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Sponsor: Agency for International Development

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GEORGIA INSTITUTE OF TECHNOLOGY
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Project Title: HSL II - Technical Assistance, Handpump Evaluation

Project No: A-2195

Project Director: Phillip W. Potts

Sponsor: Agency for International Development

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DEVELOPMENT OF A MANUFACTURING CAPABILITY FOR THE AID/BATTELLE HAND PUMP IN THE DOMINICAN REPUBLIC

Prepared for
The U.S. Agency for International Development

by

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June 1979.
CLARIFICATION

The opinions expressed in this report are those of the author, and do not necessarily represent the views of the Georgia Institute of Technology, nor of the U.S. Agency for International Development. Comments made about any product or company should not be construed as being either endorsements or criticisms by these institutions.

Full responsibility for any opinions expressed, and for any oversights, omissions, or errors, rests with the author alone.
ACKNOWLEDGEMENTS

The author owes a great deal to those who have assisted him in his work on this project. At the risk of offending through omission, acknowledgement is expressed for the help of the following individuals.

A co-worker of the author, Phillip Potts, is a Senior Research Scientist at the Georgia Institute of Technology. It was on his initiative that the project was originally proposed, and he laid the ground-work preparing for it. He was responsible for the field-testing of the AID/Battelle pump in Costa Rica and Nicaragua; he made three trips to the Dominican Republic to prepare for and initiate this project, and he provided continuing advice and support.

Engineer Manuel Valdes, of AID/Dominican Republic, introduced the author to the Dominican personnel who participated in the project. Based upon his own experience with water pumps, as well as his decades of engineering work in the Dominican Republic, he gave technical and related advice which contributed greatly to the achievement of the project.

Many other personnel from AID, the Dominican Secretariat of Health, the Georgia Institute of Technology, and manufacturers in the Dominican Republic, made important contributions to the project, for which the author is grateful.
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AID/Battelle deep-well pump installed in the community of Ceiba de Madera, Moca, in December 1978. An estimated 175 people are provided with water by this pump. The well was dug by hand, and has a pumping depth of 33 feet. The user must exert 21 pounds of force on the handle to pump water.
SUMMARY

Two manufacturers in the Dominican Republic have now produced a total of 46 AID/Battelle pumps. This has been accomplished with technical assistance from the Georgia Institute of Technology's Office of International Programs, under contract with AID.

The 46 pumps were made in two stages. First 24 pumps were made and delivered in December 1978 and January 1979. These were installed in already existing wells for field testing. A second group of 22 pumps was delivered in May 1979. Two of these are remaining in the Dominican Republic to serve as models for future manufacture (pending approval from AID/Washington), and the remainder are being shipped to other countries to serve as models for possible manufacture of similar pumps elsewhere.

The first group of pumps were of reasonable quality, considering that the manufacturers had no previous experience making pumps. They are performing well in the test sites, although they had a good deal of room for improvement.

The second group of pumps is of significantly improved quality. The dimensions of the pump components do not always fall within the tolerances called for by the design, but they are close enough for it to be reasonably expected that future pumps can be made within the tolerances called for.
Part of the reason that the pumps made thus far have not been fully within specified tolerances, is that the manufacturers had difficulty understanding the original design drawings because they were in English. This difficulty was further aggravated by the fact that some changes were made from the original design. However complete up-to-date design drawings have now been prepared in Spanish (these are presented in Annex A of this report). This should greatly facilitate future production of the pumps.

In spite of the fact that the model pumps from Central America were not identical to what was desired in the Dominican Republic, they were nonetheless of tremendous value. Local manufacturers have a difficult time visualizing a final product from design drawings, and a model is therefore almost essential.

Some modifications from the original design, prepared by Battelle Laboratories for AID, have been made. These include the use of a PVC liner in the pump cylinder, and the use of the same "tower" shaped upper pump rod guide and pump cap, for both the shallow-well and deep-well model pumps. Previously Battelle had offered a simpler design for the guide and cap of the shallow-well pump, but field experience has indicated that it is inferior and not recommendable. This is mainly because children tend to stuff rubbish into the large hole in the cap of this design.
The shallow-well model is recomended for wells up to 22 feet deep, and the deep-well model for wells from 22 to 100 feet. The deep-well model can be used in even deeper wells, but it is felt that alternative, more expensive, pumps are recommendable for wells deeper than 100 feet.

Anticipated prices for large quantity orders of the pump are higher than early estimates. These prices are not known with certainty yet, because formal bids have not yet been requested for such large orders. Also, there still remain some opportunities for lowering the cost of manufacture, such as modifying the design of the piston. Prices should be between US$ 100 and US$ 175 for the shallow-well pump, and about US$ 25 more for the deep-well model.

The Dominican machine shops and foundaries have demonstrated a higher level of competence than could be expected in most developing countries. They are clearly competent to produce the AID/Battelle hand pumps.

The AID/Battelle pumps should need no more maintenance than the best reciprocating hand pumps available from other countries. However, there is no such thing as a maintenance-free pump, and adequate preparation must be made for a maintenance program.
BACKGROUND

In response to the need in developing countries for a reliable and improved supply of safe water, and the corollary worldwide need for a long-lasting, easily repaired, economical, locally manufactured hand pump, the Agency for International Development (AID) began in 1966 a series of contracts with the Battelle Memorial Institute to design and Laboratory test a reciprocating shallow and deep-well hand pump. A final design was developed and, in late 1976, AID contracted with the Office of International programs at the Georgia Institute of Technology to evaluate the performance and acceptability of the AID pump in comparison with other pumps used in developing countries, and the feasibility of local manufacture of this pump. This work was carried out in Costa Rica and Nicaragua.

By January 1978 sufficient progress had been made to draw the most important conclusions. It was concluded that, with some limited design modifications, the pump was suitable and recommendable for meeting rural water supply needs in many developing countries. It was pointed out that the availability of adequate foundry facilities with acceptable pump prices and quality controls are matters that must be determined for each individual developing country.
In early 1978 Phillip Potts, Senior Research Scientist at the Georgia Institute of Technology, made two preliminary visits to the Dominican Republic. During these visits it was concluded that the level of machine shop and foundry skills existed to produce the AID/Battelle pump. Preliminary estimates by local shops indicated that the price of large quantity orders would be competitive on the world market.

A contract was signed in August 1978, between AID/Dominican Republic and the Georgia Institute of Technology, which was implemented between August 1, 1978, and June 30, 1979. The central objective of this contract was to develop a local capability to manufacture the AID/Battelle hand pump, and to field-test and evaluate prototypes of pumps.

AID was especially interested in achieving this because it was at the time negotiating (and has since signed) an agreement with the Dominican government referred to as the Health Sector Loan II agreement. This agreement includes the objective of installing approximately 2,650 hand pumps in the western region of the country. AID wanted the option of locally manufacturing these 2,650 pumps, because this could be expected to result in prompter and more convenient availability of spare parts, generation of local employment, and possibly lower prices for more appropriate pumps.
The description of the statement of work in the contract includes the following:

1. Providing technical assistance concerning the AID/Battelle water pump to local manufacturer(s).

2. Selecting field-test sites and providing technical assistance in preparing the sites for pump installation.

3. Providing technical assistance to local, rural villagers and/or governmental agencies in the installation of no less than 20 AID/Battelle pumps.

4. Determining the quality of water through chemical and bacteriological analysis.

5. Testing of locally manufactured pumps under field conditions for a four month period.

6. Preparing a final progress report.
Two local machine shops/foundries were contracted to produce a total of 46 AID/Battelle pumps. The first of these pumps were paid for out of the contract between the AID mission in the Dominican Republic, and the Georgia Institute of Technology (G.I.T.). The next 22 pumps were paid for out of a separate contract between AID/Washington and G.I.T., for shipment to other countries where they can serve as models for possible local manufacture.

The two shops which made the pumps can be considered to be among the best representatives of the two extremes of factories existing within the Dominican economy. One, INDUSTROQUEL C. por A., is a small shop in which the owners themselves are machinists who personally supervise everything done there. They exhibit enthusiasm, technical competence, and dedication. The other factory is ASTILLEROS NAVALES DOMINICANOS C. por A., (Dominican Naval Shipyard, Inc.). This is a very large and even bureaucratic operation, owned by the Dominican government but operated on a competitive basis as if it were part of the private sector. It appears to have more and better machine shop and foundry equipment than any other factory in the country. Each aspect of its work is supervised by different people, sometimes resulting in
coordination problems. They have a sales manager, a chief engineer, a supervisor for the machine shop, and a supervisor for the foundry (who unfortunately died of a heart attack during the course of this project).

At the end of August, 1978, these two shops began work on their first pumps, and these were delivered during the period from late November 1978 through early January, 1979. These included six shallow-well models and six deep-well models from each shop, resulting in a total of twenty-four pumps.

Twenty-one of the twenty-four pumps were installed in wells in the Cibao valley. The remaining three were used to provide spare parts. Most pumps were installed in December 1978, although a few were installed the following month.

The test pumps are now all functioning well. Representatives of the Secretariat of Health, AID, both manufacturers, and the Georgia Institute of Technology, have inspected these pumps and been favorably impressed.

Initially, some of these pumps had problems, which was to be expected when a product such as this is introduced into production in a country for the first time. As subsequent orders are processed through the manufacturer's plant and as personnel become familiar with the pump itself, quality control should be
refined to the point where the orders are considered to be normal production. This has been borne out by the significant improvement in quality, and the more rapid production of, a second group of pumps ordered in February 1979 and delivered less than two month later.

The problems encountered were limited to only a few of the first 24 pumps, and were not found in any of the group of 22 additional pumps ordered later. These problems are described in detail in the following section of this report.

An attempt was made to properly prepare, disinfect, and test for bacteriological contamination, the wells which were used for testing the original prototype pumps. The results were disappointing, but did provide information of value to future programs. This is discussed in Annex C, "Water Quality".

G.I.T. additionally provided the AID mission with some services not specifically called for in the contract. This was done upon mutual agreement, because these services were of assistance towards accomplishing the objectives of the contract. These additional services included the following:

A regional laboratory was set up in the city of Santiago, in the Cibao valley, for the testing of bacteriological quality of water samples. Dr. Fisher Craft, of G.I.T., spent one week teaching a group of Dominican hospital technicians how to operate the laboratory. This is discussed in Annex C, "Water Quality".
This final report includes the evaluation of the quality of second group of pumps, locally manufactured under a contract between G.I.T and AID/Washington. An amendment was made to the original contract with AID/Dominican Republic, extending the completion date of the project from March 30, to June 30, 1979, in order to allow time for this additional evaluation. However, no addition was made to the total project budget.

A full set of design drawings and specifications, in Spanish, have been prepared. These are presented in Annex A, and a larger set of original drawings in being presented separately to AID.

The AID mission and the Dominican Secretariat of Health have been provided with advice concerning alternate hand pumps. This has been done informally over the course of the project, and is summarized in Annex E, "Alternate Pumps".
EXPERIENCES IN PROTO-TYPE MANUFACTURE.

It was fully expected that a fair number of problems would be encountered the first time AID/Battelle proto-type pumps were manufactured in the Dominican Republic. A primary reason that AID contracted the Georgia Institute of Technology (G.I.T.) to provide technical assistance was to guide local manufacturers in overcoming such problems. In fact, all such problems were overcome.

Before discussing the problems encountered, this should be placed in the perspective of realizing that in general the project went very well. Two out of the three local manufacturers who were originally contracted to produce proto-types, displayed a commendable level of competence and dedication. By the end of this project they had produced pumps of acceptable quality.

Following is a discussion of the more notable problems encountered in the manufacture of the first group of 24 proto-type pumps.

