmills, pump jacks, and force pumps. This provides a more rugged pump for the heavier job. Multiple-cup plunger use is based on the depth the cylinder is in the well, the number of cups being proportional to the head of water being pumped.

It was also learned that ball valves as used in the Philippines are not recommended by American manufacturers because of distortion of the valve seats caused by the pounding of the heavy ball checks. This more or less correlated with observation made in the Philippines.

ANALYSIS OF FOREIGN SURVEYS AND OBSERVATIONS

The foreign survey was without question the most important input to the program. The nations selected for visitation were: the Philippines, Thailand, East Pakistan, India, and Jordan. The visits were made not only to some of the major cities in each country, but also to many outlying rural areas. The major city visits were concerned with interviewing native persons responsible for community or rural water and inspecting pump manufacturing facilities. The visits to the rural areas were made to see the actual conditions under which pumps must operate. Observations recorded can be summarized as follows:

General Need for Pumps

Without question there is a tremendous need for hand pumps in developing nations. In many cases, 300 or more people get their water from one pump; in some areas they get it from a well without any pump. Many people are still required to get their water from rivers or ponds or pools of collected rain-fall. In one arid locality, 7000 people, and as many goats and burros, get their water from one pumpless well.

Well Drilling Problems

In many areas dry wells are a problem. There are few if any geologic or hydrologic reports available. There seem to be no programs planned by any agency or any group responsible for studying the area in which wells are required. There is little or no evidence of the logging of existing well histories. Cores are seldom taken during drilling to determine the best water-bearing formations.

Pump Design Problems

Pumps themselves are in great need of improvement and there is very little effort being made in any of the areas visited to bring about the needed improvements. In Thialand it was found, however, that various pumps from other countries are being tested. But, again, this is on a low key.

The major problem in most of the areas is the rapid wear of the leather cups used in the pumps. Very little effort is being made to improve the smoothness of the bore of the cylinders or the quality of the leather used in the cups. Another problem in some areas is that very poor nuts and bolts are used to fasten the pump components together. There has been no appropriate change in design and no effort to make better nuts and bolts. Actually, in some areas, selective fitting is required because the nuts will not fit over the bolts, or they fit so loosely that they slide up to the head. In order to make any assembly at all, it is often necessary to wrap jute around the threads so that some fastening can be accomplished with the nut and the bolt.

Storage Problems

Storage of pumps and pump components is also a major problem. Because of the high humidity that prevails in some areas, pump cylinders rust out and become ineffective when finally placed in location.

Maintenance Problems

Maintenance is very poor to nonexistent. No responsibilities are given to or defined for any group; consequently, once a pump is installed it is effective only as long as it works properly. On failure, the pump might be torn down and the people resort again to rope and buckets, to rivers and ponds, for their water.

There is a definite lack of skills. The people do not take it upon themselves to effect repair, but only wait until a mechanic can come. There is a definite lack of good parts and quite often if the parts are secured they are not capable of doing the job that is required because they are of poor quality, broken, or cannot be assembled.

In almost all the areas visited there are no performance records available; consequently, no one could discuss causes and effects with the Battelle team. There was one exception, however, in a single area. In Singur, India, good records have been kept and a excellent paper was written by one of the founders of the program. However, even in this case some of the data are subject to question.

Acceptability Problems

Acceptability is a problem - acceptability of the idea of using pumps for getting water, acceptability of the pump design from an aesthetics standpoint. This is a major problem, and the introduction of any design must be handled through a very definite education program. Options in terms of appearance will be required in each area for acceptance.

RESULTS OF TESTING PROGRAM

The analysis of the survey indicated that additional information obtained through testing was required before the design of a new pump could be started. For example, it was felt that the major causes of cup wear should be analyzed and the effectiveness of various valve types should be determined so that the best arrangements could be used in the design. A test program was set up to investigate cup wear and to evaluate various cylinder materials, cup materials, and types of valves in such a way that each of these variables could be assessed on its own merit. Consequently, four major studies were made:

(1) Determination of relative wear and effectiveness of leather cups associated with guided and unguided pump rods.

(2) Determination of relative wear and effectiveness of leather cups associated with single-cup or multiple-cup plungers.

(3) Determination of relative wear and effectiveness of leather cups associated with cylinder materials.

(4) Determination of relative wear and effectiveness of various types of valves.

Tests were conducted on modified, commercially available pumps rather than on completely redesigned laboratory pumps. These pumps included both shallow-well suction pumps and deep-well lift pumps. Four pumps were set up over a 12-foot-deep pool and operated 24 hours a day during the 6-month test program. The pumps were mechanically operated at about 50 strokes per minute by electrically driven pump jacks. Each of the pumps was fitted with an hour meter so that evaluations and comparisons could be made on the basis of time. Figure 3 shows the laboratory test facility over the 12-foot-deep pool. One deep-well and one shallow-well pump was equipped with a pump rod guide.

The four major studies consisted of eight basic tests. These tests utilized 40 plunger cups with an average of almost one million pumping cycles per cup. Four different types of valves were used as well as seven pairs of cylinders made from iron, brass, steel, coated steel, and plastic. An additional test was also made utilizing a pump imported from India for purposes of comparison and inspection.

Cup Wear Analysis

The major complaint of all the people interviewed in the developing nations concerned short cup life. In some instances, cup life is only 3 to 4 months; consequently, the effectiveness of the pump is only 3 to 4 months and then the people are without well water until the services of a mechanic can be procured. Sometimes this period may be as long as a year. Therefore, anything that can be done to improve cup life will be a major improvement.

All the laboratory tests were conducted with 3-inch cylinders and with standard medium-grade leather cups purchased from the same manufacturer. Following the experimentation with leather cups, additional tests were also made with cups of various materials.

Cup Wear with Guided and Unguided Pump Rods

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. Consequently, specific information from controlled tests was needed. Apparently, the main reason for using guided pump rod is to provide a more stable pump rod for use with windmills, pump jacks, force pumps, or heavy-duty equipment.

Shallow Well. Cup wear was less than 20 percent in the shallow pumps and there was insignificant difference in the wear between the unguided pump rod and the guided pump rod, as can be seen in Figure 4. Iron cylinders were chosen for many of these example illustrations because more wear occurred with the iron cylinders than with cylinders made from other materials.

Deep Well. Generally, cup wear in the deep-well pumps was more than twice that of the cups in shallow-well pumps and there was more than twice the wear in cups from pumps with unguided rod than in cups from pumps with guided rod. Deep-well cup wear can be noted in Figure 5.

Conclusions. There is no reason to have pump rod guides on shallow-well pumps. Although oscillation of the cups is greater in shallow-well pumps, there is no large head of water on the cups to cause the wear. In deep-well pumps it does appear that pump

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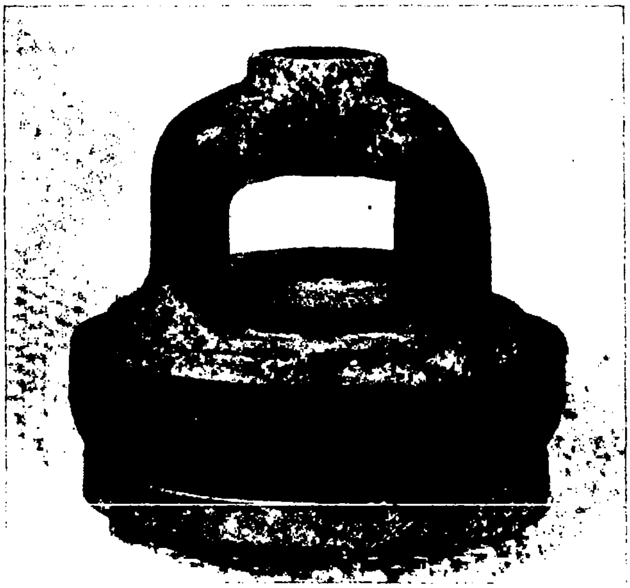
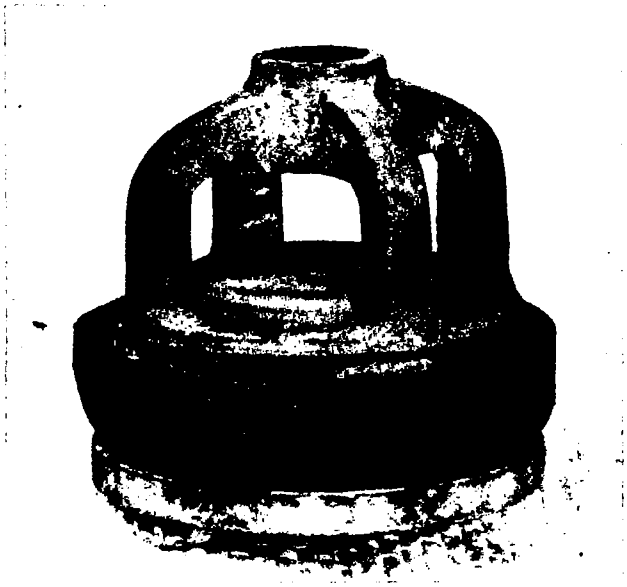
FIGURE 3. LABORATORY TEST FACILITY OVER 12-FOOT-DEEP POOL



35865
a. With Unguided Pump Rod

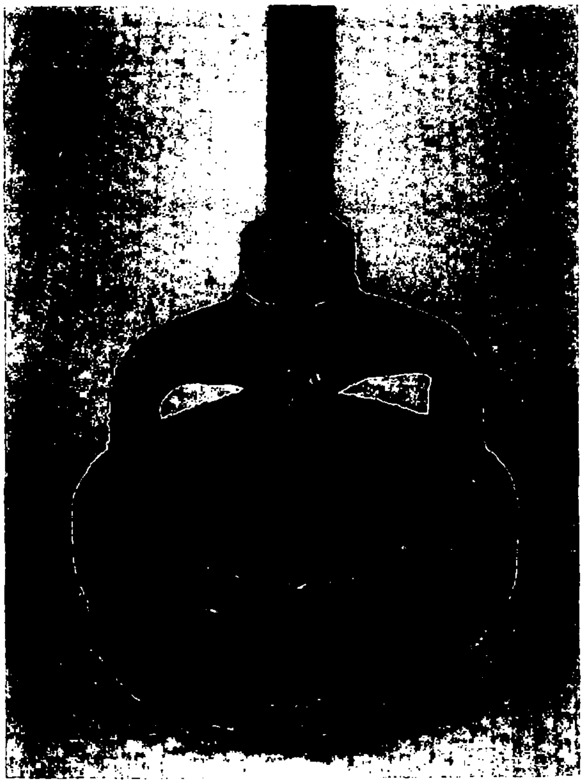


35866
b. With Guided Pump Rod

FIGURE 4. LEATHER CUP AFTER TEST IN IRON CYLINDER OF SHALLOW-WELL PUMP

35515

a. With Unguided Pump Rod



35516

b. With Guided Pump Rod

FIGURE 5. LEATHER CUP AFTER TEST IN IRON CYLINDER OF DEEP-WELL PUMP

guides are helpful in retarding cup wear, at least in pumps with the cylinder 12 feet below the pump body. Additional tests are required to detect whether this is true in deeper wells. Deeper wells, of course, provide a greater head of water on the cups, forcing them harder against the cylinder walls but, at the same time, oscillation is much less.

Cup Wear with Single-Cup and Multiple-Cup Plungers

All of the shallow-well pumps investigated have single-cup plungers. However, many of the deep-well pumps, such as those investigated in the Philippines, have as many as four cups on a plunger. One of the manufacturers in the United States suggested that one-cup plungers be used to the 50-foot depth of the cylinder, then two cups be used to the 125-foot depth, and three cups to the 200-foot depth. Some of the wells visited in the Philippines were 400 feet deep, but generally water came to within 75 feet of the surface. These pumps had four cups. The tests conducted at Battelle were conducted with two-cup plungers.

Shallow Well. The cups of shallow-well multiple-cup plungers show more than twice the wear than cups of single-cup plungers. In the laboratory the pump with the unguided pump rod failed (snapped draw pipe) after 88 hours of operation because of the violent action set up by the binding, oscillating pump rod. Figure 6 shows the result of this test.

Deep Well. A very slight decrease in wear was noted between the two-cup arrangement and the single-cup arrangement. Results of tests with such cups can be seen in Figure 7.

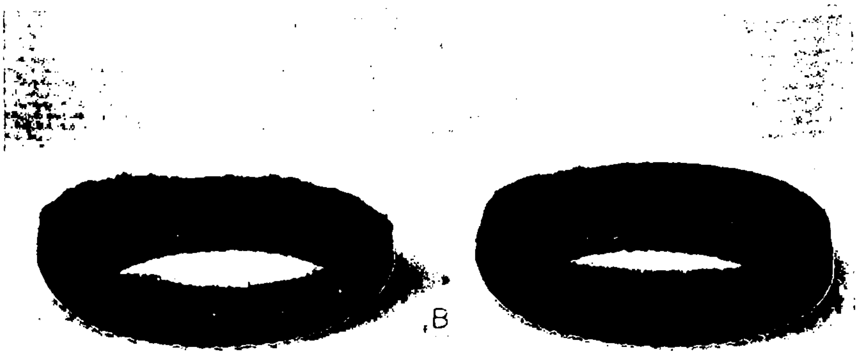
Conclusions. Without question, multiple leather plungers should not be used in shallow-well pumps and they certainly do not appear to provide an advantage in deep-well pumps when installed in shallow wells. Further testing at various depths in deep wells would be necessary to determine at what precise depth additional cups become necessary. Apparently, multiple cups in the deeper wells with the greater heads of water act as labyrinth seals, and when multiple cups are not used, the increase in head can actually turn a single cup inside out.

