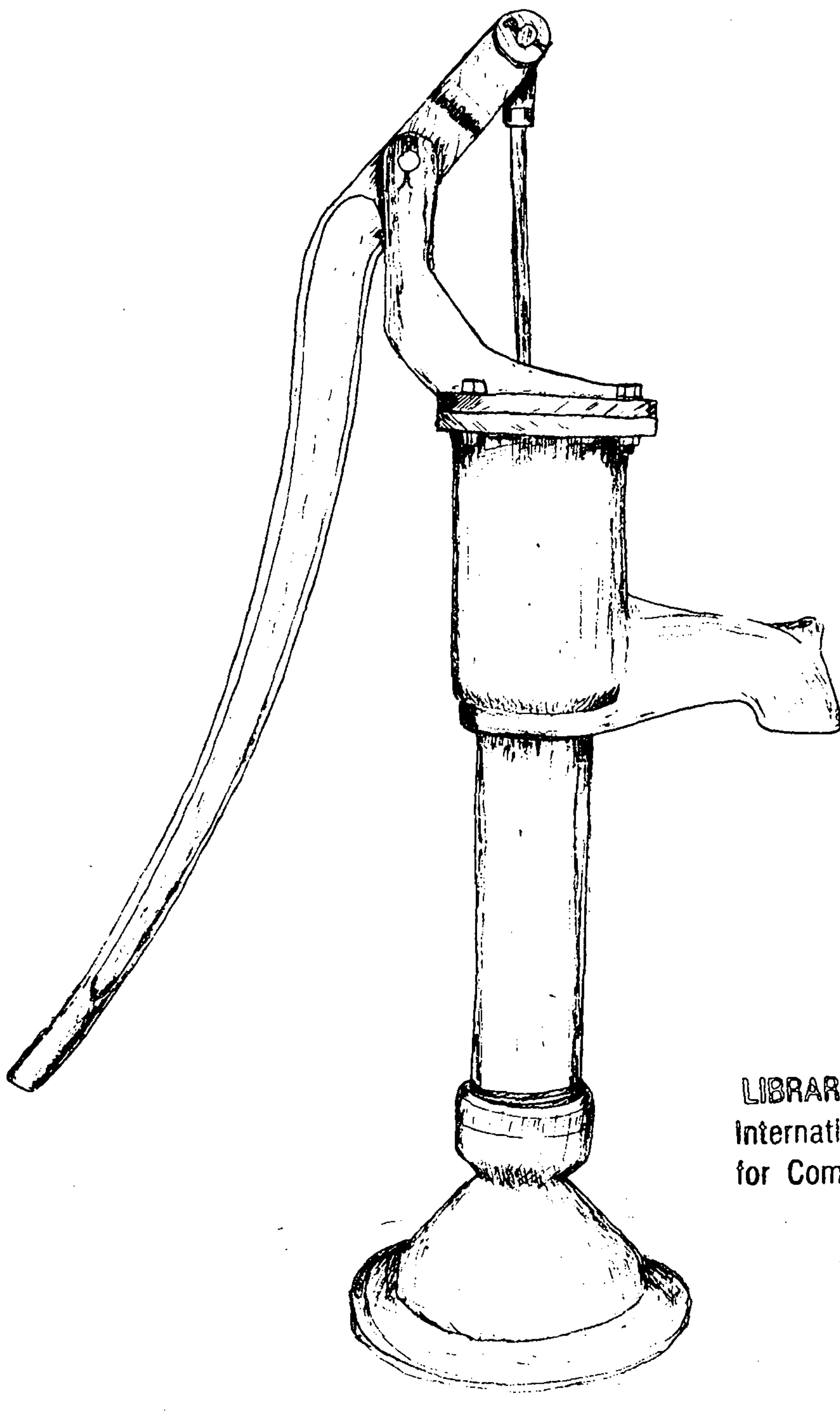
FINAL REPORT ON THE UTILIZATION/EVALUATION OF AN AID HAND-OPERATED WATER PUMP



Project A-1894

FINAL REPORT ON THE UTILIZATION/ EVALUATION OF AN AID HAND-OPERATED WATER PUMP

Prepared for

The U.S. Agency for International Development
under Contract No. AID/ta-C-1354

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Atlanta, Georgia
January 1979

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Acknowledgments

This program of field testing the AID/Battelle hand-operated water pump would never have come into being without the help of many individuals who have supplied large quantities of factual information and have given freely of their time, permitting project personnel to profit from their seasoned judgment. This program did not contractually require active participation by local Agency for International Development Missions in Costa Rica and Nicaragua, but assistance was given abundantly in the form of personnel, vehicles, coordination of program activities, interest and insight into local conditions within each country. Personnel of the Ministries of Health in each country have contributed significantly with their own resources of vehicles, tools, and employees possessing noteworthy technical skills, dedication, and professionalism.