- Failure of One Manufacturer to Meet Commitments:

One out of the three manufacturers originally contracted, gave the pumps a low priority, produced almost nothing, and had to be dismissed from the project. Originally three manufacturers were to produce 8 pumps each. Between August and November, 1978, SOSA C. por A. began work on patterns for casting the pump compo-
nents, but neither completed this nor accomplished anything else. Therefore they were dropped from the project and the orders from the other two manufacturers were increased from 8 to 12 pumps each. Increasing these orders at such a late date was the main reason why some of the pumps were not delivered until January, 1979.

- Faults In Design Drawings And Model Pumps:

  The design drawings and the model pumps brought from Central America both had some faults (although they were nonetheless of tremendous value). Because the drawings were in English, they were of only limited use. Also, some design modifications did not appear on the drawings or in the Central American models, and were handled verbally.

- PVC Plastic Liner For Cylinders:

  In Central America it had been concluded that a PVC plastic liner should be placed in the pump cylinder. However, it was left to each country which might manufacture the pump, to determine how best to accomplish this. The solution will vary from country to country, depending upon what is available in the local market and what local manufacturers are capable of producing.

  In the Dominican Republic it was decided to specially manufacture a PVC pipe with an interior diameter of 2.75 inches, and
an exterior diameter of 3.068 inches (corresponding to the I.D. of the galvanized steel pipe into which it is inserted to form the cylinder liner).

Ultimately this solution worked in an excellent manner. However, the production of the original PVC pipe, by ALAMBRES DOMINICANOS C. por A., involved a number of delays. The first pipe was not ready until October 1978, and it was then discovered that it had a "ripply" interior. There was no known precedent upon which to determine if such "ripply" PVC would create an unacceptable amount of wear on the piston leather cups which rub against it on every stroke of the pump operation. Therefore samples of the PVC were taken to G.I.T. in Atlanta, where they were laboratory tested. A motor-driven "hand" pump was lined with this PVC and used to pump water 24 hours a day, at about the speed (gallons per minute) that a person would pump. After pumping 64,000 gallons, no significant wear had taken place on the leather cups rubbing against the PVC, and so the "ripply" PVC was determined to be acceptable. (The test was continued and little wear had taken place even after about twice this number of gallons had been pumped).

Although ALAMBRES DOMINICANOS produced a smaller quantity of pipe for the prototype pumps, they have stated that in the future it would not be worthwhile to produce less than RD$ 2,000 (about US$ 2,000) worth of this special PVC pipe at a time. The
cost would be about $1.40 per foot, which is equivalent to $1.63 for the 14 inch piece needed for each pump (allowing for wastage, this might be estimated to cost about $1.75 per pump). This price is quite reasonable. It should be noted that the minimum order of $2,000 worth of pipe corresponds to a quantity sufficient to make about 1,143 pumps.

- Tolerances:

Tolerances have not been within the +/- 1/32 inch specified for most dimensions in the design drawings. In the original group of 24 proto-type pumps this resulted in some pieces fitting too loosely, while others fit too tightly. The poor tolerances were nonetheless good enough for the pumps to function well during the test period. However, they can be expected to result in increased wear over the long term.

In the second group of pumps, manufactured to serve as models for use in other countries, the dimensions were very significantly improved. They still tended to be outside of the specified tolerances which would result in an optimal pump, but they were close enough to result in acceptable pumps.

Now that the factories have had experience producing the pumps it can be expected that they can produce future pumps within the tolerances specified on the design drawings. This will be further facilitated by the fact that they will have drawings in Spanish, and that factory personnel have visited the field test sites and have a much improved understanding of the purpose of the component designs and tolerances.
QUALITY CONTROL AND INSPECTION OF PUMPS.

The major responsibility for quality control in the manufacture of the pumps should be left in the hands of the manufacturer. This can be enforced by means of requiring that they provide a limited warranty, as described in Annex A.

In any case at least the first ten pumps manufactured as part of a larger order, should be carefully inspected by a representative of the purchasing agency. A calipers should be used to measure all dimensions and assure that they are within specified tolerances. A simple inspection may reveal any large and unacceptable air pockets in the cast iron components.

After the first ten pumps have been inspected, not all pumps need be carefully inspected by the purchaser. The author would suggest that careful time-consuming inspections be made, by the purchaser, with unacceptable pumps being rejected, only until quality improves to where ten sequential pumps are found to be acceptable. At this point he will know that the manufacturer fully understands and is capable of meeting the design specifications. With luck this will take place from the start, with acceptance of all pumps.

Once it is demonstrated (by the acceptability of ten sequential pumps) that the manufacturer is capable, later inspections can be left to the manufacturer himself. He will have
ample incentive to do proper inspection, as a result of the warranty he must provide with the pumps, as well as the fact that his reputation, and future orders, will depend upon his providing good quality control.

In regard to the control of ingredients used in the making of the cast iron, the following should be considered. These ingredients, and especially the phosphorus content, are critical if the iron is not to be unduly brittle or otherwise unacceptable. The purchaser could pay a laboratory to determine the contents of cast iron samples, but this has several disadvantages. First of all, as compared to the simple inspections of dimensions and appearance of the pumps, such laboratory analysis would be time consuming, inconvenient, and costly. Secondly, even if some pumps were determined to be made of acceptable cast iron, this would not assure that other pumps did not have unacceptable cast iron.

As an alternative to the purchaser's testing for the contents of the cast iron, it is suggested by the author that this also be left to the manufacturer. It is specified on design drawings number 101 and 102 that the manufacturer must assure that the cast iron is of acceptable quality.

It is important to note that the leather cups must be of good quality and of the proper size, as specified in the corresponding design drawing. This is discussed in Annex I, "Fabrication Of Leather Cups".
PRICES

The price of locally manufactured hand pumps, when ordered in quantity, will probably be significantly greater than was anticipated at the beginning of this project. However, the actual prices will not be known until formal bids are made.

At the beginning of this project, local manufacturers made preliminary rough estimates that the price of the shallow-well model AID/Battelle pump, when produced in large quantities, would be around RD$ 110. The price of the deep well model would be about RD$ 135. However, now that the manufacturers have had experience making the pumps, they have increased these estimated prices to RD$ 175. for the shallow-well, and RD$ 198. for the deep-well pumps. (Officially RD$ 1.00 equals US$ 1.00).

These estimated prices for locally manufactured pumps are higher than for an approximately equivalent pump produced by Dempster Industries Inc. in the U. S. A Dempster Model 21OF pump, together with a 2.1/2 inch diameter PVC plastic cylinder and brass piston with double leather cups, has a total list price of $ 185.50. They have recently sold pumps to Church World Services in the Dominican Republic with a 50 % discount, equivalent to US$ 92.75 F.O.B. Nebraska, plus shipping.
Of course U. S. made pumps do not provide the advantages of ready local availability of spare parts and employment generation in the Dominican Republic. They represent an increased drain on Dominican balance-of-payments reserves. Also, when comparing prices it can be hoped that the price for Dominican made pumps will be reduced first during the bidding stage, and reduced still further as the factories gain experience in the future. Some opportunities for further price reductions are presented below.

Additional investigation is still needed for two possible ways to significantly reduce the price of the pump. First of all, the agency purchasing the pumps could separately purchase much of the material needed for manufacture, and then pay a local manufacturer to fabricate them. These materials are listed in Annex G. INDUSTROQUEL C. por A. has stated that it could reduce the price of the deep-well pump from RD$ 198. down to RD$ 128.75, and the price of the shallow-well pump form RD$ 175. down to RD$ 124., if is supplied with all materials except leather for the cups and materials for the iron castings.

The purchasing agency could probably buy the needed materials more cheaply than can the local manufacturers. This could possibly reduce the cost of the average pump by at least $10.00.
Another opportunity for reducing the cost of the pump without sacrificing quality, lies in the possible change of the piston design. This change would include making the piston form polyethylene discs, instead of cast iron. Such a plastic piston could be produced for under $2.00 (not including leathers), as compared to the current cast iron piston which represents about $16.25 of the price of the pump. This is more fully discussed in the "Follow-Up Activities" section of this report.

In summary, if all of the cost reduction possibilities mentioned are successfully accomplished, then the shallow-well model pump might cost as little as US$100. Otherwise, it might cost as much as US$175. The deep-well pump would cost about US$23.00 more than the shallow-well pump.
PUMP USAGE

The AID/Battelle shallow-well pump can be used in wells up to 22 feet deep (depth measured from the surface of the water in the well to the base of the pump). At elevations greater than 1000 feet above sea level, this would have to be slightly reduced, but such elevations are not typical of the populated areas in the Dominican Republic.

For wells less than 22 feet deep either the shallow-well or deep-well models could be used. However, the shallow-well model is recommended because it is easier to maintain, and is also lower in price.

For wells greater than 22 feet deep, the deep-well model should be used. There is no precise limit to the maximum depth at which this pump can be used, but the author feels that a 100 foot limit might be appropriate for the Dominican Republic. It could be used successfully at greater depths, perhaps up to about 150 feet. However, this would require that the users exert a proportionately greater force on the handle, and would also cause a proportionately greater stress and wear on the pump components. This would result in the need for increased maintenance, and at the same time maintenance would be made more difficult by the great depth of the well. Even at 100 feet, it can be calculated that theoretically, the user will have to
exert a force of 60 pounds on the pump handle in order to pump water. (Annex H., contains a discussion of the subject of the force that must be exerted on the handle).

Once the pump is installed, almost any healthy persons, including children, should be able to use it comfortably and fairly easily. The shallower the well the easier it will be to pump water and to maintain the pump, and the less costly will be the construction of the well. Nonetheless the pump should provide excellent service at depths up to at least 100 feet, and possibly deeper. With proper maintenance, it will provide many years of service and help to meet one of the pressing needs in rural areas of the Dominican Republic.
The key to the continued functioning of a hand pump is adequate maintenance. If maintenance is not going to take place, then it is probably a waste of effort to install a pump, because it will eventually break-down. Most hand pumps throughout the world, apparently including in the Dominican Republic, are not functioning because they have not been maintained.

This report cannot devote as much space to this subject as its importance would call for. The subject is adequately treated in publications listed in Annex J, "Recommended Publications". This together with Annex F, "Spare Parts", should provide those with responsibility for developing a maintenance program, with an adequate orientation.

Here it will merely be mentioned that the AID/Battelle pump was designed with the specific objective of withstanding serve intensive use, and should therefore need equal or less maintenance than competitive reciprocating hand pumps which might be imported. Nonetheless, there is no such thing as a maintenance free pump.
"FOLLOW-UP" ACTIVITIES

It is recommended that AID and/or other interested agencies in the Dominican Republic do the following "follow-up" actions related to manufacture of the AID/Battelle pump.

As discussed in the "Prices" section of this report, it would be worthwhile to investigate the possibility of using a polyethelene disc design for the piston, instead of the current cast iron design. This could lower the cost of the pump by about $15.00, without sacrificing quality. However, the polyethelene design for which the author has left a sample with AID, has only thus far been used (in Bolivia) for pumping depths less than 40 feet. It will require some design modification and experimentation to develop a similar piston which can withstand the pressures associated with deeper wells. Experimental models could be made in a local shop, and they could readily be installed in some of the AID/Battelle test pumps which are already functioning in the Cibao valley. A local factory, Polyplast C. por A., and possibly other factories, should be able to make the piston economically. The author has left related information with AID personnel.

Purchasing agencies may possibly want to investigate how much money could be saved by purchasing materials separately, and paying local manufacturers to fabricate pumps from such materials (see Annex G).
RECOMMENDATIONS

1. "Follow-up" activities outlined in the previous section should be pursued.