Cup Wear with Various Cylinder Materials

This group of tests was probably the most significant in relation to cup wear. There is a greater corollary between cup wear and smoothness of cylinder bore than between cup wear and any other single variable. Most of the cylinders that are used today are made either from cast iron or from brass and, without question, most of the trouble or short life occurs with the iron cylinders. The laboratory tests proved conclusively that cup wear is proportional to the smoothness of the cylinder. Because of the high cost of brass, and also because brass is virtually unobtainable in some areas, other materials were also tested for possible cylinder materials in these areas.

Top Cup Bottom Cup 36881

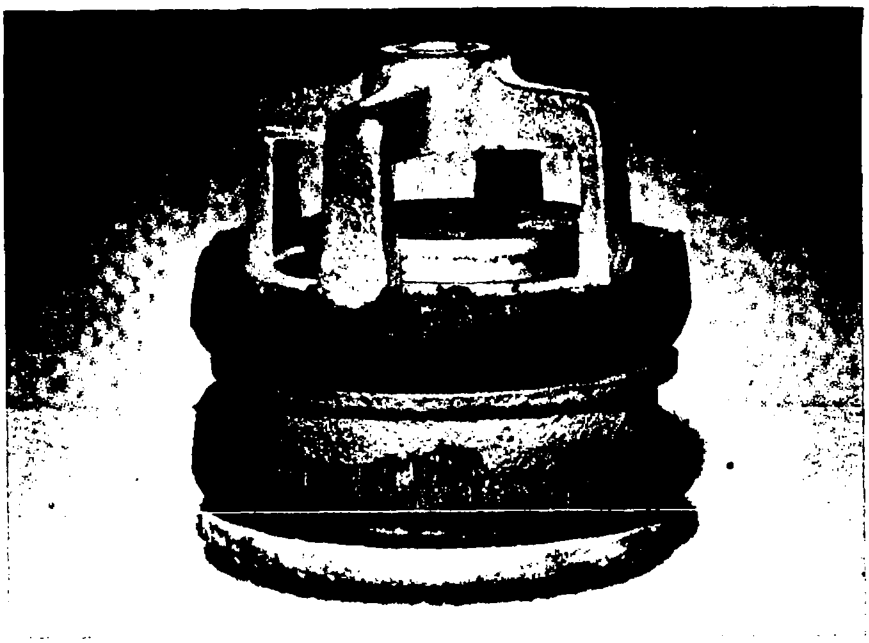
a. With Unguided Pump Rod, Failed After 88 Hours Due to Virbration



Top Cup Bottom Cup 36884

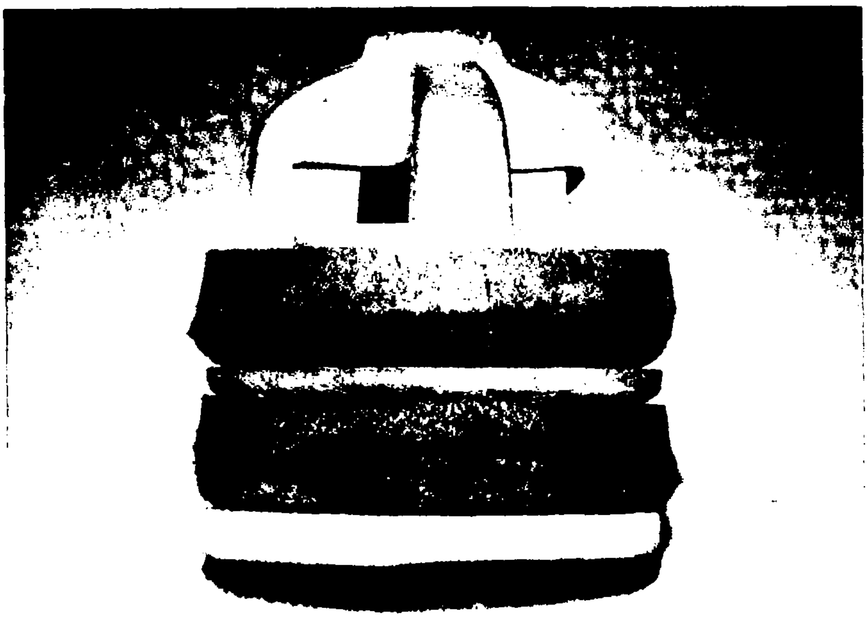
b. Pump With Guided Pump Rod

FIGURE 6. DOUBLE LEATHER CUPS AFTER TEST IN IRON CYLINDER OF SHALLOW-WELL PUMP



36211

a. With Unguided Pump Rod



36210

b. With Guided Pump Rod

FIGURE 7. DOUBLE LEATHER CUPS AFTER TEST IN IRON CYLINDER OF DEEP-WELL PUMP

Cup Wear with Iron Cylinders. The smoothness of iron cylinders used in the United States ranges from 50 to 200 microinches, with the average smoothness well over 100 microinches. Cup wear in the iron cylinders in both shallow-well and deep-well pumps was noted to be 20% or greater then with the brass cylinders. Figures 4 through 7 indicate the wear under various conditions tested. It was also noted that the iron cylinders quickly rusted in the areas not being wiped by the cups. If for any reason the plunger action should be moved to another section of the cylinder, cup wear would be significantly increased. It is therefore easily understood why cup wear in some of the pumps in the developing nations is so high. Particularly in East Pakistan and India, roughness of rusted cylinder bores of pumps in storage must have been close to 1000 microinches or more. This, coupled with poor quality cups would make the effective life of a pump very short.

Cup Wear with Brass Cylinders. The smoothness of the bore of the brass cylinders examined measured between 4 and 8 microinches as compared with the smoothness of the iron cylinders of 50 to 200 microinches. Even when the tests were run twice the average time there was no significant cup wear. Comparison can be made between Figure 8 showing the brass cylinder and Figure 5a showing the iron cylinder. These seem to be the worst cases for wear, representing the deep-well pump with an unguided pump rod.

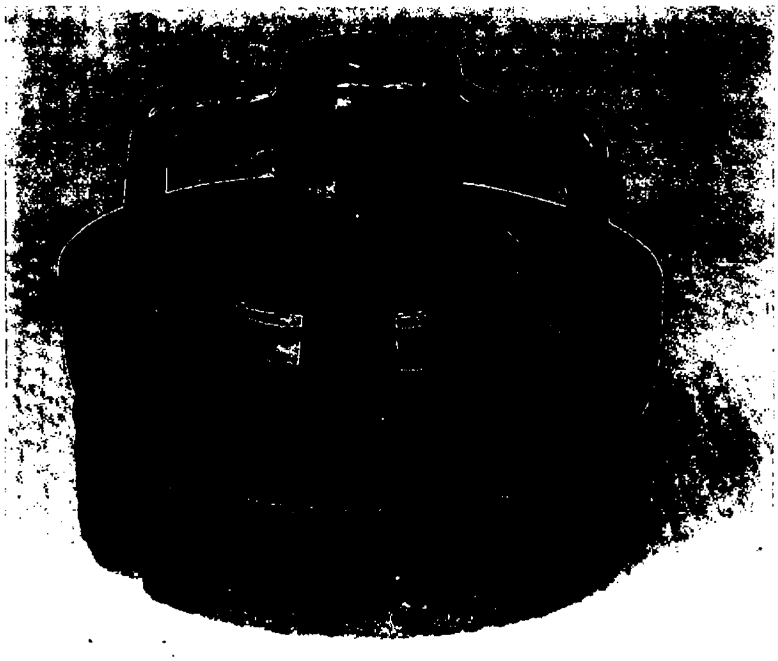


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FIGURE 8. LEATHER CUP AFTER TEST IN BRASS CYLINDER-DEEP WELL PUMP WITH UNGUIDED PUMP ROD

Cup Wear with Plain-Steel Pipe (Schedule 40) Cylinder. Because of the machine shop practices observed in many of the developing nations, it is believed that steel pipe would make an effective cylinder for pumps. Plain-steel pipe has an inside surface finish between 140 and 180 microinches, which is certainly comparable to that of iron cylinders which measure between 50 and 200 microinches inside surface finish. It was disappointing to find that plain-steel pipe cylinders did not perform as well as iron cylinders, as seen in Figure 9. This cylinder lasted only one-half the average test time.

36889

FIGURE 9. LEATHER CUP AFTER FIRST HALF OF TEST IN PLAIN-STEEL-PIPE CYLINDER - DEEP-WELL PUMP WITH UNGUIDED PUMP ROD

It has been hypothesized that the reason for the greater wear of the plain-steel-pipe cylinder, even though the smoothness of the cylinder is equal to that of the iron cylinder, is that the surface is relatively smooth but with peaks. The iron cylinder is relatively smooth with valleys in the surface caused by the machining. Because the steel pipe is harder than the iron cylinder, the sharp peaks tend to tear and abrade the cups more rapidly. Another advantage the iron cylinder seems to have over the steel pipe is that the iron cylinder tends to become smoother with the honing action of the leather cup. It was decided to clean out or burr the steel pipe with a cutting mechanism such as is used to clean boiler tubes. This did not significantly improve the surface finish, but apparently dulled the cutting edges of the minute protrusions. Figure 10 shows the effect of burring the cylinder. Figure 11 shows a cup after testing in the burred cylinder in a shallow-well pump.

Cut Wear with Plain-Steel Pipe Cylinders with Coatings. Because plain-steel pipe offers a strong, round cylinder with smoothness comparable with that of iron pipe, it was decided that steel pipe would make good cylinders if the inside surfaces were coated. This is a relatively inexpensive process and steel pipes could be quite effective as cylinders at a relatively small cost as compared with brass cylinders.

Three coatings were tested. The first was an epoxy phenolic coating which required a 30 minute bake period at approximately 425 degrees. Several coats were required. The second coating tested was a tung oil phenolic which required air drying between several coats and final baking for one hour at 275 degrees. The third coating was a moisture-cured urethane that required only curing at room temperature for 72 hours. Pipe preparation was the same in all cases. The pipes were scaled with a wire brush and degreased with a common solvent. The coatings were all applied in the same manner. This application was quite simple; one end of the pipe was stoppered and the coating poured in the open end. The open end was then stoppered and the pipe rolled

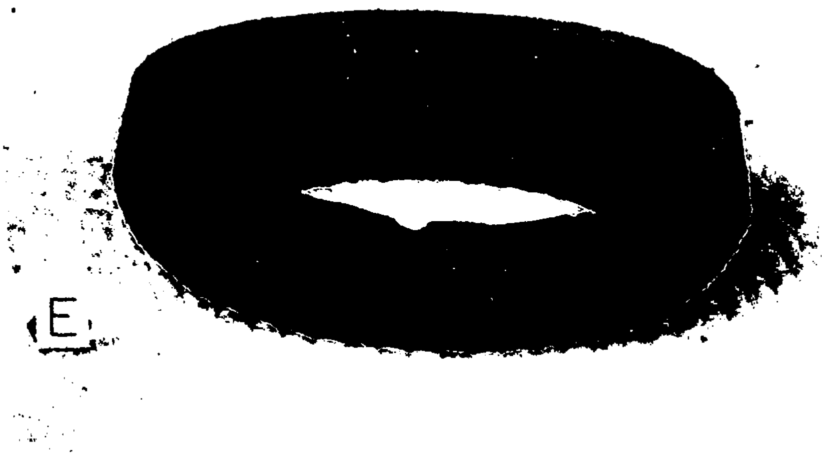

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FIGURE 10. LEATHER CUP AFTER SECOND HALF OF TEST IN PLAIN-STEEL-PIPE CYLINDER-DEEP-WELL PUMP WITH UNGUIDED PUMP ROD (BURRED CYLINDER)