While it is impossible to list all individuals who have rendered assistance to the program, the authors of this report would like to acknowledge the following, with a special note of appreciation to Mr. Rene Uriza and Mr. José Zúniga in Nicaragua and Mr. Heriberto Rodriguez and Mr. Roberto Contreras in Costa Rica.

Dr. Carmelo Calvosa, M.D., present Minister of Health in Costa Rica

Dr. Herman Weinstok, M.D., previous Minister of Health in Costa Rica

Dr. Edmundo J. Bernheim, M.D., present Minister of Health in Nicaragua

Min. Adan Cajina Ríos, previous Minister of Health in Nicaragua

Mr. Stephen E. Knaebel, present Mission Director, USAID/Costa Rica

Mr. Joseph J. Sconce, previous Mission Director, USAID/Costa Rica

Mr. Arthur W. Mudge, Mission Director, USAID/Nicaragua

Dr. James E. Sarn, M.D., previous Chief Public Health Advisor, USAID/Nicaragua

Mr. Heriberto Rodriguez, General Engineer, USAID/Costa Rica

Mr. Rene Uriza, Assistant I (Public Health), USAID/Nicaragua

Dr. Guillermo Contreras, M.D., present Director of the Department of Rural Health, Ministry of Health in Costa Rica

Dr. Carlos Eduardo Valerín, M.D., previous Director of the Department of Rural Health, Ministry of Health in Costa Rica

Mr. José María Zúniga, Director of PLANSAR, Ministry of Health in Nicaragua

Mr. Roger Madriz, President of Mecanizados Mofama, the AID pump manufacturer in Costa Rica

Mr. Leonel García Lara, consultant to Cometales, the AID pump manufacturer in Nicaragua

Mr. Jaíro Triano Harker, President of Cometales, the AID pump manufacturer in Nicaragua

Mr. Edison Rivera, Director of Environmental Health, Ministry of Health in Costa Rica

Mr. Guillermo Esquibel, Engineering and Architecture Department, Ministry of Health in Costa Rica

Mr. Roberto Contreras, Supervisor of Pump Programs, Ministry of Health in Costa Rica

Mr. W. K. (Tim) Journey, International Development Research Centre, Ottawa, Canada

Mr. Robert D. Fannon, Jr., of Battelle's Columbus Laboratories, also has been very helpful in supplying working drawings of the AID/Battelle pump and background information on the history of the pump.

The field testing program, it should be noted, has presented many unforeseeable problems. A severe drought occurred in both Costa Rica and Nicaragua in March, April, and May of 1977 that necessitated deepening many wells or switching to other sites before pumps could be installed. The same drought restricted the supply of hydroelectric power in Nicaragua to the point where the manufacturer was allowed only four hours per day of electricity to run his plant (and manufacture pumps). Further, civil disorder in Nicaragua during both the early months and the last months of 1978 somewhat restricted project personnel in that country from maintaining and monitoring the test pumps. Despite these delays the project remained basically on schedule. The required 12-month test-pump monitoring period in Nicaragua was completed prior to the civil disorders that are still continuing at the time of this writing, and the long-range effects of the disorders on the operational performance of the pumps are unknown.

Despite the many problems encountered during the life of the project, there have been many instances of overwhelming satisfaction. For example, at La Lamilla, Nicaragua, where a U.S.-manufactured Dempster pump was installed, community leaders have gone on record that "before the pump program was begun in the La Lamilla area, the infant mortality rate from diarrhea and vomiting was extremely high. Today, the infant mortality rate from these causes has practically disappeared, as have the symptoms." Such statements have made the problems, no matter how large, seem insignificant. The Georgia Institute

of Technology is grateful to the Agency for International Development, especially to Mr. James F. Thompson, Chief, Environmental Health Division, Office of Health, Development Support Bureau, U.S.A.I.D., Washington, D.C., for the opportunity of participating in such a program.