2. The pump design shown in the design drawings and specifications of Annex A should be used. This design includes some improvements over the original Battelle design, based on the lessons learned from field testing of the pump. These changes include the use of a "tower" shaped pump rod guide on both shallow-well and deep-well model pumps (Battelle recommended a simpler but not as advantageous a design for the cap of the shallow-well pump). It also includes the use of a PVC pipe specially manufactured with an interior diameter of 2.3/4 inches, as a cylinder liner. Other modifications were more minor.

3. As part of the specifications, the manufacturer should be required to provide a one year limited warranty for replacement of any pump components which are defective when they leave the factory. This is described in Annex A.

4. For an order of the magnitude of roughly 2,650 pumps which will be needed for the Health Sector Loan II project, attention must be given to the RATE at which a local manufacturer will be required to produce the pumps. The manufacturer will probably have to invest in an expansion of his facilities to produce the pumps. Therefore, the more time the deliveries are spread out over, the less he will have to invest in expanding and the longer
he will be able to utilize the expanded operation.

For convenience and efficiency, delivery should probably be in batches of many pumps at a time.

If, for instance, it is decided to require delivery of one batch every 3 months, then the following schedule might be approximately appropriate. The first batch should be very small, to make sure that the manufacturer is meeting all of the specifications (the pumps produced thus far have been close to, but not within, the specifications of Annex A). A first batch of between 10 and 50 pumps would seem about right. Three months later a batch of about 50 to 100 pumps might be required. After that, roughly 100 pumps every three months could be required for the next 6 to 12 months. Finally larger orders could be required.

5. Adequate storage must be provided. Leather cups must be stored in a dry area free from mildew. Unpainted steel components, such as the pins which hold the handle and fulcrum assembly, should be coated with oil or grease before they leave the factory. This will both minimize corrosion while in storage, and provide lubrication when the pump is installed.

6. For wells deeper than 100 feet, alternative pumps described in Annex E should be considered.
7. Attention must be given to the manner in which the pumps are installed. This is discussed in Annex B.

8. Adequate spare parts must be provided, although it is difficult to predict the quantities needed. This is discussed in Annex F.

9. Creation of a good maintenance program, including training of those responsible for maintenance, should be given a high priority.
LIBRARY DOES NOT HAVE

Design Drawings and Specifications
DISCUSSION OF SPECIFICATIONS

Design drawings and specifications, in Spanish, are presented on the following pages. The author recognizes that AID may also eventually need specifications in English. Nonetheless Spanish was chosen for the following reasons:

- G.I.T. was contracted to assist in the development of a local capability to manufacture the AID/Battelle pump. The need to prepare drawings and specifications in Spanish was directly related to development of this local manufacturing capability.

- Betty Facey, AID engineer, requested in writing that such drawings and specifications be prepared in Spanish.

It should be realized that these Spanish drawings and specifications are only partially a translation of the original drawings, prepared by Battelle Laboratories. Among the changes are modifications of the pump cap and fulcrum, and addition of a PVC plastic liner, as recommended by G.I.T. field testing in Central America. Also, where Battelle offered several options for the design of certain components, the Spanish drawings present only the options recommended for use in the Dominican Republic. A piston (plunger) assembly with double leather cups is the only piston shown in the design drawings, and is to be used for all pumps (Battelle had previously offered the option of a single leather cup for shallow-well pumps).
WARRANTY AS PART OF SPECIFICATIONS

The author strongly recommends that a requirement for a limited warranty be added to the specifications presented on the design drawings. It is suggested that the required warranty be approximately like the following:

All pumps must be warranted for one year against defects in materials and workmanship and to perform adequately when properly installed, operated, and maintained. The shallow-well model pump will function in wells up to 22 feet deep when used in locations between sea level and 1,000 feet elevation. The deep-well model pump is warranted to function in wells up to at least 100 feet deep.

Should any part prove defective within one year from date of delivery to the purchaser, the part will be replaced C. I. F. Santo Domingo, Dominican Republic, provided the defective part is returned to the manufacturer, transportation changes prepaid.
ANNEX B:

INSTALLATION OF PUMPS
An excellent pump will only provide acceptable service if it is properly installed. Unfortunately, most of the pumps seen by the author in several developing countries, were NOT properly installed. This is a completely unnecessary state of affairs, because the difference in time, effort, and money, between proper and improper installation, is almost zero (except for the costs associated with placing a concrete apron extending five feet around the well, which in any case is not very expensive). All it really requires is that the personnel who install the pump receive and follow instructions regarding proper procedures.

The subject of pump installation is covered in several of the publications listed in Annex J of this report: "Recommended Publications", as well in the literature provided by many pump manufacturers. The installation of the AID/Battelle pump is virtually identical to that of any other reciprocating hand pump. Therefore we will only discuss here those aspects of installation which are most frequently improperly executed in most hand pump projects. This includes the tasks of preparing the 4 bolts which hold the pump base to the concrete slab below it; the protection of the well against contamination; and the disinfection of the well.
PREPARATION OF ANCHOR BOLTS:

The apparently simple placing of the bolts for the base is a subject which has been given inadequate attention, both in the literature about pumps and in the actual work done in the field. In fact, it is a rare pump which has these 4 bolts placed in the right positions, with the correct extension above the concrete slab, and with adequate anchorage within the slab. Failure to achieve this, results in pumps which rock and sway as they are used. This in turn both wastes part of the energy exerted by the person using the pump, and puts an added stress on several pump components.

A solution that has worked successfully with the installation of the AID/Battelle test pumps, is the following. 4 bolts of diameter 3/8 inch and length of 4 inches, are prepared in a shop before being brought to the pump site. In the shop they are welded to 2 rings of 1/4 inch diameter (or larger) reinforcing steel bars, of the type normally used to reinforce concrete. These rings are arranged as shown in the following drawing. Then the mason takes this pre-welded arrangement of bolts and places it within the concrete when he makes the cover slab for the well. This solution has the following advantages:

1. The mason's work is simplified.
2. The bolts cannot turn when subjected to tightening against the pump.

3. The hole below the pump is guaranteed to have reinforcing bar placed in the concrete around it, thus insuring greater strength in this critical area of the cover slab.

4. It is more likely that the bolts will be in the proper locations when the concrete sets. (Of course, to assure this the mason should preferably use a wooden template, or alternatively must measure the distance between the bolts and adjust the reinforcing bar if it has been bent in transit).
ARRANGEMENT OF BOLTS FOR CONNECTING PUMP BASE TO CONCRETE SLAB

TOP VIEW OF BOLT AND REINFORCING BAR ARRANGEMENT (Welded)

6 \frac{3}{8} in. diam.
bezw. centers of bolts

6 \frac{3}{4} in. inch inside diam.
of reinforcing bar ring

SIDE VIEW:

6 inch diameter
PVC pipe nipple,
aprox. 7.25 inches long, to be placed in slab over hand-
dug wells. For drilled-wells, the well casing should be made to extend about 1.25 inches above the concrete base, and into the bottom of the pump.
PROTECTION AGAINST CONTAMINATION:

It is important that the well be sealed in a sanitary manner which will assure that surface and sullage water, as well as other carriers of contamination, cannot enter it. This includes the practices commonly recommended (and rarely implemented) of placing a concrete apron extending 5 feet around the well (sloped outward, without open cracks), placing a protruding curb around the lip of any openings in the cover slab, and placing covers which cannot be casually removed, over all such openings.

For drilled wells, it is a standard recommendation (once again not always followed) that the well casing should protrude into the bottom of the pump base. This is absolutely essential to prevent sullage water from entering the well through the hole in the cover slab, under the pump. The AID/Battelle pump has a base which is designed to allow a well casing to extend up to 1.5 inches into it. Similarly, the Moyno helical rotor hand pump (discussed in Annex E: "Alternate Pumps") allows an even longer extention of the well casing into the base of the pump. Any pump whose design does not permit the extention of the well casing into its base, should be rejected for use in rural water supply projects.
The Health Sector Loan II project will be installing pumps in drilled-wells. Therefore it is essential, if contamination is to be minimized, that the well casing be installed with an extension about 1.25 inches above the concrete base that the pump will rest on. This will result in the casing protruding about 1.25 inches into the bottom of the pump.

It is currently planned that all pumps for the Health Sector Loan II project will be drilled. However, there remains a very good possibility that at least some of the pumps will instead be installed in hand-dug wells (such wells might either be pre-existing, or specially dug for the project). For this reason, project field personnel should be aware of the following recommendation for installation of pumps in hand-dug wells.

Hand-dug wells do not have casings made of (typically) 4 or 6 inch diameter pipe, such as drilled wells have. Therefore it is not as straightforward a matter to extend such a casing into the bottom of a pump placed on a slab over a hand-dug well. Nonetheless, this can be easily resolved. All that need be done is to use a piece of 6 inch diameter PVC pipe as the form to hold the shape of the hole when the mason prepares the concrete cover slab for the well. This PVC pipe (or alternately pipe of any other material) need only be about 7.25 inches long to allow an extension of about 1.25 inches beyond the top of the concrete slab. Use of such a PVC pipe is shown in the preceding drawing.
DESIINFECTION:

It should be standard practice to disinfect a well with chlorine immediately after installing a pump, and again each time the well is opened for maintenance. Disinfection need not take place at other times. This is because if the well is properly sealed against the entrance of contamination, then disinfection will not be needed except when it has been opened temporarily for pump installation or maintenance. On the other hand, if the well is not properly sealed, disinfection would be pointless because it would become recontaminated shortly thereafter anyway.

As part of this project, a simple table was developed, indicating the quantity of calcium hypochlorite powder (HTH) that should be used in wells of varying sizes, in order to disinfect it. This table indicates the amounts of HTH which result in a solution of 100 ppm if all of the HTH is dissolved in the well water. However, it is probably more prudent to use double the doses presented in the table, for the following reasons. First, much of the HTH may not reach the bottom of the well, if a good proportion of it is allowed to run down the walls and thus disinfect the walls. Second, HTH loses about 10% of its strength for each year it has been in storage (this varies with storage conditions), and so it may be weaker than the user realizes. Finally, technicians may become somewhat careless and use less than the recommended amount. Therefore, if one wants to be SURE that the strength of the chlorine solution is AT LEAST 100 ppm, one should probably aim for an approximate level of 200 ppm.

Following is the table referred to, in Spanish. It includes a description of how to mix the powder with water BEFORE pouring it into the well.
### Dosis de hipoclorito de calcio para pozos excavados

(1 onza de HTH por cada 7 pies cúbicos de agua almacenadas, resultando en una solución de 100 ppm de cloro)

<table>
<thead>
<tr>
<th>Profundidad del Agua en el pozo, en pies</th>
<th>CANTIDAD DE HTH (HIPOCOLORITO DE CALCIO), EN ONZAS</th>
<th>DIÁMETRO INTERIOR DEL POZO, EN PIES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>3 pies</td>
</tr>
<tr>
<td>3 pies</td>
<td></td>
<td>3 oz</td>
</tr>
<tr>
<td>4 pies</td>
<td></td>
<td>4 oz</td>
</tr>
<tr>
<td>5 pies</td>
<td></td>
<td>5 oz</td>
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<tr>
<td>6 pies</td>
<td></td>
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<td>7 pies</td>
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<td>7 oz</td>
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<tr>
<td>8 pies</td>
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<td>8 oz</td>
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<tr>
<td>9 pies</td>
<td></td>
<td>9 oz</td>
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<tr>
<td>10 pies</td>
<td></td>
<td>10 oz</td>
</tr>
<tr>
<td>12 pies</td>
<td></td>
<td>12 oz</td>
</tr>
<tr>
<td>14 pies</td>
<td></td>
<td>14 oz</td>
</tr>
<tr>
<td>16 pies</td>
<td></td>
<td>16 oz</td>
</tr>
<tr>
<td>18 pies</td>
<td></td>
<td>18 oz</td>
</tr>
<tr>
<td>20 pies</td>
<td></td>
<td>20 oz</td>
</tr>
</tbody>
</table>

**Notas:**
- 2 cucharadas soperas tienen 1 onza.
- En pozos taladrados o hincados, son suficientes 2 o 3 cucharadas soperas por pozo, cualesquiera sea la profundidad de agua y diámetro.