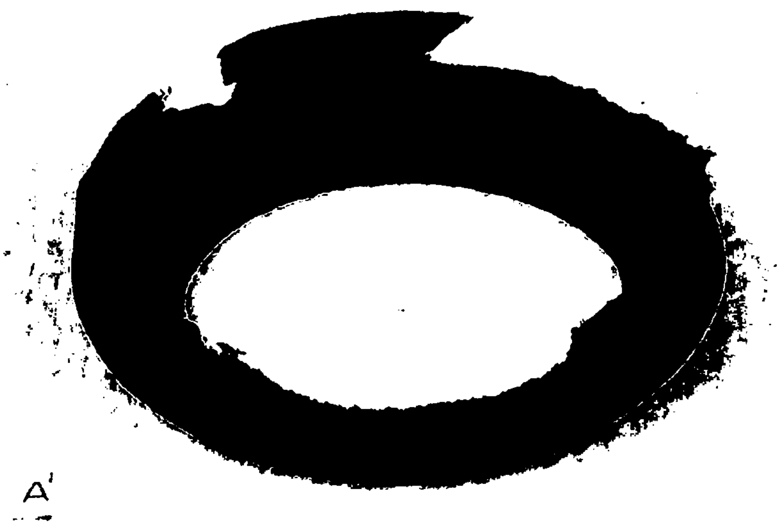

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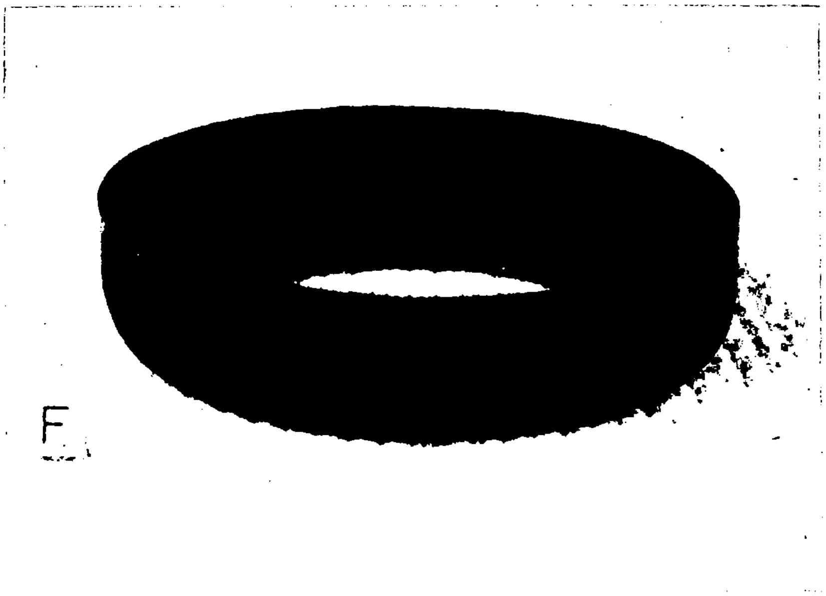
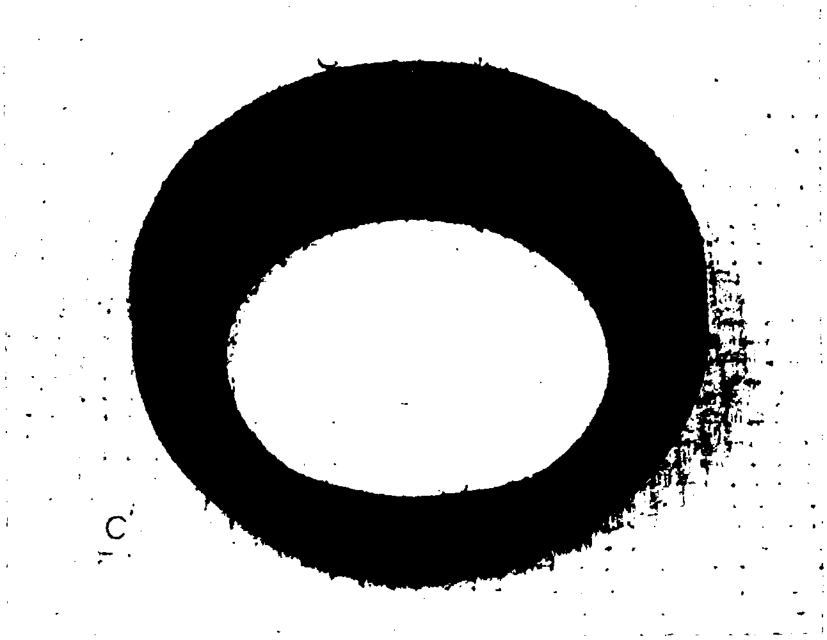
FIGURE 11. LEATHER CUP AFTER TEST IN PLAIN-STEEL-PIPE CYLINDER-SHALLOW-WELL PUMP WITH GUIDED PUMP ROD (BURRED CYLINDER)



36893

FIGURE 12. LEATHER CUP AFTER TEST IN PLAIN-STEEL-PIPE CYLINDER COATED WITH AN EPOXY-PHENOLIC-DEEP-WELL PUMP WITH UNGUIDED PUMP ROD



37125

FIGURE 13. LEATHER CUP AFTER TEST IN PLAIN-STEEL PIPE CYLINDER COATED WITH A TUNG OIL PHENOLIC-DEEP-WELL PUMP WITH UNGUIDED PUMP ROD

horizontally so that the coating would contact all of the interior surface. The stoppers were then removed and the excess coating poured out. The pipes were then stored vertically to drain forming a uniform coating on the interior surface.

Cup Wear with Plain-Steel Pipe Cylinders Coated with the Epoxy Phenolic Coating. The smoothness of the epoxy-phenolic coating was from 8 to 12 microinches. As with all the other cylinders, testing was done in both shallow- and deep-well pumps and with both guided and unguided pump rods. Wear of the cups was insignificant as it was with the brass cylinders. Figure 12 shows a leather cup after testing in a pipe cylinder coated with the epoxy phenolic coating.

Cup Wear with Plain-Steel Pipe Cylinders Coated with the Tung Oil Phenolic Coating. The smoothness of the tung oil phenolic coating was from 4 to 7 microinches. However, this coating did not perform as well as the epoxy phenolic coating and tests were discontinued. Figure 13 shows a cup after testing.

Cup Wear with Plain-Steel Pipe Cylinders Coated with Moisture-Cured Urethane Coating. The moisture-cured urethane coating had a surface smoothness of 3 to 8 microinches. Tests indicated that wear of the leather cups was as good as with the epoxy phenolic coating. Figure 14 shows a cup after testing. It might be significant to note here, though, that later tests involving the proposed design showed that the coating began to peel because of water seepage between the coating and the pipe.

37372

FIGURE 14. LEATHER CUP AFTER TEST IN PLAIN-STEEL-PIPE CYLINDER COATED WITH A MOISTURE-CURED URETHANE-DEEP-WELL PUMP WITH UNGUIDED PUMP ROD

Cup Wear with Plastic Cylinders. Because plastic pipe is now being used for many underground applications and because it can withstand substantial pressures, there is no reason to suspect that plastic pipe cannot be used successfully for pump cylinders. Therefore, a sample of plastic pipe of polyvinyl chloride was made into a cylinder. The surface smoothness was measured from 4 to 10 microinches. Tests indicated that plastic pipe is as good as brass pipe when the wear of the cups is compared. (See Figure 15.) It should be noted that the plastic pipe should be used only in deep-well applications because structurally it would not be rugged enough to use in connection with the pump body above the ground.

Cup Wear with Maya No. 6 Pump from Calcutta. The bore of the pump imported from Calcutta measured between 240 and 280 microinches finish. This shallow-well pump was operated the full test time. However, the leather was badly worn (twice that of the 3 in. cups in U.S. manufactured cylinders), as can be seen in Figure 16. However, the wear of the leather was at the heel rather than on the sides of the cup. This is probably due to the larger diameter (3-1/2 inches), poor tanning of the leather, and the flexure of the leather while in operation. Moreover, the portion of the cylinder not wiped by the cup was quite rusted after only two weeks of pumping.

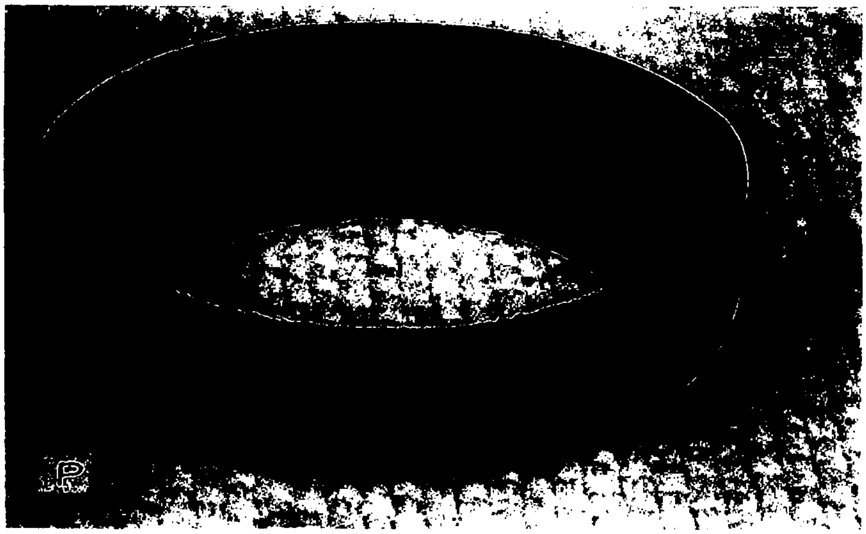
Conclusions. The results of the tests indicate that cylinder bore smoothness is the most important single variable controlling cup wear, and that a good pump design will include a cylinder with as smooth a bore as possible. Although the tests were conducted under laboratory conditions, it is probable that any conditions more strenuous than the test conditions would only amplify the findings.

Cup Wear with Various Cup Materials

Leather appears to be an excellent cup material because of its availability and because it can be manufactured with a wide tolerance range and, if properly tanned, will give long life. The greatest disadvantage, however, is the range of quality of leather and the fact that leather will crack under cyclic wetting and drying conditions. Therefore, other possible materials should be investigated for properties that might be better than those of leather. By the end of the testing program, many new variations of materials and cup designs were procured through material suppliers such as Du Pont and E. F. Houghton & Company and through various cup fabricators. However, time permitted only two of these materials to be tested.

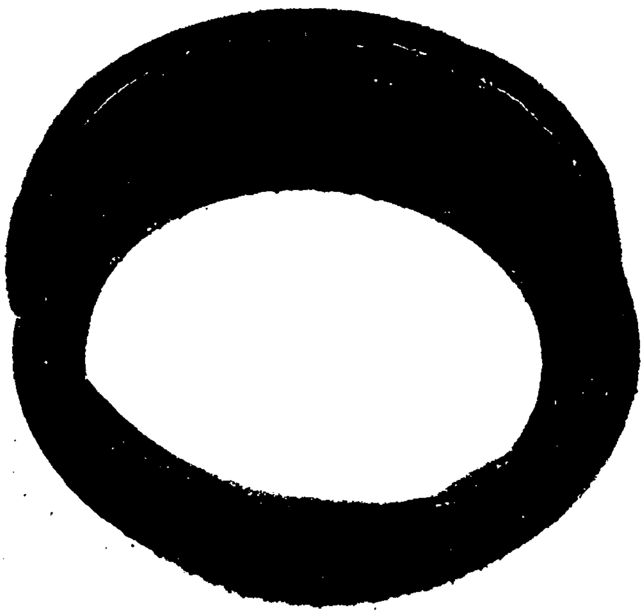
Cup Wear with Cups Made from Rek-Syn (E. F. Houghton & Company). This cup, which is compounded from a special resin and elastomer, is used by one manufacturer in pumps exported to South America. Two cups were procured; however, one was too small and would not pump at all. The second was a good fit with the cylinder and did very well. It was used in conjunction with the plain-steel pipe cylinder (burred) and no significant wear was noted at the end of the test. Figure 17 shows this cup after test.

Cup Wear with Cups Made from Corfam Impregnated with Urethane (E. I. Du Pont de Nemours & Company, Incorporated). This cup wore much more rapidly than the Rek-Syn cup, as can be seen in Figure 18. However, the test performed was not a good test because the cup was too large for the plain-steel pipe cylinder (burred) used.



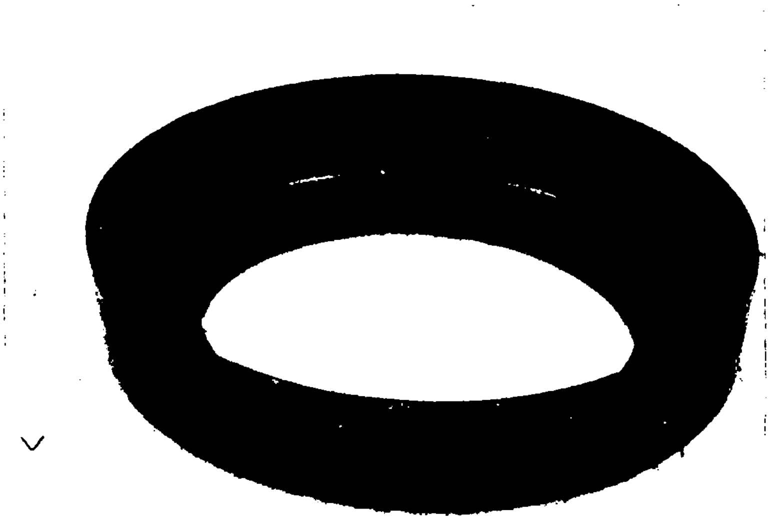
37793

FIGURE 15. LEATHER CUP AFTER TEST IN PLASTIC (PVC) PIPE CYLINDER-DEEP-WELL PUMP WITH UNGUIDED PUMP ROD



39736

FIGURE 16. LEATHER CUP AFTER TEST IN IRON MAYA NO. 6 SHALLOW-WELL PUMP



38069

FIGURE 17. SYNTHETIC (RESIN-ELASTOMER) CUP AFTER TEST IN PLAIN-STEEL-PIPE CYLINDER - DEEP-WELL PUMP WITH GUIDED PUMP ROD (BURRED CYLINDER)

39077

FIGURE 18. CORFAM IMPREGNATED WITH URETHANE AFTER TEST IN PLAIN-STEEL-PIPE CYLINDER - DEEP-WELL WITH GUIDED PUMP ROD (BURRED CYLINDER)

Conclusions. At this time, leather is still the best material for cups. However, in many areas tanning could be improved. Leather is best because of the wide tolerances permissible in the manufacture of the cups. In the case of the synthetic cups, tolerances must be very close because there is very little stretching of the cup and, consequently, they cannot conform to the cylinder walls as do the leather cups. It is believed, however, that cups can be made from synthetic materials if they are properly designed and if materials of proper compositions are used. These cups would have better abrasive and wetting and drying qualities than the leather cups now being used; however, an additional research and development program would be required to provide these cups.

VALVE-TYPE EFFECTIVENESS

The two most common types of checkvalves used in hand pumps today are the poppet valve and the flapper valve. The poppet valve is always used in the plunger; however, the lower check valve in the cylinder can be either a flapper valve or a poppet valve. Generally speaking, all of the shallow-well pumps examined in the United States and developing countries during this program had leather flapper valves in the bottom of the cylinder. Conversely, almost all of the deep-well pumps had poppet valves in the bottom of the cylinder.