Summary

Recognizing the need in developing countries for a reliable supply of potable water and the corollary worldwide need for a long-lasting, low-cost, easily repaired, locally manufactured hand pump, the Agency for International Development (AID) began a series of contracts with the Battelle Memorial Institute to design and laboratory test a reciprocating shallow- and deep-well hand pump for LDC manufacture and use. 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 the AID pumps. Cooperating with Georgia Tech on the project was the Central American Research Institute for Industry (ICAITI) and local Ministry of Health and AID officials in Costa Rica and Nicaragua.

Costa Rica

Costa Rica was chosen as a test country because of a sizable well and hand-pump loan that had been made to that country by AID and because of the country's need for an expanded water pump program. Provisions of the loan specifically included installation of water pumps on a large-scale basis, and it was felt that assistance in such areas as pump selection, installation techniques, and pump maintenance, as a part of this field-test program, would greatly benefit the government of Costa Rica. Costa Rican Ministry of Health and AID officials also strongly felt that a locally manufactured hand pump offered by the AID/Georgia Tech/ICAITI program had many advantages that should be included in the Costa Rican loan program (mainly employment generation, spare parts availability, and lower cost than for commercially available hand pumps).

Active work began in Costa Rica in January 1977, when AID/Washington and Georgia Tech jointly agreed that Costa Rica and Nicaragua should be the test countries for the program described herein. A machine shop that purchases rough iron castings from a local foundry was contracted to manufacture 20 AID pumps (eleven deep-well and nine shallow-well). These pumps were produced and delivered to a Ministry of Health warehouse for storage and installation in April 1977. Two different kinds of pumps were chosen with which to compare the

AID pump: a Dempster and a Japanese "Lucky" pump. Thirty-one sites, representative of Costa Rica, were chosen to receive the test pumps (16 AID pumps and 15 competitive pumps).

Wells were randomly tested by chemical and bacteriological analyses prior to test-pump installation and found to contain large numbers of intestinal bacteria, indicating that contamination was not being sealed off from the water. The pumps were installed by the Ministry of Health, the wells were disinfected with a chlorine-yielding compound and attempts were made to seal off the contamination sources. However, subsequent bacteriological testing has shown no improvement in the quality of the water due to poor construction of the upper well structures by the rural villagers, as well as their reluctance to accept an adequate amount of disinfection -- a matter that has caused great concern within the Ministry of Health. As a result, internal organizational changes have been made, and technicians and engineers are now being hired and trained in an attempt to alleviate the situation.

The prices of the AID pumps manufactured in Costa Rica were as follows:

Shallow-well	$ 98 (each)
Deep-well	$128 (each)
Patterns	$498 (one-time charge only)

It should be noted that it has been very difficult during this program to arrive at a "representative" price for the AID pump because of extreme variances in manufacturing costs, especially overhead, between different countries and even between different manufacturers within the same country. For example, in Nicaragua, prior to placing an order with the manufacturer, price quotes were received from seven foundries that ranged from $69 (shallow-well) and $75 (deep-well) to $225 (shallow-well) and $250 (deep-well). During a trip to Ghana, the project director for this program discussed the AID pump with AID and Ghanaian government officials and discovered that prior investigations into the use of the AID pump for that country indicated a cost of approximately $500 per pump (shallow-well or deep-well) for a relatively large order (100 pumps or more). Inquiries into the manufacture of the AID pump in the Dominican Republic have provided cost estimates ranging from $160 (shallow-well) and $200 (deep-well) to $261 (shallow-well) and $298 (deep-well), with the cost of patterns for making the castings included here in the price of the pumps, rather than as a separate cost.

To complicate matters even more, a judgment of expected quality must be balanced against the price of the pump and, in some cases, higher prices have not necessarily reflected a potential for the highest level of quality. However, various cost estimates show that the AID pump (shallow-well or deep-well) can be provided for an attractive price of below $100 (for instance, Indonesian foundries are manufacturing the deep-well pump for $60 and the shallow-well pump for $50 on orders of less than 50 pumps per order).

In general, the functional performance and acceptance of the Costa Rican-manufactured AID pump has been satisfactory, but serious casting defects were encountered which necessitated the replacement of five handles, two shallow-well caps, and one modified handle fulcrum. In all cases, these failures were caused by a lack of quality control at the foundry, which was not possible without laboratory facilities for testing the cast iron. The foundry used for the manufacture of the AID pumps in Costa Rica was representative of what might be found in many developing countries, but was not considered by project personnel to be the best in the country. Better foundries were available; however, these foundries were not interested in initial small orders even though the potential for much larger orders existed for the future.