El pozo debe limpiarse lo más completamente que sea posible, de substancias extrañas, antes de la desinfección. La desinfección se logra por la adición de una solución fuerte de cloro. Entonces, debe agitarse completamente el contenido del pozo y dejarse reposar durante varias horas preferiblemente 24. También debe tenerse cuidado de lavar toda la superficie sobre el nivel del agua en el pozo con la solución desinfectante. A continuación, debe bombearse agua del pozo durante suficiente tiempo para cambiar varias veces el contenido de éste y expulsar de él el exceso de cloro.

Una solución de aproximadamente 100 ppm de cloro se puede obtener agregando la cantidad de HTH presentada en el cuadro arriba. Usualmente, por conveniencia de aplicación, se hace una solución preliminar mezclando el HTH con una pequeña cantidad de agua para formar una pasta suave y, después, agregar esta pasta al agua en un recipiente (los recipientes de metal se corroen y deben evitarse). El recipiente debe contener por lo menos medio galón de agua por cada onza de HTH que se usa. Entonces debe echar en el pozo la mitad de la solución hecha en el recipiente. Con lo demás, debe mezclar suficiente agua adicional para usar en el lavado de las paredes interiores del pozo. Después del lavado, debe echar el sobrante de la solución en el pozo.

- Por Ing. Andrés Karp, Georgia Institute of Technology, noviembre 1978
OTHER MATERIALS NEEDED FOR PUMP INSTALLATION:

When installing a pump, obviously more materials are needed than just the pump itself. In this section we will only list those materials which connect directly to the AID/Battelle pump.

<table>
<thead>
<tr>
<th>ITEM DESCRIPTION</th>
<th>QUANTITY</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchor bolts and nuts. 3/8 diam. and 4 inches long.</td>
<td>4</td>
<td>Usually common steel is used, and this can be done with the AID/Battelle pump. However, stainless steel is recommended because it will last longer, and bolts will be easier to remove when maintenance is to be done.</td>
</tr>
<tr>
<td>Strainer &amp; foot valve diam. 1. 1/4 inches.</td>
<td>1</td>
<td>This is placed at the very bottom of all of the elements connected to the pump, near the well. The vertical check valve contained in commercially available combination foot valves and strainers, acts as &quot;insurance&quot; against the possibility of the check valve in the pump failing.</td>
</tr>
<tr>
<td>1. 1/4 inch diam. schedule 40, galv. steel pipe.</td>
<td></td>
<td>The amount needed will clearly depend upon the depth of the well. This is for use as &quot;drop&quot; pipe.</td>
</tr>
<tr>
<td>ITEM DESCRIPTION</td>
<td>QUANTITY</td>
<td>COMMENTS</td>
</tr>
<tr>
<td>-------------------------------------------------------</td>
<td>----------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1. 1/4 (or 1. 1/2) inch diameter PVC, schedule 40, pipe.</td>
<td></td>
<td>PVC plastic drop pipe may be used only with the shallow-well model pumps. A maximum of only about 28 feet of such pipe may be needed per well, since the pump is only intended for pumping from less than 22 feet (an extra few feet of pipe will allow it to extend deeper into the water).</td>
</tr>
<tr>
<td>7/16 inch galv. steel pump rod and couplings.</td>
<td></td>
<td>This is only needed with deep-well model pumps. The exact same length of rod and drop pipe are needed (however, in practice a slightly different length may be needed to compensate for the differences in length lost in the couplings).</td>
</tr>
<tr>
<td>1. 1/4 inch PVC male threaded adapters</td>
<td>2</td>
<td>Only needed for shallow-well model pumps using PVC drop pipe. These adapters are needed to connect the PVC with the pump on one end, and with the foot valve at the other end.</td>
</tr>
</tbody>
</table>
ANNEX C:

WATER QUALITY
This annex contains some controversial information which in certain cases even the author's colleagues at the Georgia Institute of Technology do not fully agree with. Therefore, this annex should be treated as personnel comments made by the author only.

It comes as a surprise to many people to learn that there is a current international debate over the relation of water quality to health, as well as the means to assure that water is "safe" to drink. Even the definitions of the words "safe water" and "potable water" are being debated by public health officers, sanitation engineers, and other representatives of agencies responsible for improving rural water supplies in the less developed countries.

Clearly, in places where drinking water supplies can economically and reliably be made to meet World Health Organization standards, this should be done. Furthermore, in congested areas, such as cities and urban fringe areas, it is essential that water be provided of a quality which will not spread epidemic diseases. However, in disperse rural areas of typical less developed countries, including the Dominican Republic, it is more difficult (though not at all impossible) to assure that water supplies approach or meet W. H. O. standards.
Even given the difficulties, there would be less of a
debate if it were not for some recent studies which indicate
that health may show no improvement at all when safe water
supplies are substituted for supplies which have been proven
to contaminated. One such study is presented in Water, Health
and Development, listed in Annex J of this report: "Recommended
Publications". The conclusion in that book is that safe water
may be a necessary, but is not a sufficient, requirement for
lowering the incidence of water-related diseases. This conclu-
sion was reached after what is perhaps the best study to date
on the subject. The study was done by an internationally respected
team, commissioned by the British Ministry of Overseas Develop-
ment, OXFAM, and the Government of Lesotho. Following are some
quotations from this study which may be of interest to those
working in the Dominican Republic:

WHO claims that, for individual or small community
supplies, water should be condemned if it is repeatedly
found to contain more than 10 coliforms or 1 Escherichia
coli per 100 ml. These standards are far too stringent
for developing countries, and would lead to the
condemnation of the vast majority of their existing rural
water supplies. (page 217)

In the faecal-oral category, diarrhoeal diseases (especially
among infants) are a major cause of acute morbidity and
mortality in all developing countries and much of this
diarrhoeal disease may be non-water-borne... they are reduced
by increasing the quantity, availability and reliability of
the water supply, almost irrespective of its quality.
(page 218).
If one concludes that water is necessary but NOT sufficient for improving health, then it is essential that any program which is improving rural water supplies with the objective of improving health, do the following. The water should be part of either an integrated rural health program, including other health related activities, and attention should be given to assuring that the water is supplied in adequate quantities and convenient locations. This is in fact the approach being taken by the AID sponsored Health Sector Loan II project, for which it is to be commended.

All of the above still leaves open the question of what, if anything, should be done to improve the quality of the water. The author believes that relatively simple and inexpensive actions should be adequate, and more involved and expensive actions should be avoided. These simple actions include the following:

1. Well covers should be sealed in a manner which will prevent the entrance of surface and sullage water. (See Annex B).

2. Wells should be disinfected with chlorine at the time a pump is installed, and again whenever the top of the well is opened for maintenance. (See Annex B).

3. Wells should be placed at least 50 feet from latrines, and to the degree possible latrines should not be dug so deep as to intercept the ground-water table.
4. Occasional checks should be made to determine the level of bacteriological contamination in only some selected wells. This should be done for the purpose of verifying if the METHODS used to prevent contamination, listed above, are typically being properly implemented.

The low cost of the approach recommended above makes it attractive even if it remains debatable whether or not the improved bacteriological quality of the water will improve the health of the users. Within the context of the Health Sector Loan II project, it can in fact be expected that health will improve, and that the improved water quality will contribute to this. Nonetheless, an inordinate expenditure trying to approach 100% assurance that W.H.O. standards are being met, would not be justified under the circumstances.

As part of the project undertaken by the Georgia Institute of Technology, work was done related to the quality of the water in the 20 wells in which AID/Battelle test pumps were installed. An attempt was made to properly seal all of the wells, to thereby prevent the entrance of contamination, and to disinfect them. Also an attempt was made to have bacteriological analysis done on samples from all wells. The purpose was to demonstrate proper methods of well preparation, and then demonstrate that this
resulted in improved water quality, possibly approaching or meeting W.H.O. standards. The results, however, were disappointing, as described below. Nonetheless, some valuable lessons were learned, and so the effort was not wasted.

The first problem was that a few of the wells were placed too close to latrines (one was only 16 feet away). This was accepted because even prior to installation of the pumps, the people were getting their water from these wells, and we felt that the test results might provide interesting information.

The next problem was that, in spite of our attempts, not a single well was fully sealed against the entrance of contamination from above. Concrete aprons were built, extending five feet around the wells, a curb was placed around all entrances to prevent the entrance of sullage water, a cover that was difficult to move (due to its weight of close to 200 pounds) was placed over the entrance, and the concrete base below the pump was raised about an inch or more to help prevent sullage water from entering around the pump base. Because these were all hand-dug wells, they did not have a casing pipe of around 4 to 6 inches diameter, such as typical drilled wells have. Therefore, we lacked the opportunity of extending this casing about one and a quarter inches beyond the top of the concrete pump base, thereby entering into
the pump from below (the AID/Battelle pump has space to accept up to a 1.5 inch extension). Such an extension is absolutely necessary to prevent sullage water from entering the well from around the pump base. We did attempt to place a short piece of 6 inch diameter PVC in the opening below the pumps, with instructions to the masons to extend this beyond the concrete slab. However, the masons in no case followed this instruction, and we thereafter mistakenly hoped that the raised concrete curb around the pump base would be sufficient. Later we actually found mud which had worked its way under the pump base, and could enter the well due to the lack of this simple pipe extension under the pump.

The final problem related to keeping the water from becoming contaminated, was that in some cases, and probably most cases, the wells were not adequately disinfected at the time of pump installation. A Dominican pump technician was responsible for these installations. He was shocked when he saw the quantity of chlorine which Georgia Institute of Technology personnel put in the well. He said that he had always put in only a small fraction of that amount, because larger quantities would result in an undesirable taste which would last for several days. We explained the purpose of the larger dose of chlorine, and he used such a dose in our presence at a few wells. We also explained to the local
people that if they pumped the well nearly dry the next day, they could eliminate the strong taste of the chlorine, and even without pumping it dry the taste would dissipate over time. In any case, the chlorine would not harm them. However, based upon observations made by others, as well as discussions with the pump technician, we believe that he reverted to his old method of using too little chlorine, whenever we were not actually watching him. It should be mentioned that various authorities recommend that enough chlorine be added to result in from 50 to 200 ppm concentrations in the well water, in order to "super-chlorinate" the well at the time of pump installation. However, we believe that the pump technician put in quantities which would only result in about 5 to 15 ppm, which is definitely inadequate. It should be pointed out that the chlorine is very inexpensive, costing about RD$1.00 for a quantity sufficient to disinfect a typical well. Also, this is not a time-consuming process, since the technician can accomplish it in a few minutes when he is finished installing the pump.

Lastly, we had the bad luck of having part of our laboratory equipment break-down. We had imported for the use of this project, two incubators, and related equipment. One of these incubators proved to be a "lemon" and would not function. It took the distributor, the Hach Chemical Corp., several months to
replace the heating element and thermostatic control, in spite of our personally carrying these back to the U.S. and urging them to provide prompt replacements. As a result, only a maximum of five samples could be analyzed at a time, and only E. Coli counts could be measured (no total coliform counts were made). Furthermore, even this was difficult to accomplish with the one incubator we had. We could have brought our samples to another lab in Santo Domingo, but this would have destroyed the opportunity we wanted to create for the newly formed lab in Santiago to gain experience in the analysis of water samples. In the end, only some of the wells had their water quality analyzed.