There are various types of poppet valves and flapper valves. In the Philippines, the poppet valves are all of the ball type in which the valve is composed of a seat, a cage, and within the cage a ball. In other areas the more common standard tee-shape (in cross section) poppet valve is used. The seal is merely metal-to-metal as is the ball poppet-type valve. American manufacturers are now placing a rubber gasket in the poppet valve, so that every time the valve closes, a rubber gasket cushions the impact. Only in one instance in East Pakistan were springs used to help close the valve. In the United States several designs of poppets are used, depending on whether the poppet is enclosed in a cage or whether it is restrained by virtue of its design.

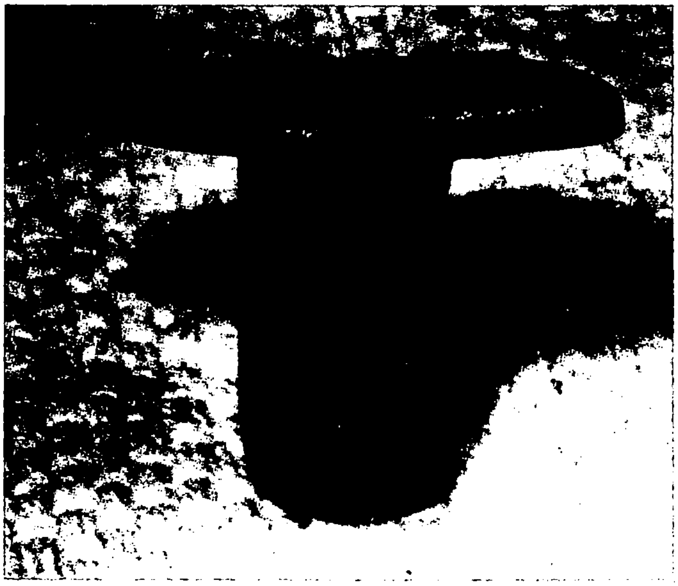
Flapper Valves

Flapper valves are of two types. The type used in all the developing nations is the full-circle type in which a full-circle leather is squeezed between the valve body and the cylinder; the flapper is cut out from this portion except for a connection point. Weight is added to the flapper to assist in closing. The other type of valve is made in the United States and is used in cylinders where the caps are threaded into the inside of the cylinder. Only the flapper itself is attached to the valve housing by means of two screws. This valve provides no advantage over the full-circle valve other than that it requires less material. The operation is the same. This valve performs reliably in both deep-well and shallow-well arrangements in the laboratory, and there is no reason to assume that it cannot be used in deep-well applications, unless it is because of the frequency of needed replacement.

Because the quality of leather enters into the performance of the flapper valve, a new material was tested, a nylon fabric impregnated with neoprene marketed under the trade name of "Fairprene" 12-003 by Du Pont. Valves of this material do an excellent job and were never replaced in the laboratory tests. In comparison, leather valves used in the test were replaced frequently because of cracking and the fear of failure before a test was completed. According to the manufacturer, "Fairprene" or similar materials have virtually zero fatigue and they can be used almost indefinitely. They are not affected by cyclic conditions of wetting and drying as leather valves are.

Poppet Valves

Two types of poppet valves were examined: poppet valves with metal-to-metal contact and poppet valves with a cushioning gasket. Both types seem to be satisfactory for light use; however, distortion of the poppet was very noticeable in those valves in which there was no cushioning gasket. This distortion was even more noticeable where the poppets had large movements. Figure 19 shows the distorted cast-iron poppet from a plunger valve after several test periods. The poppets that had cushioning gaskets showed no distortion at all. This does not mean that the poppets or the rubber gasket would not distort after a period of time; but it does show that cushioned valves will last longer.



39826

FIGURE 19. DISTORTED CAST-IRON POPPET FROM PLUNGER VALVE AFTER SEVERAL TEST PERIODS

Conclusions. Both the poppet and the flapper valves are adequate. However, poppet valves should have a cushioning gasket and should only have lift enough for 100 percent through area to reduce the pounding effect. Flapper valves should be made from Fairprene or similar material for long life. At this time, it is recommended that poppet valves be used in all plungers and in deep-well pump cylinders. Flapper valves made from the nylon impregnated with neoprene should be used in all shallow-well pump cylinders. Flapper valves with the improved material should perform most satisfactorily in deep-well applications; however, further tests are necessary to substantiate this conclusion.

Metallurgical Analysis

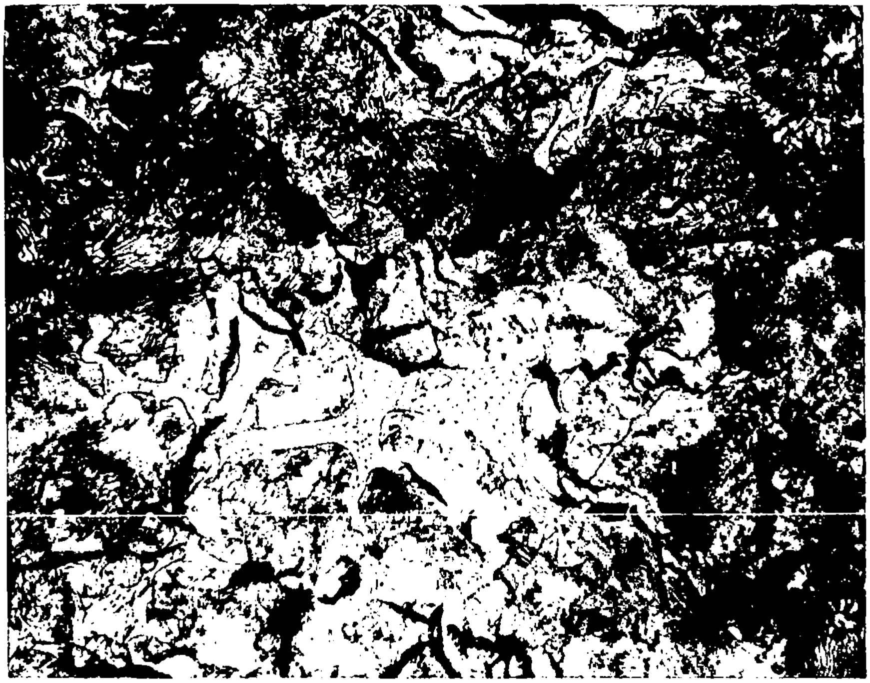
In many of the areas visited by the Battelle team, complaints were received concerning the brittleness of the pumps being manufactured. However, the manufacturers of these pumps were not able to supply accurate analyses of the iron being used. Therefore, samples of materials were brought back to Battelle for analysis. Table 1 shows the analysis of the gray iron samples from the JSPR Manufacturing Company in Howrah, India; the Maya Pump Company in Calcutta, India; the Government foundry in Korat, Thailand; and the Fabrication Foundry & Engineering Works in Dacca, East Pakistan.

TABLE 1. CHEMICAL ANALYSES OF GRAY CAST-IRON SAMPLES

Values Given in Percent

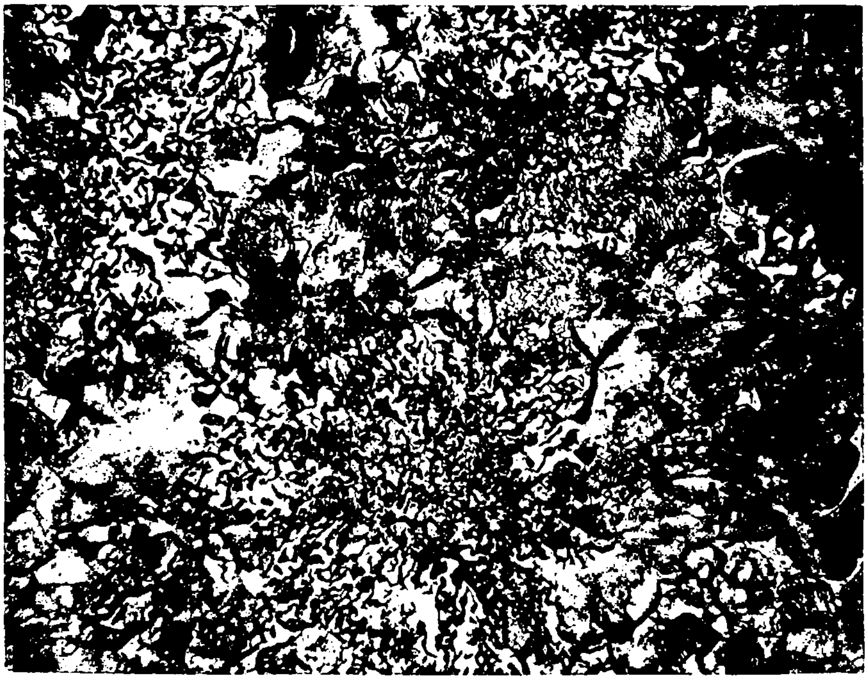
Sample Identification	J.S.P.R.	Korat	Dacca	Maya
Total Carbon	3.75	3.57	3.18	3.30
Silicon	1.65	2.03	2.19	1.96
Manganese	0.44	0.20	0.52	0.38
Phosphorous	0.271	0.259	0.188	0.403
Sulfur	0.082	0.050	0.100	0.110
Carbon equivalent	4.39	4.33	3.96	4.10
Aluminum	0.001	0.001	0.007	0.007
Antimony	<0.002	<0.002	<0.002	<0.002
Arsenic	0.014	0.037	0.019	0.012
Barium	<0.002	<0.002	<0.002	<0.002
Beryllium	<0.0005	<0.0005	<0.0005	<0.0005
Bismuth	<0.002	<0.002	<0.002	<0.002
Boron	<0.001	<0.001	<0.001	<0.001
Chromium	0.02	0.08	0.25	0.02
Cobalt	0.005	0.008	0.006	0.004
Columbium	<0.01	<0.01	<0.01	<0.01
Copper	0.006	0.31	0.29	0.007
Germanium	0.002	<0.002	<0.002	<0.002
Lead	0.003	<0.002	0.002	0.002
Molybdenum	0.002	0.01	0.14	0.005
Nickel	0.008	0.08	0.09	0.009
Tellurium	<0.002	<0.002	<0.002	<0.002
Tin	0.005	0.019	0.11	0.005
Titanium	0.135	0.023	0.059	0.105
Tungsten	0.015	<0.01	0.01	0.01
Vanadium	0.009	0.009	0.009	0.009
Zinc	<0.002	<0.002	<0.002	<0.002
Gallium	0.002	0.002	0.002	0.002
Calcium	<0.001	0.001	0.001	<0.001

The chemical analysis showed very high phosphorus content, particularly in the Maya sample. This alone could be responsible for the excessive breakage. The effect of the phosphorus is shown in the top photomicrograph in Figures 20 through 23. The irregular shaped light constituent with the dark dots is massive Steadite, an eutectic mixture of iron carbon and iron phosphide. It is extremely hard and brittle and tends to



500X 4B960

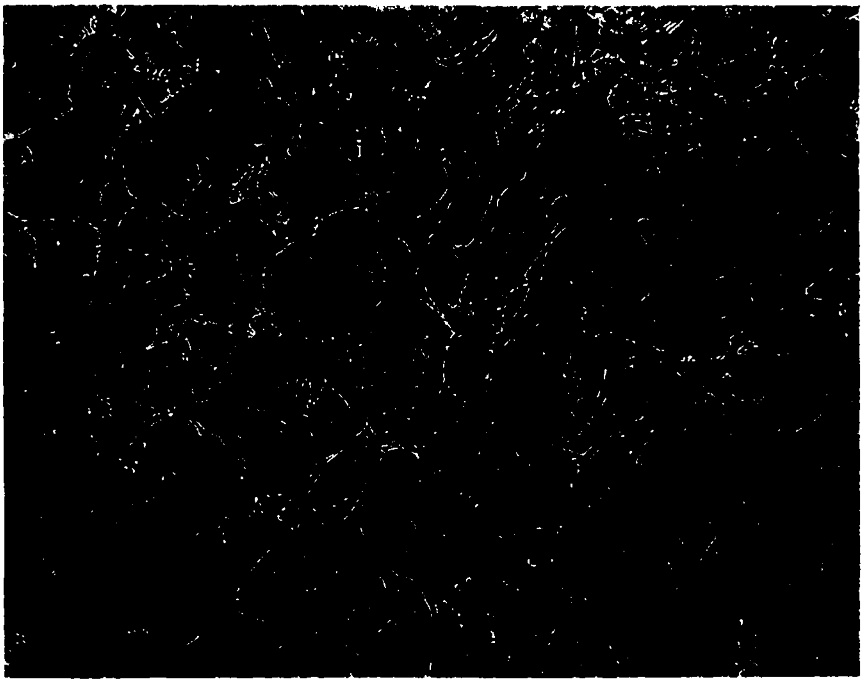
a. Massive Steadite



500X 4B961

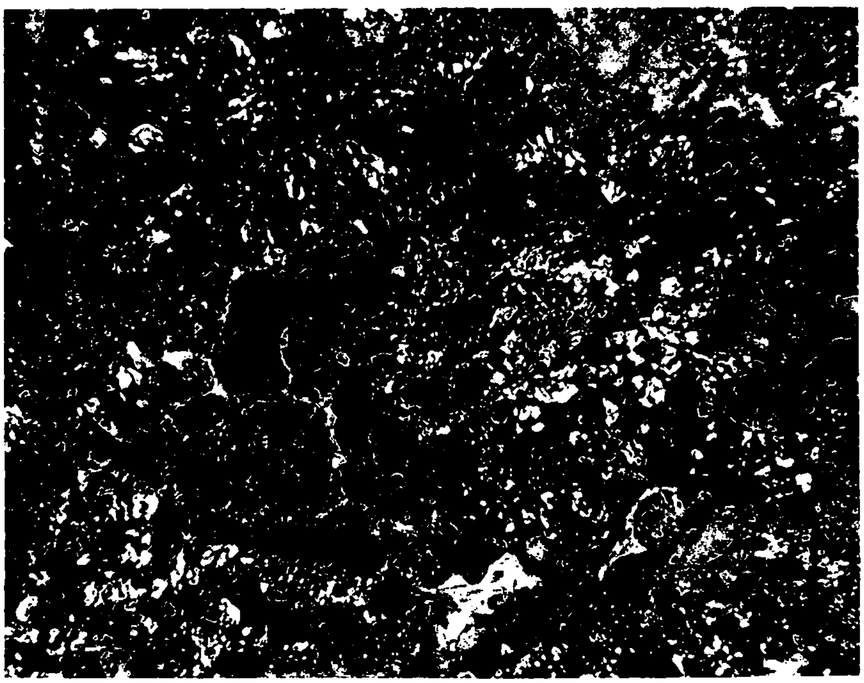
b. Areas of Fine Graphite Surrounded With Ferrite