Nicaragua

Nicaragua was chosen as a test country because of a rural water supply and hand-pump program loan by AID to that country involving the installation of hand-operated water pumps. The loan provisions included potable water systems that will construct 300-340 wells by the end of 1979. The AID/Georgia Tech/ICAITI program has complemented this program by providing technical assistance in pump selection, installation techniques, and pump maintenance, and has enabled the Ministry of Health in Nicaragua to take advantage of locally manufactured hand pumps that can be produced at a cost lower than commercially available pumps. This local program increases spare parts availability, reduces foreign exchange outflow, and stimulates local employment, as well as provides all other benefits of the AID pump mentioned in the introduction to this report.

As in Costa Rica, program activities began in Nicaragua in January 1977. A local foundry was chosen to manufacture 20 AID pumps (eleven deep-well and nine shallow-well), which were produced and delivered to a Ministry of Health warehouse for storage and installation in May. Two kinds of locally available pumps were chosen for comparison with the AID pump: a Dempster and a Brazilian "Marumby" pump. A pump developed by the International Development Research Centre (IDRC) of Ottawa, Canada, also was used for comparison. Thirty sites, representative of Nicaragua, were approved to receive the test pumps (16 AID pumps and 14 comparative pumps), and all of the sites required extensive preparatory work before pumps could be installed. Pumps were installed by a Ministry of Health installation team, and the wells were disinfected with a chlorine-yielding substance. As in Costa Rica, the sites had chemical and bacteriological testing prior to installation of test pumps and showed excessive amounts of intestinal bacteria.

In manufacturing the AID pumps in Nicaragua, a somewhat surprising situation was encountered -- foundries were plentiful, but pattern makers, a very necessary requirement for local production, were almost nonexistent. A foundry was located that appeared to have the resources, including pattern makers, to manufacture a quality AID pump, and a contract was signed for the manufacture of eleven deep-well pumps and nine shallow-well pumps. The prices of the pumps, for an order of 20, were as follows:

Shallow-well	\$ 69 (each)
Deep-well	\$ 75 (each)
Patterns	\$1,000 (one-time charge only)

Two major maintenance problems with the AID pump became apparent when installation of the pumps began. The most critical problem was that the deep-well pump cap's weakest point was where maximum stress was being applied by the handle fulcrum upon the pivot arm of the cap, causing the pivot arm to break off from the cap. This problem was partly the fault of the design and partly the fault of the manufacturer. Because of an indented contour of the top plate of the pump body, it was not possible to cast the pump body as specified by the drawings (the patterns for the pump could not be removed from the molding sand without destroying the mold). Therefore, the manufacturer eliminated the indented contour of the top plate of the pump and then did not have enough clearance between the pivot arm of the cap and the top of the pump body. In order to obtain a better fit between the pump cap and the pump body, the manufacturer milled away a fillet on the pivot arm, thereby leaving a notch at the point of maximum stress. To alleviate the entire problem, the pump cap was redesigned by lifting the pivot arm up and away from the pump body and positioning it so that it does not absorb so much of the stress caused by the downward force of the pump handle. The redesigned cap was put into production at the manufacturer's foundry, installed on the pumps in the field, and has presented no additional problems.

The second major maintenance problem encountered with the AID pump in Nicaragua evolved when the manufacturer could not find 3-inch (inside diameter) PVC pipe for the deep-well cylinders. As a result, the manufacturer used 3-inch (outside diameter) PVC pipe and expanded it, by heating, to a 3-inch inside diameter. Quality control for such an approach was most difficult, and the results were unacceptable. While several of these PVC cylinders were installed in the field, it was decided that metal cylinders coated internally with epoxy (a Battelle option) would have to be used until the correct size PVC could be made available locally or imported from another country. In July (1978) the correct size PVC pipe was obtained from a local manufacturer and cylinders were produced according to specifications to be used for future pump installations.