The analyses that were done indicated that the wells remained highly contaminated. Only one well had very low contamination levels. For the reasons outlined above, it was not surprising that the wells remained contaminated.

Annex B contains an additional discussion about installation of the pump in a sanitary manner.
ANNEX D:

TEST PUMP INSTALLATIONS:

LOCATIONS AND DESCRIPTIONS
21 AID/Battelle test pumps were installed in 20 hand-dug wells in the Cibao Valley of the Dominican Republic. One of these wells received two pumps, because of the very high usage at that site.

The criteria for choosing test sites were the following:

1. Approximately half had to be suitable for shallow-well model pumps, and the other half for deep-well models.
2. The wells had to already exist, and could not already have adequately functioning hand pumps.
3. A large number of people had to use the well for their water supply. (The sites selected averaged over 100 users each).
4. The wells had to be reasonably close to one another, and easily accessible, in order to facilitate inspections.
5. The users had to express a desire for a hand pump, and grant permission for its installation (this was never a problem).

Of the 24 test pumps manufactured for this project, 21 are currently installed and functioning. Another is at the AID office, and the remaining two are being stored in the community of Guayabal, as the responsibility of the pump technician Julio Mejía of the Secretariat of Health. He is using them for spare parts as needs arise.

Following is a description of each site, and a rough map indicating how to reach them.
<table>
<thead>
<tr>
<th>SITE NAME</th>
<th>DEPTH (approx)</th>
<th>MANUFACTURER AND MODEL OF PUMP</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epenito Sabaneta (Sr. Mota)</td>
<td>9 ft.</td>
<td>Industroquel Shallow-well</td>
<td>Poor casting resulted in a leak through the base. Otherwise working well.</td>
</tr>
<tr>
<td>Epenito Sabaneta (Sra. de Fernández)</td>
<td>11 ft.</td>
<td>Industroquel Shallow-well</td>
<td>Working well, although masons did a poor job placing anchor bolts.</td>
</tr>
<tr>
<td>Guaco</td>
<td>15 ft.</td>
<td>Astilleros Navales Shallow-well</td>
<td>Originally had old style pump cap. Children stuffed sharp pebbles in through the hole in this cap design. The pebbles caught on the piston leathers and ripped them apart. Needs more regular greasing. Otherwise working well.</td>
</tr>
<tr>
<td>Santo Cerro</td>
<td>34 ft.</td>
<td>Astilleros Navales Deep-well</td>
<td>Working well.</td>
</tr>
<tr>
<td>Rincones de Yabanal</td>
<td>33 ft.</td>
<td>Industroquel Deep-well</td>
<td>Broken cotter pin. Lacks sufficient greasing. Otherwise working well.</td>
</tr>
<tr>
<td>Yabanal Arriba</td>
<td>30 ft.</td>
<td>Industroquel Deep-well</td>
<td>Pump functions well, in spite of rocking caused by poor work of mason, who did not leave enough of the anchor bolts protruding to secure the pump properly. Also much contamination due to poor masonry work.</td>
</tr>
<tr>
<td>SITE NAME</td>
<td>DEPTH (approx)</td>
<td>MANUFACTURER AND MODEL OF PUMP</td>
<td>COMMENTS</td>
</tr>
<tr>
<td>---------------------------</td>
<td>---------------</td>
<td>-----------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Guayabal (Sr. Bealto)</td>
<td>25 ft.</td>
<td>Industroquel Deep-well</td>
<td>Functioning well. People are greasing the pins regularly.</td>
</tr>
<tr>
<td>Guayabal (Sr. Frometo)</td>
<td>29 ft.</td>
<td>Industroquel Deep-well</td>
<td>Functioning well. People are greasing the pins regularly.</td>
</tr>
<tr>
<td>Maguey</td>
<td>40 ft.</td>
<td>Astilleros Navales Deep-well</td>
<td>Functions, but must be pumped rapidly or no water is raised. This indicates that the check valve (flapper valve) in the cylinder is not sealing.</td>
</tr>
<tr>
<td>Palmar</td>
<td>7 ft.</td>
<td>Astilleros Navales Shallow-well</td>
<td>Two bushings were lost, and then replaced with new ones. Otherwise functioning well.</td>
</tr>
<tr>
<td>Las Guazumas</td>
<td>13 ft.</td>
<td>Astilleros Navales Shallow-well</td>
<td>Functioning well.</td>
</tr>
<tr>
<td>Castillo</td>
<td>4 ft.</td>
<td>Industroquel and Astilleros Navales (1 shallow-well each)</td>
<td>Both pumps are functioning well.</td>
</tr>
<tr>
<td>Ceiba de Madera (Sr. Hierra)</td>
<td>33 ft.</td>
<td>Astilleros Navales Deep-well</td>
<td>Functioning well.</td>
</tr>
<tr>
<td>Ceiba de Madera (Sr. Clemente)</td>
<td>24 ft.</td>
<td>Industroquel Deep-well</td>
<td>Functioning well.</td>
</tr>
<tr>
<td>SITE NAME</td>
<td>PUMPING DEPTH (approx)</td>
<td>MANUFACTURER AND MODEL OF PUMP</td>
<td>COMMENTS</td>
</tr>
<tr>
<td>-------------------</td>
<td>------------------------</td>
<td>-------------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Canca La Reina</td>
<td>35 ft.</td>
<td>Astilleros Navales Deep-well</td>
<td>Functioning well.</td>
</tr>
<tr>
<td>Canca Reparación</td>
<td>27 ft.</td>
<td>Astilleros Navales Deep-well</td>
<td>Functioning well.</td>
</tr>
<tr>
<td>San Francisco Arriba (Sr. Gonzales)</td>
<td>24 ft.</td>
<td>Industroquel Shallow-well</td>
<td>Functioning well.</td>
</tr>
<tr>
<td>San Francisco Arriba (Sr. Vasque)</td>
<td>20 ft.</td>
<td>Industroquel Shallow-well</td>
<td>Functioning well, but needs more grasing.</td>
</tr>
<tr>
<td>San Francisco Arriba (Sr. Roja)</td>
<td>21 ft.</td>
<td>Industroquel Shallow-well</td>
<td>Functioning well.</td>
</tr>
<tr>
<td>San Francisco Arriba (Sr. Peralta)</td>
<td>19 ft.</td>
<td>Industroquel Shallow-well</td>
<td>Functioning, but check valve (leather flapper valve) leaks water very slowly. It therefore must be primed every morning.</td>
</tr>
</tbody>
</table>
MAPA DE LOS POZOS DONDE LAS BOMBAS DE PRUEBA SERÁN INSTALADAS

6/Noviembre/78
por Ing. Andrés Karp

Notas:

Todos los distancias indicadas son en millas. (1.0 milla = 1.6 km)
ANNEX E:

ALTERNATE PUMPS
In addition to the AID/Battelle hand pump discussed in this report, other pumps can of course be considered for use in the Dominican Republic. It is not the purpose of this report to provide detailed information about all of the many alternate pumps available. However, a brief discussion is offered here in order to give the reader some perspective on the subject.

First, when considering alternate pumps, as a general rule the quality of the pump should be given considerably more importance than the price. The fact that most of the hand pums in the world are not currently functioning, attests to the fact that "savings" made by buying lower quality pumps and/or providing insufficient maintenance, have been false economies. Any pump which is not at least as rugged and sturdy as the AID/Battelle pump, should not be considered for widespread use in the Dominican Republic.

Consideration of alternate pumps should also not be allowed to interfere with a reasonable degree of standardization. While it may be advantageous to avoid complete dependancy on one manufacturer, one should avoid the other extreme which would require stocking spare parts and training maintenance personnel for too many different types of pumps.
It is recommended that a maximum of three pump designs be used in the Health Sector Loan II program. These would be a shallow-well model for wells less than 22 feet deep (with the piston and cylinder located within the pump body); a deep-well model for wells from 22 feet to about 100 feet deep (with a piston identical to that of the shallow-well model, but placed in a 2 3/4 inch diameter cylinder at the bottom of the well); and a special very heavy-duty pump for wells more than 100 feet deep. The first two types of pumps, could be the AID/Battelle shallow-well and deep-well pumps, with their advantages of interchangeable parts, ruggedness, and local manufacture. Alternately, the best of the imported pumps can be considered. For wells more than about 100 feet deep (and certainly for wells more than 150 feet deep) the higher initial price would be justified for a special very heavy-duty helical rotor hand pump. To the author's knowledge, the only U.S. manufacturer of such a pump is the Moyno Division of the Robbins & Myers company.

There are three justifications for investing in a better pump, such as the Moyno helical rotor hand pump, for wells deeper than about 100 feet:

1. At pumping depths greater than about 100 feet, the force which the user must exert on the handle of a reciprocating pump (such as the AID/Battelle pump) approaches or surpasses excessive levels. With the AID/Battelle pump described in this report, the required user force on the handle would theoretically exceed 60 pounds for pumping depths greater than 100 feet (Annex H indicates
that the actual force can be expected to be slightly greater than the theoretically calculated force). This compares to only about ten pounds of force which have to be exerted on each of the two handles on the Moyno pump.

2. At pumping depths greater than about 100 feet, the pump components will be subjected to greater stresses, resulting in increased wear and maintenance requirements. At the same time, maintenance will be made more difficult by the increased depth. The alternative of using a stronger pump, such as the Moyno pump, would dramatically reduce these maintenance requirements.

3. For wells greater than about 100 feet deep, the investment in elements of the water supply system, exclusive of the pump itself, is already very high. For instance, the costs of drilling and lining a 100 foot well, plus the cost of 100 feet of drop pipe and pump rod, would typically cost over $1,000 (in addition to administrative and overhead costs). For a 200 foot well the cost would typically be over $2,000. In such cases, the incremental investment in a Moyno pump costing about $450, instead of a reciprocating pump costing about $100 to $175, is a small percentage of the total cost of the well and pump water supply system. Because it will increase the reliability of the total system greatly, this alone would justify it. In addition, the saving in what would otherwise be particularly high maintenance costs (because of the great depth of the well), should result in the higher priced pump being more
economical in the long-term.

On the following pages is presented information provided by the manufacturers of the Dempster reciprocating hand pump, and the Moyno helical rotor hand pump. Both of these companies are in the U. S. and have excellent reputations.
**HAND PUMP OPTIONS**

**FOR THE DOMINICAN REPUBLIC**

The following table presents various alternatives for choice of hand pumps for use in the upcoming Health Loan II program. It should be noted that the decision regarding choice of pumps depends mainly upon the well depths which will be included in the program. The alternatives presented here are not all inclusive, but represent the recommendations of the author (other brands using similar designs might also be considered).