FIGURE 20. J. S. P. R. COMPANY IRON



500X 4B966

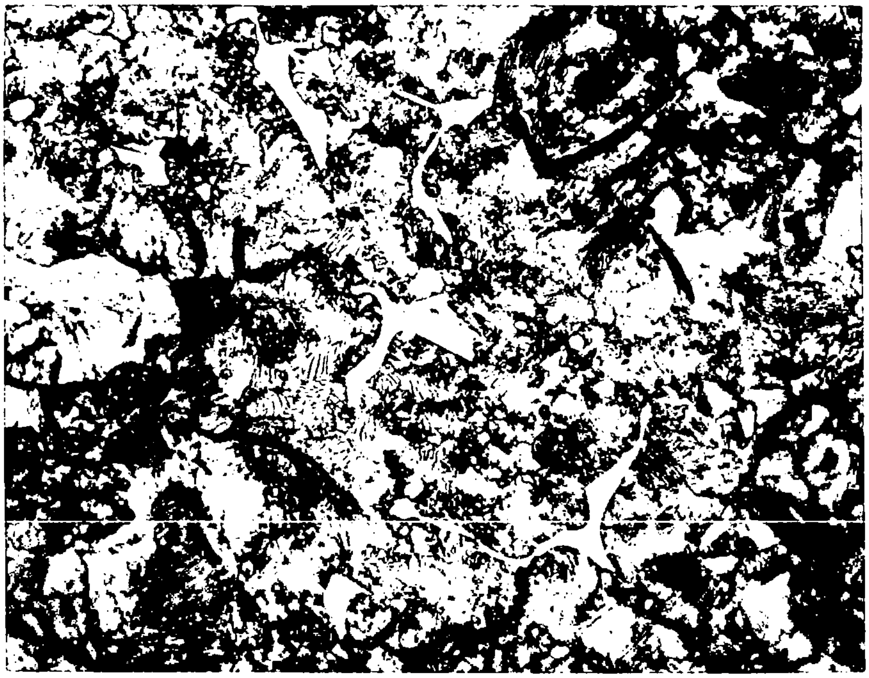
a. Massive Steadite



500X 4B967

b. Fine Graphite Surrounded With Ferrite and Some Steadite

FIGURE 21. KORAT COMPANY IRON



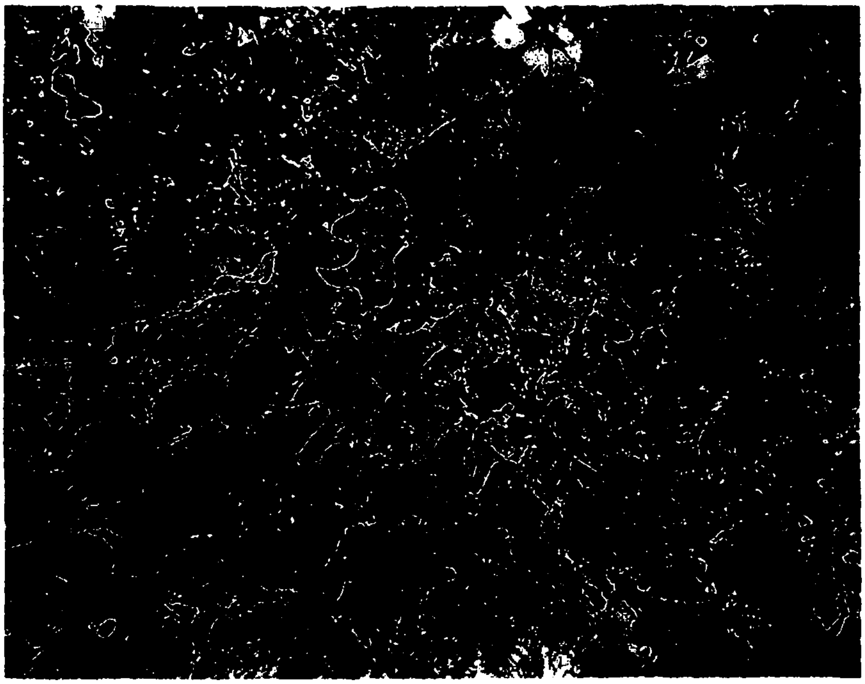
500X 4B964

a. Massive Steadite

500X 4B965

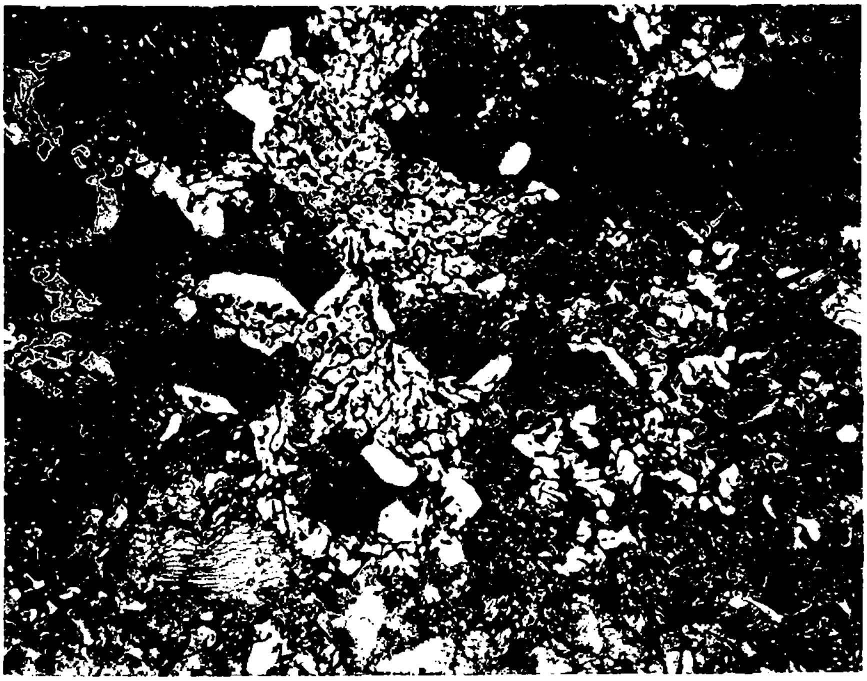
b. Fine Graphite Surrounded With Ferrite

FIGURE 22. DACCA COMPANY IRON



500X 4B962

a. Massive Steadite



500X 4B963

b. Fine Graphite Surrounded With Steadite

FIGURE 23. MAYA PUMP COMPANY IRON

make the iron brittle and weak. Such iron has low resistance to impact and is difficult to machine. The Dacca iron pictured in Figure 22 contains less than the normal maximum of 0.2 percent phosphorus. Steadite makes its appearance in the microstructure when the phosphorus exceeds about 0.15 percent.

Some additional hardening of the iron would be obtained from the 0.25 percent chromium in the Dacca iron, the 0.31 and 0.29 percent copper in the Korat and Dacca iron, and the 0.11 percent tin in the Dacca iron.

Chemical constituents in the irons which would be expected to increase the brittleness of the irons are shown in Table 2.

TABLE 2. ELEMENTS IN THE IRONS THAT WOULD CAUSE BRITTLENESS

	Percent of Detrimental Elements			
Iron	Phosphorous	Chromium	Copper	Tin
J.S.P.R.	0.271	--	--	--
Korat	0.259	--	0.31	--
Dacca	0.188	0.25	0.29	0.11
Maya	0.403	--	--	--

The bottom photomicrographs of Figures 20 through 23 show that the microstructures of all the irons contained a detrimental graphite structure. A fine graphite structure generally lowers the strength and impact resistance of irons. The graphite structure can generally be improved by proper inoculation provided that: (1) the carbon equivalent (carbon plus 1/3 silicon plus 1/3 phosphorus) equals about 4 or less, and (2) the iron temperature is high enough (over 2550 F). Inoculation of cast iron is the late addition of a material to a molten cast iron so as to affect the properties of the resultant castings to a degree that cannot be explained by the change of composition produced. A large variety of commercial inoculants are available.

Conclusions. The greatest improvement in the cast irons would be obtained by using raw materials with a lower phosphorus content, so that the phosphorus content of the irons would be under 0.15 percent. Some additional improvement would also be obtained by inoculating the irons. Some improvement in the high-phosphorus irons would also be obtained by a full annealing treatment (heat to about 1500 F and furnace cool). This treatment would transform most of the pearlite into ferrite.

There are additional aids that would be quite helpful in regulating the quality of their iron, including the segregation of raw materials, pigs, scrap iron, steel, etc., into separate piles so that the charge can be made up of known materials. Another aid would be analysis of the material cast so that the foundry might be kept aware of the quality of the castings being made. The third aid would be proper control of the air that goes into the cupola. No controls at all were seen in any of the foundries visited. Practically no control was observed over the type of coke or charcoal used in the charge.

PUMP DESIGN

On the basis of the state-of-the-art survey, contacts made with United States manufacturers, the survey made in the developing nations, and the metallurgical and design analyses, the following pump design principles were established:

(1) The pump should be of the simple piston design

(2) The basic components should be adaptable for assembly for either deep- or shallow-well operation

(3) The basic design should be flexible enough to permit use of inexpensive and conventional configurations and details whenever this is compatible with good mechanical design, to permit giving the pump a "familiar" appearance to increase its acceptability in developing nations

(4) The basic design should be flexible enough for adaptation to varying degrees of sophistication in terms of materials and manufacturing processes, to innovations in design and materials, and to differences in the conditions of individual countries

(5) The pump should consist of the minimum number of components, but this should not result in the need for complicated parts

(6) The basic design should incorporate a minimum number of threaded fasteners and use a standard pump rod with jam nuts or sealant

(7) Corrosion protection should be provided

(8) The design should allow for the use of below-grade materials

(9) The design should utilize leather cups and nylon impregnated with neoprene flapper valves where applicable; rubber cushioned poppet valves should be provided for deep-well applications and for plungers, and they should have only enough lift to provide 100 percent through area

(10) Cylinders should have as smooth a bore as possible with the available materials and tooling and should not exceed 3 inches in diameter

(11) A pump rod guide should be provided for special applications and multiple-cup plungers should be used only in wells more than 50 feet deep

(12) Maintenance should be easy and inexpensive.

Simple Piston Pump

The pump needed most in developing nations is a simple piston pump. The proposed simple piston pump is composed of a body, a fulcrum, a handle, a single cylinder, a plunger, and two check valves, one in the plunger and one in the cylinder. This pump can be used for pumping in shallow wells and deep wells, and is not designed for use as a force pump or a double-acting pump. Two versions of the proposed pump are shown in Figures 1 and 2. Layouts of the shallow-well and deep-well pump can be seen on drawings E-0005 and E-0006 which accompany this report.

Adaptation for Deep- and Shallow-Well Operation

In many of the developing nations it is necessary that pumps be available for both deep- and shallow-well pumping. At the present time in many of these areas two separate types of pumps are required. The proposed design is such that the cylinder can be placed either in connection with the body or at the end of the draw pipe below the surface of the water. No additional parts are required except where a deep-well pump is used in a shallow well. In such a case it may be necessary to replace the cap and the fulcrum to provide longer life for the cups. It is expected, however, that field testing will reveal that below some critical depth this change will not be required.

Flexibility and Appearance

In order to diminish problems of acceptability, the exterior appearance of the pump must be similar to that of pumps presently being used. That is, the body should be similar to local pump bodies, the pump should be composed of handles, fulcrums, and cylinders as known in the area. So that acceptance rates will be as high as possible, the design must be flexible enough to allow engineers in the various countries to redesign contours according to their own asthetic values. A good case in point is the Korat Pump #1 in Thailand. This pump is a perfectly good pump made from piping components. It proved to be an effective pump; however, because it did not have an appearance pleasing to the engineers of Thailand, it was never accepted. Acceptable appearance to an American designer may not be acceptable appearance to a designer in a developing nation. However, whatever changes are made in the appearance of the pump, the basic engineering principles must be adhered to.