Excessive wearing of leather cups has also presented problems for the AID pump in Nicaragua principally because of insufficiently smooth cylinders and oversized cups. Battelle drawings specify a 3-inch diameter leather cup for a 3-inch cylinder, which would be satisfactory if leather did not expand when wet. To allow for expansion, the dry cups should have been made approximately 1/16-inch undersized. A replacement order for the original oversized cups was filled by the pump manufacturer, and the wearing of these new cups has been considerably less due to the use of a blanking tool that improves the quality controls of the manufacturer.

Conclusions

Monitoring of pump performance has been concluded by Ministry of Health, AID, ICAITI, and Georgia Tech personnel. Despite many field test problems with the AID hand pump, field test results indicate that the AID pump can be manufactured with a high degree of quality in many less developed countries (LDCs). The test results, further, would most definitely encourage the manufacture, installation, and use of the AID hand pump in LDCs.

The AID pump can be manufactured in a developing country at a competitive, profitable price and at an acceptable level of quality if adequate facilities (foundries, pattern makers, machine shops and skilled machinists, raw materials, etc.) are available; however, the availability of adequate foundry facilities with acceptable pump prices and quality controls must be determined for each individual developing country. Public acceptance by rural villagers has been good, in terms of both aesthetics and ease of use by men, women and children. Further, the AID pump should have a positive impact in LDCs on the health of rural people, employment generation, and foreign exchange requirements. In addition, the demonstration of local capabilities for manufacturing a rather complicated product instead of importing it should enhance the national pride of the people.

While numerous manufacturing problems, especially quality control, have been encountered in both Costa Rica and Nicaragua, the majority of these problems have been such as to be expected when a product like the AID pump is introduced into LDC production for the first time. As subsequent orders are processed through the manufacturer's plant and as personnel become more familiar with the pump itself, quality control should be refined to the point where the orders are considered to be normal production. All manufacturing problems were satisfactorily overcome as a result of adaptation and modification designs which ultimately proved to be workable in the LDC environment.

INTRODUCTION

Recognizing the need in developing countries for a reliable supply of potable water and the corollary worldwide need for a long-lasting, low-cost, easily repaired, locally manufactured hand pump, the Agency for International Development (AID) began a series of contracts with the Battelle Memorial Institute to design and laboratory test a reciprocating shallow- and deep-well hand pump for LDC manufacture and use. 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 the AID pumps. Cooperating with Georgia Tech on the project was the Central American Research Institute for Industry (ICAITI) and local Ministry of Health and AID officials in Costa Rica and Nicaragua.

The program has consisted of the manufacture of AID pumps in Nicaragua and Costa Rica, the purchase of locally available comparative pumps, installation of the pumps in rural villages, and evaluation of the field performance of each pump over a one-year period. One manufacturer in each country was selected to manufacture the AID pump. A minimum of 30 pumps of various kinds were installed in each country, and detailed, frequent monitoring of their operation was accomplished.

Organizationally, Georgia Tech had overall responsibility for the AID hand-operated water pump field testing. Members of the Engineering Experiment Station have been, and are currently, involved in national and international programs of community and area development, management and technical assistance to business and industrial firms, industrial and economic development training, market analyses, studies of new manufacturing opportunities, manpower resources and labor productivity, stimulation of small-scale industry, technology assessment, development and conservation of energy resources, housing resources, industrial economics, economic uses of industrial wastes, adaptive technology research and development, audiovisual presentations and multimedia documentation, and professional guidance in planning industrial and economic development programs. The organization of the Engineering Experiment Station is illustrated in Figure 1.