<table>
<thead>
<tr>
<th>PUMPING DEPTH (FEET)</th>
<th>PUMP ALTERNATIVES</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>less than 22 feet</td>
<td>AID/Battelle shallow well pump (with 2.3/4 inch diam. PVC liner)</td>
<td></td>
</tr>
<tr>
<td>22 to 66</td>
<td>AID/Battelle deep well pump with 2.3/4 inch PVC cylinder.</td>
<td>IF IT IS DESIRED TO HAVE ONE CYLINDER SIZE FOR ALL PUMPS, THEN USE 2.3/4 INCH FOR A MAXIMUM DEPTH OF 100 FEET.</td>
</tr>
<tr>
<td>66 to 100</td>
<td>AID/Battelle deep well pump with 2.3/4 inch PVC cylinder OR AID/Battelle deep well pump with 2 inch PVC cylinder</td>
<td>IF A SECOND SIZE CYLINDER IS ACCEPTABLE, a 2 inch cylinder will result in greater ease for pumping from these depths.</td>
</tr>
<tr>
<td>100 to 150</td>
<td>AID/Battelle deep well pump with 2 inch PVC cylinder OR MOYNO HELICAL ROTOR PUMP</td>
<td>IF ASSOCIATED MAINTENANCE WORK IS DEEMED ACCEPTABLE, AND IF THE HEAVY PRESSURE REQUIRED TO OPERATE THE PUMP HANDLE IS ALSO ACCEPTABLE (CHILDREN COULD NOT NORMALLY USE IT).</td>
</tr>
<tr>
<td>150 to 300</td>
<td>MOYNO HELICAL ROTOR PUMP</td>
<td>THIS IS THE ONLY HAND PUMP WHICH THE AUTHOR CAN RECOMMEND FOR THESE DEPTHS.</td>
</tr>
</tbody>
</table>
CONSTRUCTION

Dempster hand and windmill pumps are adapted for wells of any depth. Neat in design and substantially built, equipped with a 4-bolt adjustable flanged top, extra long handles and heavy steel bearer pins. Tops fitted with stuffing box and packing for tight seal on the piston rod. 4-position handle adjustment for up to 10 inch stroke. Large capacity air chamber for smooth force pumping. Furnished with syphon or compression spout. Syphon spout furnished unless otherwise ordered. 2 x 1-1/4-inch suction bushing furnished with each pump.

MODEL 210F

MODEL 210F is a heavy-duty hand or windmill force pump. It has a 1-1/16-inch polished steel piston rod securely threaded to the flat bar. For wells of extreme depth, with large cylinders or continuous operation.

Type........................................Hand & Windmill
Suction Tapped..............................2 in.
Piston Rod Threaded for,
  Rod........................................7/16 in.
  Pipe......................................3/8 in.
Tapping in Rear............................1¼ in.
Approx. Weight.............................71 lbs.

MODEL 210F[CS] same as Model 210F except equipped with Model 36 Compression Spout.

MODEL 226F

MODEL 226F is normal duty hand or windmill force pump. It has a 11/16 inch steel piston rod fitted to the flat bar with a heavy cast set screw connection. For wells of shallow to moderate depth at normal farm and ranch operation.

Type........................................Hand & Windmill
Suction Tapped..............................2 in.
Piston Rod Threaded for,
  Rod........................................7/16 in.
  Pipe......................................3/8 in.
Tapping in Rear............................1¼ in.
Approx. Weight.............................70 lbs.

MODEL 226F[CS] same as Model 226 F except equipped with Model 36 Compression Spout.
 PIPE CLEVISES  
For Lifting, Lowering and Holding Pipe

MODEL 681

Model 681 is built for heavy service. Positive grip, will not slip. Easy and quick to attach. Heavy corrugated eccentric dog. The heavier the load, the tighter it grips. Odorless and tasteless, this material is approved for use in potable water systems. It is deposit-resistant and non-electrolytic.

More than 100 years of manufacturing, engineering and field experience go into the making of each Dempster pump.

Precision workmanship and highest quality materials go into each Dempster product—to give you more for your pump dollar. A complete line of pumps, windmills, water systems and accessories—for farm, ranch or suburban home.
HEAVY WINDMILL FORCE PUMPS

Model 36 Compression Spout (CS)

<table>
<thead>
<tr>
<th>Model Number</th>
<th>Catalog Number</th>
<th>List Price</th>
<th>Approx. Shpg. Wt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>210F</td>
<td>380 1 4007</td>
<td>158.00</td>
<td>71</td>
</tr>
<tr>
<td>210F (CS)</td>
<td>380 1 4008</td>
<td>167.25</td>
<td>73</td>
</tr>
<tr>
<td>226F</td>
<td>380 1 4017</td>
<td>150.00</td>
<td>70</td>
</tr>
<tr>
<td>226F (CS)</td>
<td>380 1 4018</td>
<td>159.25</td>
<td>72</td>
</tr>
</tbody>
</table>

Model 226F 11/16" Piston Rod Connected to Flat Bar with heavy cast set screw connection

HOSE CONNECTION

Threaded for standard garden hose

<table>
<thead>
<tr>
<th>Part No.</th>
<th>Description</th>
<th>Thread Size</th>
<th>List Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>380 2 4057</td>
<td>Hose Connection with Gasket</td>
<td>3/4&quot; - 14</td>
<td>6.25</td>
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</table>

PIPE CLEVIS

<table>
<thead>
<tr>
<th>Catalog Number</th>
<th>Description</th>
<th>List Price</th>
<th>Wt. Lbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>382 1 0016</td>
<td>Pipe Clevis</td>
<td>14.00</td>
<td>8</td>
</tr>
</tbody>
</table>

F.O.B.: SHIPPING POINT
FEDERAL, STATE AND LOCAL TAXES EXTRA
SUBJECT TO PRICE REVISIONS AND MODIFICATIONS WITHOUT NOTICE 1-3-78
PUMPS and CYLINDERS

ORDERING INFORMATION

DEMPSTER PUMP CYLINDERS

ALL-BRASS 2 LEATHER PLUNGER CAGE & FOLLOWER
PEERLESS LEATHERS
PEERLESS CHECK VALVE
7/16" GALVANIZED STEEL PUMP ROD
STANDARD 1-1/4" TAPPING-TOP & BOTTOM

<table>
<thead>
<tr>
<th>SIZE</th>
<th>PEERLESS</th>
<th>PVC FLUSH CAP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MODEL 81</td>
<td>BRASS-LINED</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LIST PRICE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WT. LBS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CATALOG</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NUMBER</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LIST PRICE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WT. LBS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maximum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Working Depth</td>
</tr>
<tr>
<td>DIA. X BARREL LENGTH</td>
<td>CATALOG NUMBER</td>
<td>WT.</td>
</tr>
<tr>
<td>2&quot; X 12&quot;</td>
<td>380 1 3014</td>
<td>51.20</td>
</tr>
<tr>
<td>2-1/2&quot; X 12&quot;</td>
<td>380 1 3018</td>
<td>57.70</td>
</tr>
<tr>
<td>3&quot; X 12&quot;</td>
<td>380 1 3021</td>
<td>65.40</td>
</tr>
<tr>
<td>2&quot; X 16&quot;</td>
<td>380 1 3015</td>
<td>54.20</td>
</tr>
<tr>
<td>2-1/4&quot; X 16&quot;</td>
<td>380 1 3017</td>
<td>57.60</td>
</tr>
<tr>
<td>2-1/2&quot; X 16&quot;</td>
<td>380 1 3020</td>
<td>63.00</td>
</tr>
<tr>
<td>3&quot; X 16&quot;</td>
<td>380 1 3023</td>
<td>78.30</td>
</tr>
</tbody>
</table>

If tailpipe is required, use semi-rigid plastic pipe

For Model 81 Cylinder

<table>
<thead>
<tr>
<th>SIZE</th>
<th>PLUNGER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LIST PRICE</td>
</tr>
<tr>
<td>2&quot;</td>
<td>380 2 3011</td>
</tr>
<tr>
<td>2-1/4&quot;</td>
<td>380 2 3014</td>
</tr>
<tr>
<td>2-1/2&quot;</td>
<td>380 2 3017</td>
</tr>
<tr>
<td>3&quot;</td>
<td>380 2 3020</td>
</tr>
<tr>
<td>3-1/2&quot;</td>
<td>380 2 3040</td>
</tr>
</tbody>
</table>

For Check Valve

<table>
<thead>
<tr>
<th>SIZE</th>
<th>CHECK VALVE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LIST PRICE</td>
</tr>
<tr>
<td>2&quot;</td>
<td>380 2 3023</td>
</tr>
<tr>
<td>2-1/4&quot;</td>
<td>380 2 3027</td>
</tr>
<tr>
<td>2-1/2&quot;</td>
<td>380 2 3031</td>
</tr>
<tr>
<td>3&quot;</td>
<td>380 2 3035</td>
</tr>
<tr>
<td>3-1/2&quot;</td>
<td>380 2 3041</td>
</tr>
<tr>
<td>4&quot;</td>
<td>380 2 3045</td>
</tr>
</tbody>
</table>

*For previous sizes

For PVC Cylinders

<table>
<thead>
<tr>
<th>SIZE</th>
<th>PLUNDER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LIST PRICE</td>
</tr>
<tr>
<td>2&quot;</td>
<td>380 2 3011</td>
</tr>
<tr>
<td>2-1/2&quot;</td>
<td>380 2 3018</td>
</tr>
<tr>
<td>3&quot;</td>
<td>380 2 3020</td>
</tr>
</tbody>
</table>

Prices do not include stub rods. If required, order from Repair Catalog.

F.O.B: SHIPPING POINT
FEDERAL, STATE AND LOCAL TAXES EXTRA
SUBJECT TO PRICE REVISIONS AND MODIFICATIONS WITHOUT NOTICE

8-1-78
**ROBBINS & MYERS HAND PUMPS**

Models 1V2.6 & 2V2.6

<table>
<thead>
<tr>
<th>QUANTITY</th>
<th>PRICE SCHEDULE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 99 Units</td>
<td><strong>MODEL 1V2.6</strong>&lt;br&gt;$473.00 ea.</td>
</tr>
<tr>
<td>100 - 499 Units</td>
<td>433.00 ea.</td>
</tr>
<tr>
<td>500 - 999 Units</td>
<td>408.00 ea.</td>
</tr>
<tr>
<td>1000 - 2499 Units</td>
<td>378.00 ea.</td>
</tr>
<tr>
<td>Over 2500 Units</td>
<td>357.00 ea.</td>
</tr>
</tbody>
</table>

Above prices are for above ground portion and pump cylinder. Well extension assemblies (pump rod, drop pipe, and associated couplings) are quoted on a per foot basis at price in effect at time of quotation.

Prices are net to consumer, FOB Columbia, South Carolina, subject to change without notice.
Hand Pumps for Rural Water Systems

Easy operation, minimum maintenance, maximum life
The Robbins & Myers hand pump design eliminates the trouble spots found in most conventional hand pumps:

- No Stuffing Boxes
- No Packing
- No Gaskets
- No Pins
- No Pin Bushings
- No Cup Seals
- No Cylinder Valves

Ideally suited for dense population areas where a single pump must serve the needs of many people, or for rural schools and clinics, where dependability is a must.

Not a modified farmyard pump, but a pump designed from the well strainer up to meet today's requirements for high performance, year-in-year-out dependability, long life, and low maintenance.

For wells up to 300' (90m) deep!

Advantages of the Progressing Cavity Pump Principle

Positive displacement
The progressing cavity pump incorporates a screw-like, single helix rotor turning within a double helix stator. This pumping principle gives positive displacement, with the head developed independent of the speed, and capacity approximately proportional to the speed.

Steady flow
Progressing cavity pumps provide steady, non-pulsating flows. There is no wasted motion...every turn of the handles delivers water.

Self priming
Progressing cavity pumps are self priming. Pumping action starts the instant the pump starts.

Simplicity of design
There is only one moving part in the pump elements and that is the rotor. There are no valves, valve seats, or cup seals to wear out.

Abrasion resistant
The resilient stator material allows passage of abrasive sand or silt particles without damage to the pumping elements.

Energy efficient
Utilizing the mechanical advantage of the screw-like rotor, very little effort is required to operate the Robbins & Myers hand pump, even at depths of 300 feet.
Pump stand fabricated from heavy steel plate and pipe. Will not crack or break during shipping or installation. Will withstand severe abuse in the most rugged operating conditions.