Flexibility of Technology

Because of differences in technical levels in the various developing nations, it cannot be expected that the proposed pump be manufactured exactly as presently designed in all the countries. The design of the pump must take into account present technological levels as well as changes that are expected to come. For example, it is recommended here that pump cylinders be made of either brass, coated plain-steel pipe, or plastic pipe. If only iron cylinders are available, obviously they must be used at present, but it is recommended that the bores of these iron cylinders be made as smooth as possible. At a later date better cylinders of other materials can be provided.

It is expected that many innovations will be introduced as time goes on. Types of valves can be changed as better materials become available; improved cups can be used as synthetic materials become available or a better grade of leather can be obtained. All of these modifications are possible with the proposed design.

Minimum Number of Components

The present design provides for as few components as possible. Such an arrangement provides for better interchangeability of parts, easier adaptation to deep-well and shallow-well use, smaller inventory, less expensive maintenance, and low manufacturing costs. An example of the versatility in the proposed design is the lower valve housing. This housing is so made that it can take two types of flapper valves or the poppet valve and it permits shallow-well or deep-well pumping without provision of additional parts.

Minimum Number of Threaded Connections

Because of the poor quality of the larger-size threaded connectors used in developing nations and the problem of pilferage, the proposed design excludes all threaded connections except for pump rod connections. Two small screws are used to fasten the flapper valve in the lower valve housing. The proposed design provides for standard pump rod and draw pipe as used the world over. A standard 7/16-inch pump rod is recommended. Assuming a low 20,000-psi ultimate strength, a conservative working load of 200 pounds, and a 1-1/4-inch draw pipe, this rod can be used in wells as deep as 200 feet. In deep wells where pump rod bending or pipe slapping might endanger the rod connections, guide couplings should be used. Jam nuts or sealants should be used at all threaded connections to prevent loosening of the joint.

Corrosion Protection

One of the greatest problems in many of the developing areas of the East is the problem of corrosion. Many of the stored components cannot be used because of the rust and mildew. Apparently there are two possible corrective measures: (1) provide better storehouse facilities or (2) provide parts that are immune to the corrosion. For the proposed design, the latter approach was selected. Proper painting of portions of the body, valve housing, handle, fulcrum, and cap is ample protection in most cases. More important, however, is the fact that the proposed design calls for brass, coated steel pipe, or plastic pipe for cylinders, all of which are able to withstand the elements. It would also be good practice to store the cups in sealed plastic bags to prevent mildew. Use of synthetic cup materials would make this precaution unnecessary.

Adaptability to Low-Grade Materials

One of the greatest problems existing in some areas is that low-grade materials are used for pump manufacture. This presents problems not only when the pump is in standard use but also during shipping. A high percentage of the pumps never reach their destination in one piece. Because of this, the proposed design is such that break points have been eliminated or sufficiently strengthened to withstand abuse. The design also calls for heavier sections throughout the entire pump body and other components so that long life can be expected. In the event that better materials are found, smaller cross-sections can be used.

Valves and Cups

The proposed design calls for three types of valves. The first type is the standard tee-shaped poppet. This valve is to be used in plungers and in shallow-well cylinders where repair can be easily made. The design is such that only optimum movement is provided. The second type of valve is the cushioned poppet valve designed for deep-well applications where maintenance is more difficult. The third valve is the flapper valve to be used as a lower check valve in shallow-well pumps. It is recommended that this valve be made from nylon impregnated with neoprene. Such an arrangement will provide extremely long life with practically no maintenance requirements. It is believed that further evaluation will show this valve acceptable for deep-well application.

Leather is recommended for the cup material until an improved material is developed.

Cylinders

The greatest single factor in pump longevity is the smoothness of the cylinder bore. Without question, every care should be taken to provide as smooth a bore as possible. It is recommended that cylinders be made from brass, coated steel pipe, or plastic pipe. These materials not only provide for long pumping life but also for the long shelf life which is necessary for a good water program.

It is recommended that cylinder size not exceed 3 inches to provide for easy fabrication and for use in 4-inch-diameter casings. Most cylinders used are 3 inches in diameter or less.

Pump Rod Guide and Multiple Cup Plungers

In those cases where it is expected that deep-well pumps will be used for pumping in relatively shallow wells or when eventually windmills or pump jacks will be used for operation of the pump, pump rod guides should be provided. It is also recommended that multiple-cup plungers be used only in wells more than 50 feet deep because they do not provide significantly longer cup life when they are not required, and in shallow-well use they actually decrease cup life. It is expected that field trials will define further the limitations of the pump rod guide and single cup plungers.

Maintenance

The proposed design provides for easy, inexpensive maintenance. The pump is made from rugged, simple components, few in number, that can easily be assembled or disassembled with a few standard tools. Because of the small number of parts and the interchangability of parts for deep-well and shallow-well applications, warehousing problems should be reduced.

PUMP EVALUATION

It was necessary that the proposed design be evaluated to determine as much as possible the future effectiveness of the pump and to compare it with pumps already in existence. Two tests were set up. The first and major test was a life test of the combined components operating as a shallow-well pump and deep-well pump. The second test was a sand test in which the same two pumps, one with the epoxy phenolic coated cylinder and the other with a plastic cylinder was set up to pump water with a high concentration of river mud and sand.

For the first test, two pumps of the proposed design were set up to pump at a rate equivalent to 1500 gallons of water a day for 365 days. At the end of this accelerated test, practically no wear was observed on the leather cups used, as shown in Figures 24 and 25. As shown in Figure 26, the plain-steel pipe cylinder coated with an epoxy phenolic also came through with flying colors; practically no wear was noted on the coating of the cylinder. However, the cylinder coated with the moisture-cured urethane did not fare as well. Figure 27 shows how the coating began to peel, not as a result of the piston movement within the cylinder, but rather as a result of the action of the water. It is hoped that further work will provide an effective moisture-cured coating, but a coating not affected by water. The failure shown here might also be a result of incorrect coating application, and further work might also reveal different or better means of applying the same or similar coatings. Practically no wear was seen on any of the pinned joints of the pump and, as expected for such a short-duration test as this, there was no deterioration.

Figures 28 and 29 show results obtained in the second test with the leather cups after approximately one million cycles. As can be seen, these cups are in remarkably good condition for pumping water such as this. The cylinders did show some wear in terms of abrasion to the side walls in the area of the piston movement, but each of the cylinders could be used for many more years of pumping under normal conditions.

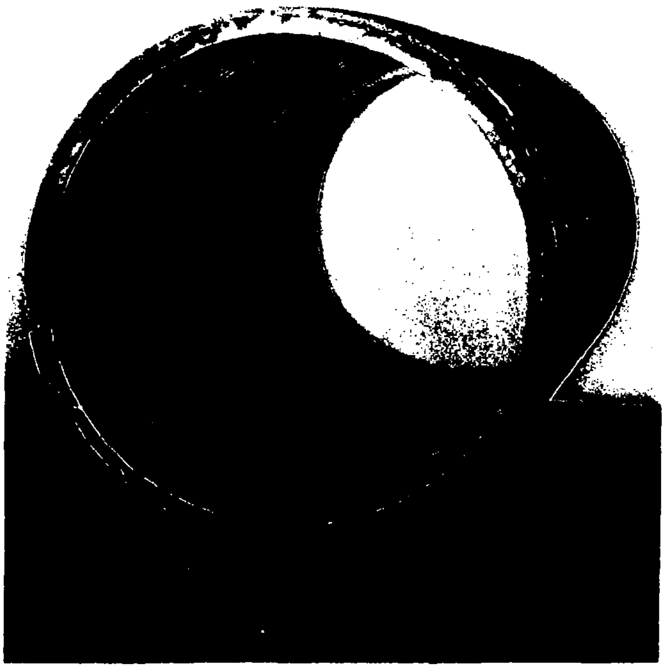
It is believed that the pump as proposed – assembled without the use of threaded fasteners, with valves made according to the specifications, and with cylinders made of brass, plain-steel pipe coated with an epoxy phenolic, or plastic pipe – would be accepted in any of the developing nations and used effectively, giving long service and providing water for many peoples. However, this design should be introduced to developing nations through a specific program. That program should include field testing for the dual purposes of proving out the design still further and of identifying additional possibilities for simplification of the components. Such a field test program would serve as an excellent opportunity for effective introduction of the pump to the influencial people of a developing nation. Further laboratory research should also make possible further simplification in terms of valves, cylinder coatings, and synthetic cups.

PRODUCTION FACILITIES

It is difficult to lay out a foundry and machine shop to produce the proposed pumps when such things as the amount of space available for the facility, the availability and types of machine tools, the skills and incentives of the personnel, and the types of tooling

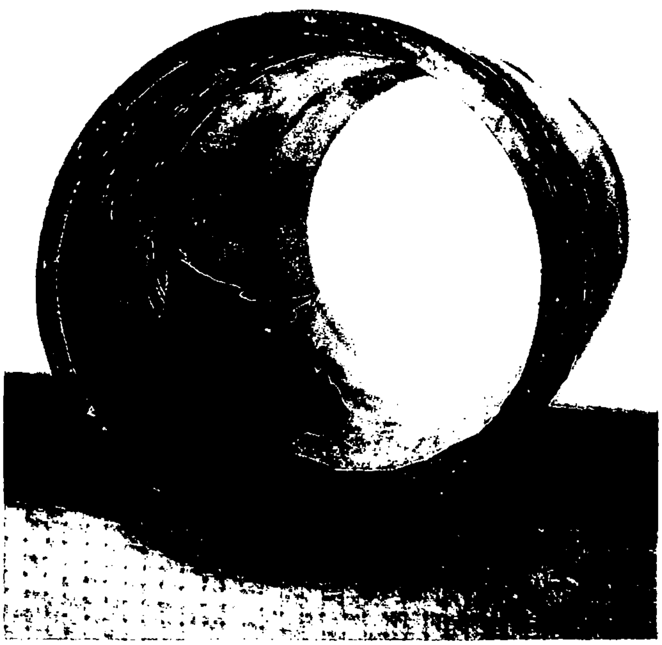
FIGURE 24. LEATHER CUP AFTER EQUIVALENT OF 1-YEAR OPERATION IN PLAIN-STEEL-PIPE CYLINDER COATED WITH AN EPOXY PHENOLIC-DEEP-WELL PUMP WITH GUIDED PUMP ROD

FIGURE 25. LEATHER CUP AFTER EQUIVALENT OF 1-YEAR OPERATION IN PLAIN-STEEL-PIPE COATED WITH A MOISTURE CURED URETHANE-SHALLOW-WELL PUMP WITH UNGUIDED PUMP ROD



39083

FIGURE 26. PLAIN-STEEL-PIPE CYLINDER COATED WITH EPOXY PHENOLIC AFTER LIFE TEST



39084

FIGURE 27. PLAIN-STEEL-PIPE CYLINDER COATED WITH MOISTURE-CURED URETHANE AFTER LIFE TEST

39735

FIGURE 28. LEATHER CUP AFTER SAND TEST IN PLAIN-STEEL-PIPE CYLINDER COATED WITH EPOXY-URETHANE - DEEP-WELL PUMP WITH GUIDED PUMP ROD

39739

FIGURE 29. LEATHER CUP AFTER SAND TEST IN PLASTIC (PVC) PIPE CYLINDER - DEEP-WELL PUMP WITH GUIDED PUMP ROD

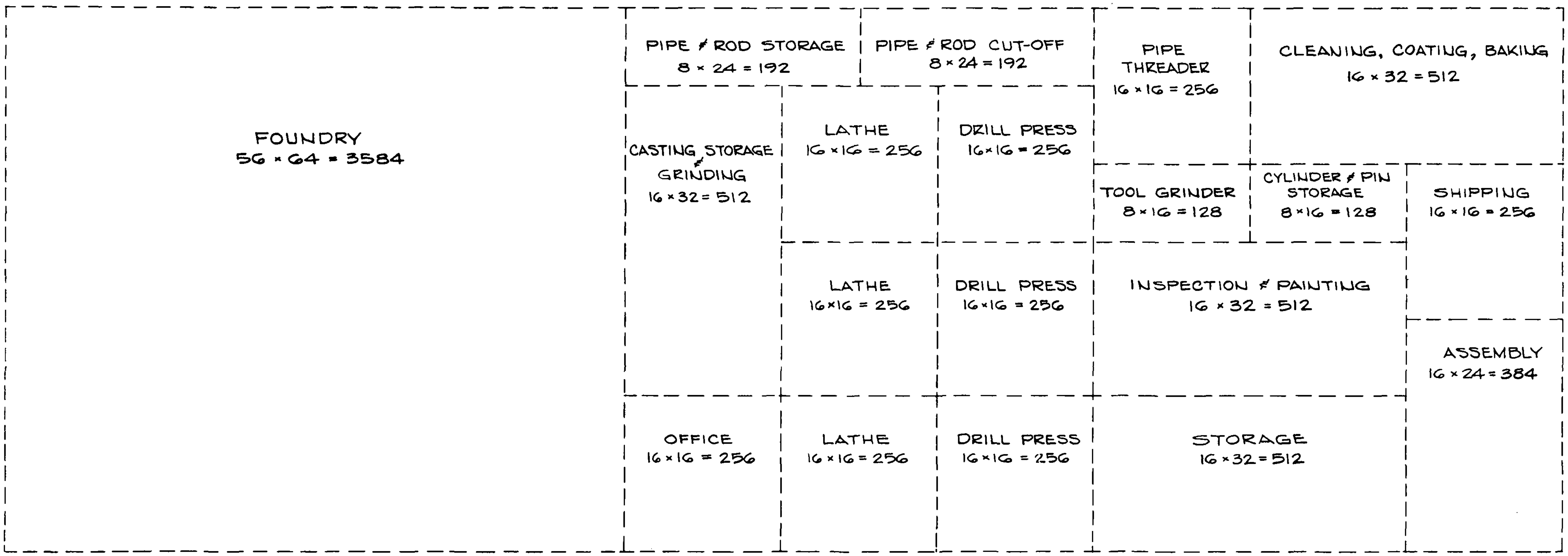


FIGURE 30 LAYOUT OF POSSIBLE FOUNDRY AND MACHINE SHOP TO PRODUCE THE PROPOSED PUMP

and materials handling equipment are not known. However, a typical layout has been made to point out what can be done assuming limited tooling and fixed area per machine.

Machine Shop

Figure 30 shows a proposed layout for a machine shop and foundry. This layout is based on what American planners would like and provides for about 256 square feet per machine (16 feet by 16 feet). The layout does not designate exactly where machine tools are to be placed, where aisles are to be provided, or where pieces to be worked on are to be placed as these are largely dependent on the facility management. Figure 31 shows a scale model of a typical facility. Again, this should be used only as a general guide.

The layout is so constructed that there is a natural flow of materials and parts through the shop. It can be seen that the foundry is on the left; castings proceed from left to right to the machine tools, through inspection, painting, and storage, to assembly and, finally, to shipping. As shown here, finished parts are put into storage and then assembled prior to shipping. There is no reason that assembly could not be made before storage. However, as indicated in the layout, all parts are stored and components can be withdrawn for assembly into complete pumps or shipment as spare parts.

Table 3 gives some indication of needed machine shop personnel. These people, should be capable of producing anywhere from 20 pumps per day to 40 or more pumps per day. The estimate of 20 pumps per day is based on using minimum jigs and fixtures in all operations and using single-point tools. Operation is paced on the component requiring the most time, in the case of the proposed pump, the lower valve housing. With single point tools and jigs and fixtures it is estimated that approximately 2 to 2-1/2 units can be produced per hour; however, depending upon the incentive of the workers, with the change from single-point tools to more complicated, semi-automatic tooling, production could be increased to 40 or more completed pumps per day without increasing personnel.

TABLE 3. MACHINE SHOP PERSONNEL[(a)]

Operation	Number of Persons
Material, handling, shipping, receiving	2
Grinding	1
Lathes	3
Drill press	3
Cut off	1
Pipe threading	1
Pipe coating	1
Inspection and painting	1
Tap-die assembly	1
Foreman	1
Total	15

(a) Number of personnel based on a minimum of 20 pumps per day.

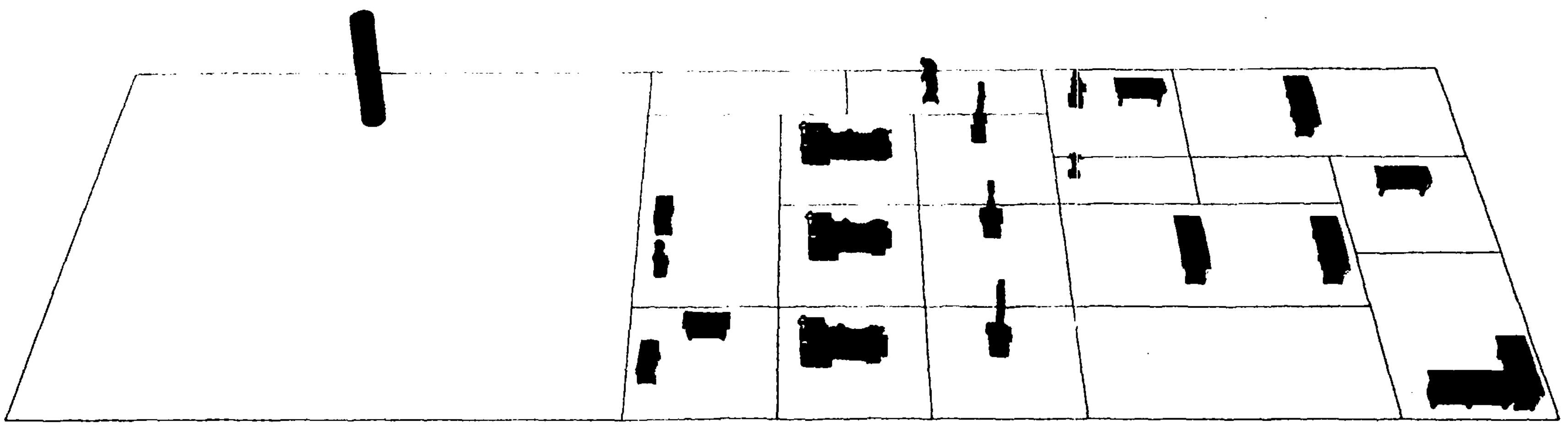


FIGURE 31. SCALE MODEL OF A TYPICAL PUMP FACTORY - MACHINE SHOP AND FOUNDRY

Foundry

Approximately 3600 square feet has been allowed for the foundry area. This is an estimate, of course, and more or less area would be required depending upon the foundry operator and his requirements for aisle space and his method of setting the molds and pouring. The 3600 square feet does not include very much area around the cupola or area for storage of raw materials, coke, etc. Table 4 shows needed foundry personnel. The foundry operation is actually based upon the machine shop requirements. This amounts to about 1200 pieces per week and if two pours per week are made, this is 600 pieces per pour or about 4300 pounds. It is estimated that 10 persons can handle this amount of work, depending upon incentive and the tools these people have to work with. For an increase in production, more than likely personnel would have to be added in the foundry before any persons were added in the machine shop. Personnel in foundry would be expected not only to make the molds but also to assist in pouring, shaking out the castings, and transporting them to the machine shop. It is assumed that the foreman and the material handlers would make the initial charge in the cupola and then would be assisted by the molders during the pouring.

TABLE 4. FOUNDRY PERSONNEL[a]

Position	Number of Persons
Moulders	7
Core makers	1
Material handlers	1
Foreman	1
Total	10

(a) Number of personnel based on pouring 4300 pounds (600 pieces) twice per week.

The shop as shown represents approximately 9000 square feet and 25 persons, and this arrangement can be expected to produce anywhere from 20 to 40 or more completed pumps per day. An increase in production could be made with few additional personnel in the foundry. No specifications are given for the cupola; however, the smallest cupola commercially made in the United States can produce about half a ton per hour and it would occupy a very small area in the foundry.

FUTURE WORK

Battelle staff members feel that this program has been an important one, not from the standpoint of technological improvements, but from the standpoint of giving many peoples of the world water from a reliable source. However, it is felt that the results of this program can be successfully utilized only through an effectively planned program. Such a program can be guided by AID and carried out through AID and other interested agencies, including Battelle. Such a program should have at least four major sections:

(1) Dissemination of information

(2) Field evaluation of pump design

(3) Cup, valve, and cylinder research

(4) Educational programs for developing countries.

These four sections are designed to simplify, introduce, and produce this pump in the developing nations.

Dissemination of Information

It is believed that the results of this program should be carefully described and the proposed pump design carefully explained to all the American Government agencies and industrial organizations interested in and participating in water programs in the developing nations. Such a program would not only aid AID in meeting their objectives, but may also provide financial assistance through these interested organizations to carry out the program. Once a course of action has been established and ratified by all the agencies, a program can be established in terms of production of pumps and maintenance programs with interchangable parts.

Field Evaluation

The suggested program of field trials has three major objectives:

(1) To determine the actual effectiveness in the field of the pump as designed

(2) To simplify pump design

(3) To provide an opportunity for introducing the pump into developing nations.

In addition to revealing the effectiveness of the pump as designed, overall the tests would reveal specifically the effectiveness of the pump guide and the nylon impregnated with neoprene valves. If the trials proceed as expected, it is believed that the pump guide will be shown to be less important for deep-well pumping and that nylon impregnated with neoprene valve might be used for all valves, including the valve in the plunger.

Probably the most important function of the field tests would be introduction of the pump to government officials, future manufacturers, and, most significant, the users. Various reactions, likes, and dislikes can be determined before the final introduction and certain needed modifications are made. A good corrolary to keep in mind is the tremendous amount of field evaluation and public opinion sampling that American manufacturers schedule for their products before general introduction of these products to the market.

Cup, Valve, and Cylinder Research

The most significant improvements and simplifications of the pump design will be related to cups, valves, and cylinders. A limited amount of additional research should yield valuable results.

Cups

Near the end of this program, a tremendous amount of interest was stimulated in material manufacturers and cup fabricators. Many samples of cups were received for trial in hand-operated water pumps. With proper material selection and well-thought-out cup design, there is an excellent chance that a synthetic cup could be manufactured with abrasive-resistant qualities better than that of leather, with manufacturing tolerances approaching that of leather cups, and with ability to withstand many repeated cycles of wetting and drying without cracking. Probably cups made of some synthetic material would not have to be packaged or warehoused under such restricted conditions as leather cups should be.

Valves

Also, near the end of this program it became apparent that the nylon impregnated with neoprene could be quite effective in all of the valve applications. However, there was not time enough to prove this conclusively in the laboratory. Moreover, no field trials had been made in deep wells to determine whether flapper valves can be used in deep-well as well as shallow-well applications. There is some evidence that poppet valves currently used in plungers could be replaced with valves made from a nylon and neoprene combination. Such an arrangement would call for new design of the plunger. However, it should be possible to make a simplified valve that would require virtually no maintenance.

Cylinders

Indications are that an inexpensive but effective cylinder can be made from plain-steel pipe coated with an epoxy phenolic. Such cylinders have been tested and found quite satisfactory. However, application of such a coating does involve a simple baking procedure. During the program, experiments were also conducted with other coatings and a moisture-cured urethane coating was found to give good results. However, unfortunately, either due to improper coating procedure or because of the nature of the material, it was water-sensitive. With continued work a simpler and more acceptable coating can probably be found. As simple as the recommended coating is to apply and to use, it still may be objectionable in some areas because of the need for baking. Therefore, further work should be done to find a still simpler coating.

Educational Programs

Three types of educational programs are recommended. The first type is a program of pump introduction to the countries. Although this would not be a technical program, it deserves careful consideration. Such a program is necessary for the success of the water program. Unfortunately, many peoples of the world have to be taught to drink water from a good source and to develop and maintain the source.

The second program would be directed toward improvement of machining practices. Without question modern technology can improve production without any appreciable increase in cost. For example, manufacturers in developing nations might be shown the necessity for methods of making smooth cylinder bores if iron cylinders are preferred. But more important than this, they might be shown the value of jigs and fixtures for increasing their production rate and for making interchangeable parts. The use of jigs and fixtures alone for assuring interchangeable parts could not be overstressed in any educational program.

Another area of needed education is foundry practices. Better pumps could be made from better materials with better control. A little instruction in the segregation of materials to provide the proper charge would significantly increase the quality of the iron with little increase in cost. The need for analysis and cupola control should also be stressed. An introduction into some of the more important modern foundry practices should be provided.

This educational program may be accomplished in one or both of two ways: The first way would be to offer a program similar to the program being conducted on ground water at the University of Minnesota. Invitations could be extended to selected personnel of various countries to attend symposiums or classes being taught by qualified people in the United States.

A second way would be to put together teams of qualified American personnel to go to the various developing nations and instruct people in their own shops and foundries.

These major educational programs would insure good water and promote disease control in developing countries. They would also further develop friendships that have already been established by AID and similar agencies. The programs as described would be relatively inexpensive to execute if properly planned and staffed.

RDF:DWF/spr

APPENDIX

REPORT ON FOREIGN TRAVEL

APPENDIX

REPORT ON FOREIGN TRAVEL

To properly determine the requirements imposed upon hand-operated water pumps in less-developed countries, a trip was made to five selected areas by D. W. Frink and R. D. Fannon. This report summarizes the information obtained on this trip area by area. This summary is based upon reports, charts, drawings, photographs, and various other records which are on file. Trips were made to the Philippines, Thailand, East Pakistan, India, and Jordan.

MANILA, PHILIPPINES

Date of Visit

August 22 through August 24, 1966

Persons and Organizations Contacted

Mr. Hugh F. Tolley, Engineer, U.S. AID
Mr. Jesus Delfin, U.S. AID
Mr. Philip Ruppert, U.S. AID

NWSA (National Water and Sewage Authority) Wells and Springs Department
PACD (Presidential Arm for Community Development)
EDF (Economic Development Foundation, Inc.)
Occidental Foundry and Shop
Parpana Manufacturing Company

Field Trip

Barrio Bisig, Valenzuela, Province of Bulacan (a small Barrio outside Manila)

Summary of Information

Most of the wells used were installed by U.S. AID through subcontractors in 1957 when a Liberty Well Program was under way. Since this time, two main groups are assuming the responsibility of getting water for the people, NWSA and PACD. These groups still have the help of AID. At the present time, more than 19,000 wells have been established for a total population of more than 4,800,000 people.

The depths of the wells generally vary from 50 to 400 feet; however, the water levels vary from 5 to 75 feet from the surface. Most of the wells require a deep-well pump fitted with 4-1/2-inch casing pipe and they use 1-1/2-inch to 3-inch-diameter drop pipe. Sucker rods vary from 5/8-inch to 7/8-inch diameter, depending upon the total length of rod used, the greater depths requiring the larger diameters.

Most of the cylinders are made from seamless, hard-drawn brass 24 inches long and with a 2-3/4-inch ID. The cylinders are fitted with a 4-leather plunger and bronze ball valves and have a working stroke of 12 inches. The upper ends of the pumps are made of flanges, tees, and other fittings, and there is ordinarily a wooden handle 6 to 15 feet long mounted on a separate base.