Heavy duty gearbox incorporates a right angle gear arrangement in a rugged housing. Gears are machined and hardened steel, mounted on high strength steel shafts. Tapered roller bearings provide precise gear alignment and long life. Sealed housing along with double lip seals on both handle and output shafts prevents lubricant leaking.

Rugged steel handle arms are keyed and bolted to the handle shaft. 3/8” diameter handles permanently attached to handle arms.

Special socket head bolts used throughout to minimize vandalism or pillage.

Pumping elements designed to provide years of trouble free operation. The rotor is machined from alloy steel and plated for additional abrasion resistance and longer life; the stator utilizes a special low water swell elastomer, permanently bonded to a steel tube.
Sanitary design; easy installation

Tubular stand column fits over well casing extension (4" and smaller wells) to prevent sullage water from entering the well.

Pump stand completely sealed to prevent external contamination of the well.

Long, angled discharge spout prevents possibility of sticks and stones being dropped or forced into the well by mischievous children.

No stuffing box leakage since there is no stuffing box.

Dual sealing by means of a lip seal and a rotary seal on the drive shaft prevents lubricant leakage into the water supply.

Designed for ease of installation...
While unique in principle and design, the Robbins and Myers hand pump is simple to install. As with most other types of pumps, the pump cylinder and appropriate lengths of drop pipe and pump rod are lowered into the well and then fastened to the discharge housing and drive shaft.

Installed with conventional hand tools
When drop pipe and pump rod are furnished by Robbins and Myers, no field cutting and threading are required.

Designed for low "Total Life Cycle" cost
One of the most common mistakes in hand pump programs throughout the world has been the use of "initial price" as the basic criteria in hand pump selection. This "least cost technology" approach has led to failure rates of 30-80% and has defeated the goal of providing reliable sources of clean water.

A more realistic cost effective approach is "Total Life Cycle" cost, which takes into account not only initial price but the replacement part and maintenance costs over a 20 or 30 year period. This is the only method of determining the true cost of providing a dependable source of clean water.

While the "initial price" of a Robbins & Myers hand pump is higher than many pumps, long component life and maintenance-free design make it one of the most economical pumps on the market today from a "total life cycle" cost standpoint.

With the cost of the pump one of the lower costs in providing a village water system, it's worth spending a little more initially to assure year-in-year-out dependability and long life.
Specifications

Pump Type
Progressing cavity (helical rotor); crank operated. Can be used as lift pump or force pump without modification.

Models
1V2.6 Single stage pumping elements
For depths to 150’ (45m)
2V2.6 Two stage pumping elements
For depths to 300’ (90m)

Well Diameters
Suitable for use in 3” (7.5cm) diameter and larger well casings.

Weight
Pump Stand and Drive Assembly—114 lb. (52kg)

Pump cylinder—
Model 1V2.6—43 lb. (20kg)
Model 2V2.6—55 lb. (25kg)

10’ Well Extension Assembly—23 lb. (10.4kg)

Height
40” (100cm) from base to handle centerline.

Turning force required on each handle:
Model 1V2.6—8 lb. (3.6kg) average
Model 2V2.6—12 lb. (5.4kg) average

Well extensions
Drop pipe, 1” diameter galvanized pipe. Pump is easily modified to accept drop pipe of larger diameter.
Pump rod, 1/2” diameter steel rod with 1/2”-13 threads.

Performance curves

![Performance Curves Graph]

GPM
10.00
8.00
6.00
4.00
2.00

0 40 80 120 160 200 240 280 320

Delivery Head—Feet of Water

E-16
The Robbins & Myers Hand Pump can be converted to alternate power sources such as electric motors and gasoline engines. Please consult the factory for recommended conversions.

Robbins and Myers Hand Pumps are built to the same rigid manufacturing standards and under the same quality control procedures as pumps supplied to the chemical, food, waste treatment, and petroleum industries.

Over 40 years experience in supplying engineered products to industry stands behind every Robbins and Myers Hand Pump.

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ANNEX F:

SPARE PARTS
SPARE PARTS

Clearly spare parts for a major pump installation program should be purchased early and stored where they will be readily available when needed. While it is possible to predict the pump components which are most likely to need the most frequent replacement, it is unfortunately impossible to make even an approximate estimate of the quantities that will actually be needed over any given time period.

The frequency with which parts will need to be replaced will depend upon the following variables:

- Initial quality of the pump components when leaving the factory.
- Intensity of use (gallons per day pumped).
- Adequacy of maintenance (especially regular greasing of pivot pins).
- Depth of the well (pumping from increased depths will increase the strain and wear on pump components).
- Amount of sand and abrasive material mixed in the water.
- Abuse of the pump (including possible vandalism).
- Degree of deterioration considered acceptable before repairing.
- Possible tendency of well to regularly run dry (cyclic wetting and drying of leather cups and flapper valves will decrease their lives).

Of course the first of these variables, the initial quality of the pump components, can be controlled. However, all of the other variables which determine the need for replacement parts are impossible to predict before the pump installation program begins.

Another factor affecting the amount of spare parts to be initially purchased, is the approach taken towards maintenance and stocking of spare parts. For instance, if spare parts are to be delivered with each individual pump, then it would probably be advisable to provide a spare set of two leather cups, and a spare pivot pin for the connection of the handle to the fulcrum (this will tend to wear more quickly than the other pivot pins). Tools would also have to be provided. If an adequate training program is provided for selected local villagers, then the stocking of these spare parts with each pump would seem to be recommendable.
A more difficult question is the quantity of spare parts to be stored in a central or regional warehouse. The responsible agency will have to make its own best guess of the quantities to be initially purchased and stored, but the following notes may provide some guidance.

PUMP HANDLES: This is the most difficult part of the pump to cast, and unfortunately poor quality castings will not always be apparent upon initial visual inspection. However, such weak handles will typically break within the first few months of use (often almost immediately), and should be replaced by the manufacturer as called for by the warranty recommended in the specifications part of this report.

PIVIT PINS: Either these pins or the pump leathers will most likely be the components needing most frequent replacement. If villagers properly grease or oil these pins once a week, they should last for very many years (especially for shallow well pumps, on which they are subjected to less wear). However, the more frequent case may be that they receive almost no grease or oil, and therefore may wear to an unacceptable degree within the first few years of use (possibly within the first year, especially for pumps which are in very deep wells and are
subject to a very high intensity of use). The pin subjected to the greatest pressure and motion is that connecting the handle to the fulcrum, and this can be expected to wear out in a fraction of the time of the other pins. Of course a large number of the inexpensive cotter pins, which hold the pivot pins in place, should also be stored. While in storage, these pins should be coated with oil or grease to minimize corrosion (it should be specified that the manufacturer thus coat them before delivery).

LEATHER CUPS: In many countries wear of the leather cups in the piston assembly has proved to be the most common cause of pump breakdowns. This will be especially true if the original cups are of low quality, if the water contains abrasive material (such as sand), if the cups were subject to mildew while in storage, or if the cups are subject to repeated wetting and drying (in a shallow-well pump this can be caused by the pump regularly loosing its prime, and in a deep well pump it can be caused by the well regularly being pumped dry if it is not deep enough). There have been cases of the original cups lasting 20 years, and other cases of their destruction within a couple of months. Quality cups can be manufactured in the Dominican Republic for about $1.75 according to one shop, and possibly the price could be substantially reduced. Thus the cost of
replacement cups is not excessive. However, they should be readily available, and so should a person who has been trained in their replacement. For shallow-well pumps replacement is simple and easy. For deep-well pumps it is made difficult by the need to pull out all down-hole elements of the pump in order to get the leather cups which are in the cylinder at the bottom of the well.

**BOLTS:** Spare nuts and bolts should be stocked. However, the main cause of needing to replace them will probably be vandalism (such vandalism is especially likely when the pump is broken and inoperative for an extended period of time). Vandalism can only be deterred by local villagers, and so they should be given an incentive to do so by requiring that they pay for replacement bolts. It should be noted that the pump specifications call for the use of galvanized steel bolts for the pump cap, which should minimize corrosion.

**MISC:** A regional warehouse should also stock leather flapper valves, piston assemblies, pump rods and connectors. Spare pump cylinders for deep-well pumps, and even a few complete spare pumps should be stocked.
It should be noted that one of the advantages of the AID/Battelle pump design is that all of the mentioned spare parts, except for the deep-well cylinder, are identical for both shallow-well and deep-well model pumps. This standardization will significantly lower the number and complication of spare parts to be stored.

It is recommended by the author that careful records be kept of the spare parts actually used. This will help in making projections, providing a sounder basis for future stocking of spare parts. However, when making such projections it should be realized that following early parts replacements, most pumps should enter a relatively trouble-free period, finally followed by increased problems when they are older.
ANNEX G:

MATERIALS WHICH CAN BE PURCHASED SEPARATELY
In some cases it may prove desirable to purchase separately all or part of the materials used for fabricating the pumps. Then these materials can be supplied to the manufacturers, who would be paid to fabricate the pump from them.

The disadvantage of this approach is the obvious additional work and related complications for the purchasing agency.

The advantages may and may not outweigh the disadvantage. These advantages are the following:

1. The purchasing agency may be able to purchase at substantially lower prices than the manufacturers can, thereby reducing the final total cost of the pumps. This may be especially true if the purchaser has an international procurement office, and is not restricted to the local market.

2. The purchasing agency may be able to purchase in larger quantities than are needed for an individual order for pump manufacture. For instance, the PVC pipe manufacturer, ALAMBRES DOMINICANOS C. por A., has said that it will accept a minimum order of RD$ 2,000. for manufacturing special 2.75 inch diameter pipe. This is sufficient for about 1,143 pumps.
If a similar quantity of pumps is to be divided among several orders (either at different times or to different factories), then the factory would have to purchase more PVC pipe than it requires, and accordingly may increase the price of the pump. This can be avoided if the purchaser provides the PVC pipe.

3. An improved level of quality assurance might be achieved if the purchasing agency supplies the manufacturer of the pump with certain critical materials. This applies most importantly to the bearing pins and bushings. (With the possible exception of wear of the piston leather cups, failures of the bearings are the most frequent causes of hand pump operating breakdowns). By purchasing these separately, the agency can assure that they are of optimum dimensions and materials.

4. Small local manufacturers may find it very difficult to raise the cash needed to purchase the materials that they will use in the manufacture of the pumps. In order to accept a reasonably large order, they may have to give the purchaser the choice of either supplying the materials or making a substantial down-payment initially.
Following is a list of the materials which can be purchased separately and provided to the manufacturer. This list does not include such items as the contents of the cast iron, or miscellaneous items such as paint and oil. It is restricted to significant items which may be advantageous to purchase separately.