About half of the wells that are not producing ran dry. The lack of water is probably due to the wells' not having been dug deep enough or not having been properly placed. The greatest mechanical problem seems to be the separation of the sucker rod from the piston or from another rod either because of stripped (poor) threads or because the piston became unscrewed from the rod. Another problem is the rotting of the wood handle around the pivot-shaft bushing.

The greatest maintenance problems are, first, the replacement of leathers, and second, wear of the stuffing box. Some complaints were made that the couplings wear against the drop pipe and rods separate when 1-1/2-inch drop pipe is used; a 3-inch drop pipe has worked out better. NWSA has assembled some guide lines for their mechanics in regard to preventive maintenance and repair. At present, there are several mobile repair teams that keep up many of the wells; other wells are the responsibility of the barrio in which they are located.

At present NWSA and PACD are planning to construct 56,600 more wells for a ratio of at least one pump per 250 people. Also, at present, it costs approximately 1 peso ($.26) per inch diameter per foot depth to drill a well. Several private windmill-driven pumps are being used in the northern areas, but very little attention is given to this by NWSA or PACD.

There should be no problems in manufacturing acceptable hand pumps in the Philippines. Much more complicated equipment is presently being manufactured in production quantities. It was noted by EDF that at the present time the Philippine industry would rather copy than design. We saw only shallow-well "pitcher" pumps being made and no cylinders for deep-well use. Some double-acting force pumps (copies of the F. E. Myers pump) were being made. Castings will cost 1 to 2 pesos ($.26 to $.52) per kilo (2.2 pounds) and labor rates average 6 to 10 pesos ($1.50 to $2.60) per day. Government regulations must be considered in that a company making a product must make at least 50 percent of the components to be eligible for a tax deduction.

BANGKOK, THAILAND

Date of Visit

August 26-29 and September 4-6, 1966

Persons and Organizations Contacted

Mr. William McQuarry, Engineer, USOM (United States Overseas Mission) (U.S. AID)
Mr. John Brandt, Chief Sanitation Advisor, USOM (U.S. AID)
Mr. Chit Chaiwong, Community Health Development (Department of Health, Thailand)

Field Trip

Regional Headquarters for Northeastern Thailand at Korat (Experimental pump facilities including foundry)

Summary of Information

Approximately 85 percent of Thailand's population is rural and it is toward these people (as in other countries) that the AID program is directed. Since the present AID program has been in effect, approximately 6,300 pumps have been installed. The installation has been mostly by private contractors with AID furnishing the pump, pipe, and half the installation costs. AID is also providing some training in pump repair.

Most of the wells run from 7 to 9 meters (23 to 30 feet) deep, and deep-well pumps are used. The most peculiar circumstance concerning pumps in this area is that it appears that the pump must be "developed" by them in order to be acceptable to them. This was demonstrated by the history of the Korat Gear Pump. The first Korat pump was a joint USOM-Thai design; it tested satisfactorily but was never used. The second was entirely Thai designed and it was accepted. Both designs use American cylinders.

The Korat Gear Pump is composed of two side castings bolted together with bearing blocks top and bottom. These blocks give vertical stability to a rack which is connected to the pump rod. The rack is oscillated up and down by a sector gear to which is attached the handle. The pump is mounted on a base through which and to which the drop pipe is attached. The pump appears to be working satisfactorily.

One of the biggest problems to date is the stocking of replacement parts for all the different pumps used. This situation is being corrected to some extent with the standardization on the Korat Gear Pump.

No statistics were available as far as maintenance is concerned, but the order of repair appears to be as follows:

(1) Leathers
(2) Rod couplings
(3) Handle pivot bolts
(4) Pump rod bushings
(5) Foot valves.

Plans for the future regarding hand pumps include the installation of about 1,500 wells per year by USOM and about 500 installations per year by the Thai Health Department. Also to be installed are 200 force pumps to pump water from ground level to tanks on the tops of school buildings. Much of this work will be concentrated in the northeastern and southern sections.

There does not appear to be any reason why satisfactory pumps cannot be made in Thailand. There are six foundries in Bangkok and several are making the Korat Gear Pump. Although the only foundry we visited was the Government foundry in Korat, the pumps we saw seemed to be of good quality. Some cylinders have been made locally; however, they are generally imported from the United States. Labor rates range from 10 to 30 baht a day ($.50 to $1.50). Leathers are made locally, but imported leathers last longer.

Imported pumps cost about $50 including $15 to $20 for the cylinder. The cost of the Korat Gear Pump is about the same.

Government people are interested in the problems and an experimental facility, including a foundry, has been established in Korat (USOM money).

VIETNAM AND LAOS

These two areas were not visited. The information contained herein was obtained from persons who previously had been assigned to these areas.

Persons and Organizations Contacted

Staff MRDC (Military Research and Development Center), Bangkok, Thailand
Mr. Paul Maynard, Battelle, Bangkok, Thailand
Mr. William G. Westbrook, Battelle, Saigon, Vietnam

Summary of Information

Vietnam

A history of well drilling is given in a paper, "Well Drilling in Vietnam", by Nguyen-Van-Gang. A copy of this paper was obtained and is in our files. In addition, it was learned that the United States Sea Bees in 1964 set up a filtration plant in the south and pumped water from lakes or rivers through the filtering system into water towers. The water was then distributed through plastic pipe. The people liked this arrangement; at that time they were buying water from boat vendors. It was discovered that the people did not want to go very far for water and if well water was not convenient, they would use water from the ponds, etc. Hence, the distribution system increased the usage of well or filtered water. It was reported that two 2-man maintenance teams had been set up to service pumps. A catalog was also obtained from the Montrevil Company located in Saigon describing some French pumps.

Laos

Apparently in 1963 there was only one man familiar with pumps in Laos; however, since that time ten coring drilling rigs have been converted to well drilling. Also during this time, some money has been appropriated to establish a foundry; however, as far as we know, no further action has been taken.

Most of the wells are dug wells, and few, if any, water-table studies have been made. Some of the dug wells are lined with cast-concrete rings 3 feet or so in diameter and 18 inches in length. These wells are 15 to 20 feet deep. Some windmill-driven pumps have been tried, but lack of maintenance has terminated this.

DACCA, EAST PAKISTAN

Date of Visit

August 30 through September 3, 1966

Persons and Organizations Contacted

Mr. James Cassanos, Engineer, U.S. AID
Mr. Salam, Chief Engineer, Public Health
Representatives of Camp, Dresser, and McKee, Consulting Engineers
Mr. M. H. Khan, Executive Engineer, Comilla and two other districts

Field Trip

Comilla and two other districts (45 minutes by air south of Dacca)

Summary of Information

At the present time, the Department of Health or equivalent office of East Pakistan (of which Mr. Salam is Chief Engineer) is responsible for making water available to the people. AID has done quite a bit in the past and probably will do more in the future, as far as hand pumps are concerned; however, East Pakistan is now doing much of its own financing.

With the exception of those in the coastal area of the Bay of Bengal, most of the pumps are shallow-well pumps with water levels not exceeding 15 feet or so from the surface. In the Bay of Bengal area, some wells are as deep as 700 feet; however, the water level in most of the wells is within 20 feet or so of the ground surface and shallow-well pumps are used. In a few wells where the water in the well is deeper, modified shallow-well pumps are used.

There is very little rock or stone in East Pakistan and tube wells can be sunk by hand by a method called the sludger method. Wells are also sunk by the water-jet system.

Practically all of the pumps that are used in East Pakistan are a fairly close copy of the Maya No. 6 pump made in Calcutta, India. Prior to their independence, the people of East Pakistan obtained practically all of their pumps from India; however, since their independence, several foundries in Dacca and Chittagong have supplied East Pakistan with a poorer quality "Maya" pump. This pump is a cast-iron pump with a cylindrical stem which is bored for a 3-1/2-inch leather plunger.

The problems are manifold:

(1) Only a single rough cut made to size the bore
(2) Very poor threads on pump parts and bolts
(3) Very poor fit between plunger and plunger rod
(4) Poor poppet valve facing
(5) Poor quality leather
(6) Too brittle cast iron
(7) Poor quality steel used to make plunger rods and bolts
(8) Many pump parts become useless in storage because of rust and mildew.

At the present time, the responsibility for the pumps lies within the Union Council, which is the smallest political group and represents about 1,600 people. Also at the present time, there is one mechanic in each Thana, which is the next highest political group; however, they are gradually increasing the mechanics to two per Thana. As far as parts are concerned, they can be obtained from government warehouses; however, as soon as these components are depleted, the Union Council will purchase them on the open market.

There are approximately 150,000 hand pumps in East Pakistan and many more are needed. As in all the other areas we visited, longer operating times between maintenance periods are desired. The major problem is the short 2- to 5-month life of the leathers due to the rough bores and poor quality leather as well as constant use of the pump. Poor leather also contributes to the relatively short life of bottom flapper valves. Piston rods are constantly pulling out of pistons because of poor threads, and poor steel used in bolt manufacture makes necessary constant bolt replacing. The handles are continually being replaced, mostly because of breakage. In some areas pumps are being replaced every 4 to 10 years. As in other areas, very few hand tools were seen and very few, if any, parts were repaired; rather, they are replaced.

East Pakistan is capable of manufacturing its own pumps, but it does appear that some of its manufacturing techniques could be improved upon.

One foundry we visited could pour 40 tons of metal a week, and this could be increased to some extent.

At one time, the hand pump cost $7 or $8 American money; however, this cost has increased somewhat during the last few years. Present labor rates range from 2 to 10 rupees ($.40 to $2.00) a day for unskilled to skilled labor. Pump installation costs about 300 rupees ($63.00) for labor and is generally accomplished by a contractor.

The government is active and would like to be more active in improving hand pumps; however, the lack of technical experience and the existing methods of doing business are real handicaps. For example, 7 years ago a leather-evaluating machine was developed, but the testing parameters were loosely defined and the data obtained not reliable. Unfortunately, it was used only a few times.

CALCUTTA, INDIA

Date of Visit

September 8 and 9, 1966

Persons and Organizations Contacted

Mr. Robert Harris, Sanitary Engineer, U.S. AID
Professor Majumder, All-India Institute of Hygiene and Public Health
Mr. L. K. Majumder, Chief Engineer, Public Health Engineer, Government of West Bengal

Maya Engineering Works, Calcutta, India
JPSR Company (Mittra Dass Ghose & Company), Howrah, India (across Ganges River from Calcutta)

Field Trip

Rural Health Unit and Training Center, Singur, India

Summary of Information

The installation and care of hand pumps in India is the responsibility of Public Health Engineering, Government of West Bengal. At present very little AID assistance is being given in this area. India is much in need of more pumps, but in the area we visited, Singur Health Center, a training and demonstration center, use of protected water or water from tube wells is much more common.

The basic pump used is the Maya No. 6 pump. Most of the wells are 100 feet to 150 feet deep, but the water rises to a level where shallow-well pumps can be used. There are some areas in Calcutta, however, where the water table is being pulled down because of the demand and new pumps being installed must be of the deep-well type.

The maintenance problem was very well documented for a period in the Singur area. Some of the replacements, listed in order of frequency, are as follows:

(1) Bolts and nuts
(2) Leathers
(3) Lower flapper valve
(4) Lower flapper valve weight screw
(5) Piston rod
(6) Plunger.

It was claimed that an inoperable pump could be repaired within 48 hours. This, if really possible, is good; but faster repair might be of necessity not only to maintain health, but also to keep the pump from being broken up by the people.

One of the biggest problems is the maintenance of the tube well strainer. Apparently the screens have to be rebuilt every 4 or 5 years. Cost of maintenance has been between 9 and 10 rupees ($1.20 to $1.35) per year per pump.

The intention of the government officials is to have a well for not more than 130 to 150 persons and within 2 furlongs of each home, an intent much easier to state than to carry out.

As in East Pakistan, parts rusting in storage also presents a problem. Rusty pump bores decrease cup life.

Only two pump-producing companies were visited; however, there seems to be no problem in capability or facilities for producing pumps. It is believed, however, that some improvements in machining techniques might be helpful. These companies make their own screens from slotted galvanized pipe covered with 60-mesh brass screen.

Labor rates range from 2 to 3 rupees ($.26 to $.40) per day for unskilled labor to 4 to 5 rupees ($.52 to $.70) per day for skilled labor.

AMMAN, JORDAN

Date of Visit

September 15 and 16, 1966

Persons and Organizations Contacted

Mr. George Bell, Sanitary Engineer, U.S. AID
Mr. Aied Sweis, Engineer, U.S. AID

Ministry of Health and Environmental Sanitation

Field Trips

Jarash and Ajlon (40 and 55 miles, respectively, north of Amman)
Ramallah (60 miles west of Amman)

Summary of Information

There are practically no hand pumps in use in Jordan, and all the programs concerned with water are large-scale programs utilizing engine-driven pumping systems.

Two days of investigation did reveal a few force pumps to pump water from cisterns to roof-top tanks. The Ministry of Health and Environmental Sanitation did have some hand pumps in stock which were made in Czechoslovakia, the United States, and Jordan. The pump made in Jordan is a copy of an American pump made by a company no longer in business.

A few pumps have been installed by this Ministry, but those we could find were of Polish manufacture and of the oscillating-vane type, and they have not been working for some time.

There is need, however, for hand pumps in Jordan. Many dirty wells were seen where one or two villages were dependent upon a well for water and the only means of obtaining the water was a rope and bucket.

No factories were visited as there were none to see. There is apparently little government concern for a hand-pump program.