Quantities presented are for each individual pump. Clearly the lengths of rod and pipe presented in the list could be purchased in longer lengths, and cut down to size and threaded by the local pump manufacturer. This also applies to the lengths of bearing pin and bushing materials.
ANNEX H:

FIELD TESTS OF FORCE REQUIREMENTS FOR PUMPING
### MATERIALS USED IN PUMP MANUFACTURE WHICH CAN BE PURCHASED SEPARATELY

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>DESIGN DRAWING SHOWING THIS ITEM</th>
<th>QUANTITY PER SHALLOW-WELL PUMP</th>
<th>QUANTITY PER DEEP-WELL PUMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Pump rod, galv. steel diam. 7/16, length 21.5 inches</td>
<td>103</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>* Pump rod, galv. steel diam. 7/16, length 16.25 inches</td>
<td>103</td>
<td>none</td>
<td>1</td>
</tr>
<tr>
<td>Bearing pin, C.R.S. steel, (hard but not as much so as the journals. Roughly 40 Rc would be good) .5/8 diam.</td>
<td>105 and 106</td>
<td>2 (3.75&quot; long) 1 (5.125&quot; long)</td>
<td>2 (3.75&quot; long) 1 (5.125&quot; long)</td>
</tr>
<tr>
<td>Galv. steel pipe, diam. 3 inches (schedule 40), 14 inches long</td>
<td>119</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>PVC pipe, specially made with I.D. of 2.75 and O.D. of 3.068 inches, 14 inches long</td>
<td>119</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Galv. steel reducing cup (double female), for reducing from 3 to 1. 1/4 inch pipe</td>
<td>122</td>
<td>none</td>
<td>2</td>
</tr>
<tr>
<td>Bolts, galv. steel, &amp; nuts 3/8 diam., length 1.75 inches</td>
<td>101 and 102</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Bushings, hard steel (somewhat harder than that used for bearing pins, roughly 60-64 Rc would be good) I.D. 41/64, O.D. preferably 25/32 but may be up to 27/32.</td>
<td>108 and 104 and 125 and 126</td>
<td>6 (3/4&quot; long) 2 (1.5&quot; long) 1 (1.5/8&quot; long)</td>
<td>6 (3/4&quot; long) 2 (1.5&quot; long) 1 (1.5/8&quot; long)</td>
</tr>
</tbody>
</table>

* Note that the purchasing agency will in any case have to purchase pump rod of this material and diameter, for use in the installation of the deep-well pumps (discussed in Annex B). Therefore it should prove to be convenient to simultaneously purchase additional pump rod for use by the pump manufacturers.
The force which a pump user must exert on the handle is theoretically proportional to the depth of the well. Similarly the stresses which result in wear on the most critical pump components are also proportional to the depth of the well. The maximum depth at which it is recommendable to use a specific pump is in large part determined by these forces and stresses. This is because beyond a certain depth the required force that a user must exert on the handle will be excessive, and the wear resulting from increased stresses on the pump components will also be excessive.

For the above reasons it is of value to understand the relationship between required force that the user must exert on the handle, and the depth of the well. To the degree that this force can be predicted before installing a pump, a more scientific basis can be established for setting maximum well depths in which the pump may be used. For instance, if one sets an approximate limit of about 60 pounds on the force which a user must exert on the handle, the question will arise regarding what is the maximum well depth at which the required force will be less than the limit of 60 pounds.

Theoretical formulas have been developed to predict the force as a function of the pumping depth. However, very little field
testing has been done to substantiate these formulas. Limited tests were done in Central America by representatives of the Georgia Institute of Technology, and FOR THE PUMPS TESTED THERE, little correlation was found between the formulas and the actual force required. This was apparently due to extremely wide variations in the amount of extra force required to overcome friction of the pump components.

If a pump is kept in a well-lubricated state, has a smooth cylinder, has cups which fit snugly but not too tightly inside the cylinder, and has no surfaces that grind against each other, the amount of actual force which must be exerted on the handle will approach the theoretical value (although it will always be somewhat greater, because friction can never be completely eliminated).

The following table presents data for field tests done on six AID/Battelle deep-well pumps in the Cibao Valley of the Dominican Republic. The average pump required only about 6 pounds more force on the handle than was theoretically predicted, which is an indication that the pumps had minimal and acceptable levels of friction between their components.
### FORCE EXERTED ON HANDLES OF FIELD TEST PUMPS AS A FUNCTION OF PUMPING DEPTH

<table>
<thead>
<tr>
<th>NAME OF SITE</th>
<th>PUMPING DEPTH</th>
<th>MECHANICAL ADVANTAGE OF HANDLE ASSEMBLY</th>
<th>THEORETICAL FORCE ON HANDLE (neglecting friction)</th>
<th>ACTUAL FORCE ON HANDLE</th>
<th>FORCE REQ'D TO OVERCOME FRICTION (= difference betw. actual &amp; theor. force)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiba de Madera #1</td>
<td>24.50 ft</td>
<td>4.81</td>
<td>11.9 lbs</td>
<td>19.8 lbs</td>
<td>7.9 lbs</td>
</tr>
<tr>
<td>Canca Reparación</td>
<td>27.17 ft</td>
<td>5.36</td>
<td>11.9 lbs</td>
<td>17.6 lbs</td>
<td>5.6 lbs</td>
</tr>
<tr>
<td>Guayabal</td>
<td>29.00 ft</td>
<td>4.67</td>
<td>15.4 lbs</td>
<td>22.0 lbs</td>
<td>6.6 lbs</td>
</tr>
<tr>
<td>Ceiba de Madera #2</td>
<td>33.25 ft</td>
<td>5.52</td>
<td>14.9 lbs</td>
<td>20.9 lbs</td>
<td>6.0 lbs</td>
</tr>
<tr>
<td>Canca de Reina</td>
<td>35.00 ft</td>
<td>4.96</td>
<td>18.1 lbs</td>
<td>19.8 lbs</td>
<td>1.7 lbs</td>
</tr>
<tr>
<td>Maguey</td>
<td>39.58 ft</td>
<td>5.20</td>
<td>19.8 lbs</td>
<td>29.7 lbs</td>
<td>9.9 lbs</td>
</tr>
</tbody>
</table>

Av. = 6.3 lbs

### NOTES:

1. All actual handle forces were measured with a spring scale. They have an accuracy of about plus or minus 1 pound.

2. All pumping depths were measured at the time of the test, and represent the distance from the surface of the water in the well, to the base of the pump.

3. "Mechanical Advantage" is the ratio of the distance from the point on the handle where the force was exerted, to the pivot point on the handle, divided by the distance from the connection of the pumping rod with the handle, to the same pivot point of the handle. This is variable because the force was exerted at different points on the handle at each test site.

4. Theoretical force on the handle was calculated based upon the following formulas:
Force on handle = (Mechanical Advantage) x (Force on pump rod) MINUS (equivalent force exerted by weight of handle itself).

Force on pump rod = \[ \left( \frac{(\text{density}) \times \text{depth} \times (3.14) \times (\text{diam})^2}{4} + (U) \times \text{depth} \right) \times \text{hydraulic efficiency} \]

Where

- \text{density} = \text{density of water}, 62.4 \text{ lb/cu. ft.}
- \text{depth} = \text{pumping depth, measured in feet}
- \text{diam} = \text{cylinder diameter, 2.75 inches = 0.229 feet}
- \text{U} = \text{weight/ft of pumping rod} = 0.685 \text{ lb/ft}

equivalent force exerted by weight of handle itself

= \approx 4 \text{ lb}. That is to say, if 4 lb were exerted on the handle at the same point where the user presses when he is pumping, this would have the same effect as the weight of the handle itself has. This was determined by disconnecting a pump handle from the pump rod, leaving it to pivot freely at the point where it was connected to the fulcrum. Then a spring scale was connected to the point on the handle where the user would normally exert pressure. The weight of the handle itself was thus found to exert a force of about 4 lbs on the spring scale.
hydraulic efficiency

= Quantity of water actually pumped, divided by the quantity that would be pumped if there were no "slippage" (leakage) of water around the cup seals. This is highly variable, but was estimated at 0.95 for this calculation. (It should be noted that at extremely slow pumping speeds, this hydraulic efficiency may fall to 0.25 or lower, especially if the cups are worn out. This is why the handle may go down slowly by its own weight, with no outside force required, especially if the cups are worn or the well is very shallow).

The formula used here is a refinement of that presented in the book Hand Pumps (mentioned in Annex J: "Recommended Publications"). The author of this report has modified the old formula to include consideration of the factors for the equivalent force exerted by the weight of the handle itself, and the hydraulic efficiency. The failure to include the effects of these factors in earlier studies done by others, explains in part some of the apparent discrepancies found between field test data and theoretical calculations.
ANNEX I:

FABRICATION OF LEATHER CUPS
It is essential that the leather cups used in the piston assembly be properly fabricated, of the proper dimensions, and properly stored (away from damp mildew prone areas). Even in a well fabricated pump, with excellent leather cups, these cups will be one of the parts of the pump needing the most frequent replacement. This is because of the tremendous wear they are subjected to, rubbing against the cylinder wall on every stroke of the pumping operation. If the leathers fail, the pump will not function adequately, and may not function at all.

If quality leather cups are used, and if abrasive materials such as sand are not in the water, shallow-well pumps may go many years without the need for changing of leather cups. Of course if the pump serves more than the estimated 60 persons envisioned in the plans for the Health Sector Loan II project, then cups will wear more quickly due to the increased use, but even so they might last several years. In deep-well pumps they will last a shorter time due to the greater stresses they are subjected to and this is aggravated by the greater difficulty in changing the cups in such deep wells. Depending upon the intensity of use, the depth of the well, the materials mixed with the water, and the quality of the leather, as well as luck, these cups may last anywhere from a few months (shorter with inferior leather) to a few years.
Clearly it is important that the manufacturers understand how to fabricate excellent quality leather cups, and that they be required to do so. Therefore, on Design No. 118 (see Annex A), notes are presented (in Spanish) describing how to fabricate these cups. These notes should be understood to be part of the specifications for the pump manufacture.

Following is a translation of the notes presented on Drawing Number 118:

1. The maximum exterior diameter of the leather cup before its installation should be around 1/16 inch less than the interior diameter of the cylinder (which is 2.75 inches). Thus the diameter of the cup is 2.11/16. The components of the piston should press against the leather, but not so much that it produces a deformation. The pressure of the water against the leather cup, during the pumping stroke, will spread out the border assuring that it makes perimeter contact with the cylinder.

2. Use leather of good quality (preferably from the butt or back), without dye, and impregnated with cooking oil and grease. It can be made in wooden molds: soak it in water; place it in the mold under pressure, leave it to dry, take it out and cut the edges with a sharp knife, soak it for 12 hours in oil, wax it, and apply a light coat or graphite grease to the side exposed to wear.

The above recommendations are based on those provided on page 196 of the book Hand Pumps, listed in Annex J of this report: "Recommended Publications". On the same page of this
book, a description is given of how to make and use the wooden molds. This is quoted below:

To make the forms, use wooden boards about 3/4 inch in thickness, having holes of the same diameter as the pump cylinders (the leathers should shrink a bit as they dry, to meet the requirement of being 1/16 inch smaller than the cylinders. If inadequate shrinkage is encountered, then the forms should be remade, slightly smaller), and nailed to a stiff backboard. Cylindrical blocks, 3/8 inch less in diameter are bolted concentrically within the circular opening. The bolts should be long enough so that the wet and pliable leather, laid over the holes, can be drawn down by the bolts and blocks, forcing the leathers into position. Then proceed as before (as described in notes 1 and 2 above).

Drawing 118 also specifies that the leather be about 3/16 inch thick, which is about normal for back or butt leather. Clearly it is also important that the cup manufacturer use leather which has been properly cured, by a competent leather shop.

If the above procedures are properly followed, as they have been for the test pumps thus far manufactured in the Dominican Republic, excellent quality leather cups will be the result. These locally made cups can be equal to the best available cups made anywhere in the world, and will be better than many of the cups made by reputable pump factories elsewhere. They should also be substantially less expensive than EQUIVALENT QUALITY imported cups.
When comparing prices, care should be taken to find out if the other cups are of as good a quality. Certainly it is worthwhile to pay a premium to have high quality leather cups, because of their importance to the functioning of the pump, and the difficulty of replacing them.
ANNEX J:

RECOMMENDED PUBLICATIONS


* Typical Designs For Engineering Components In Rural Water Supply, World Health Organization, Regional Office For South-East Asia, New Delhi, India, 1976, 43 Design drawings plus explanatory pages.


Note: An asterik (*) before a book title indicates that the project has acquired a copy of it for the AID Mission in the Dominican Republic.