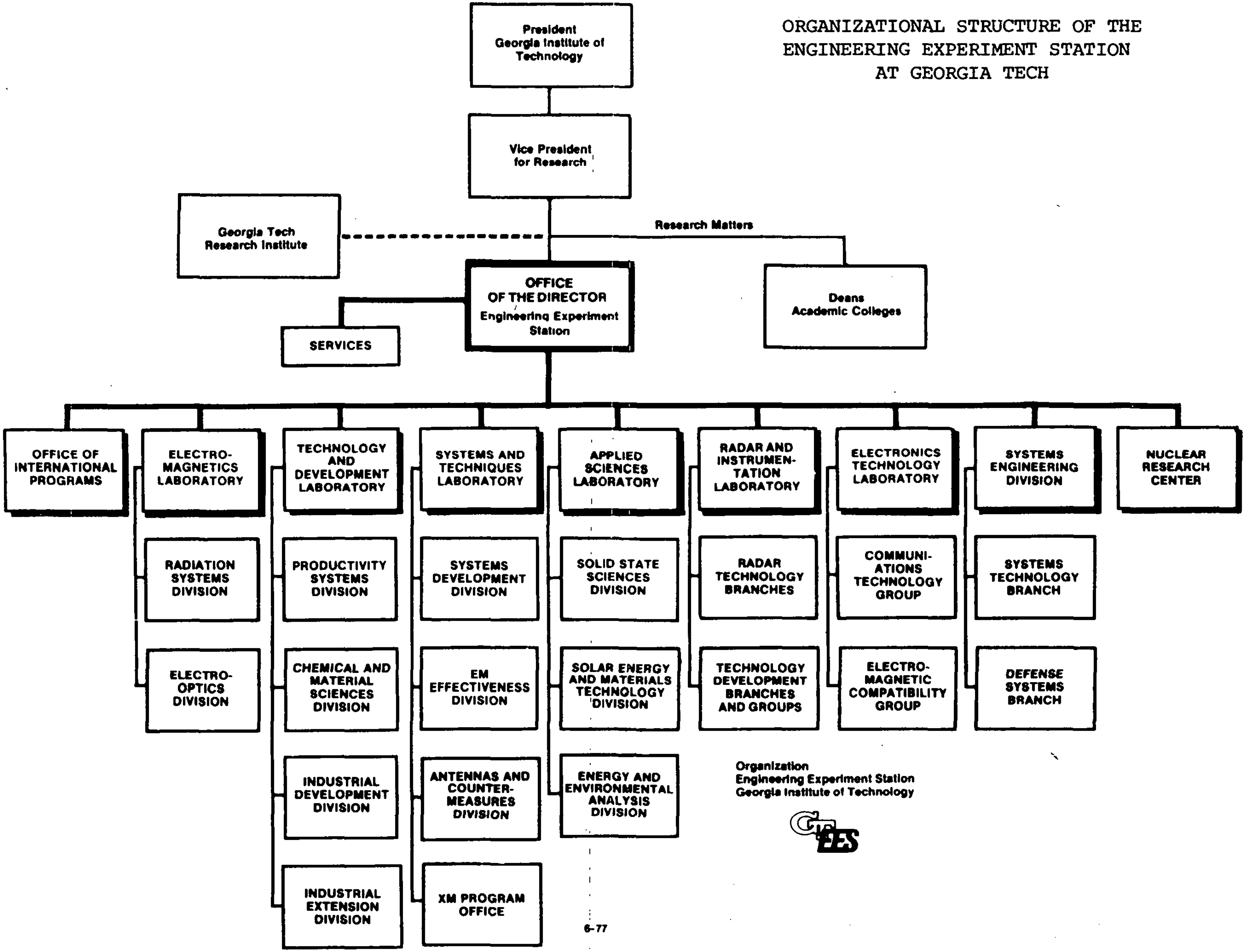


Figure 1

ORGANIZATIONAL STRUCTURE OF THE ENGINEERING EXPERIMENT STATION AT GEORGIA TECH

ICAITI, chosen as a Central American counterpart by Georgia Tech to enable efficient utilization of travel funds, to provide quick response to AID and to the Ministries of Health in Costa Rica and Nicaragua, and to take full advantage of its established working relationships with existing communities, industries, lending institutions, and governmental departments of Costa Rica and Nicaragua, is very similar to the Engineering Experiment Station. For more than 14 years, ICAITI has made significant contributions to the industrial development of Central America through the introduction of modern technologies and has completed a considerable number of related projects that have aided in the accomplishment of this program.

The program, more specifically, consisted of participation by Georgia Tech and ICAITI in the following activities:

1. Providing technical assistance for selected foundries and machine shops to locally manufacture the AID pumps.

2. Selecting and purchasing locally available pumps to be used in comparison with the AID pump.

3. Selecting 60 field-test sites for installation of 30 AID pumps and 30 locally available pumps (30 sites located in each of the two test countries).

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

5. Preparing sites (preparing new wells or rehabilitating existing wells, as necessary).

6. Installing pumps.

7. Monitoring pump performance for a 12-month period.

8. Collecting and analyzing field data.

In gathering and analyzing data on the AID pump, seven areas have been of major concern:

1. Operational performance in the field.

2. Maintenance requirements and pump reliability.

3. Competitive cost and analysis of the economics of in-country manufacturing.

4. Manufacturing problems encountered.

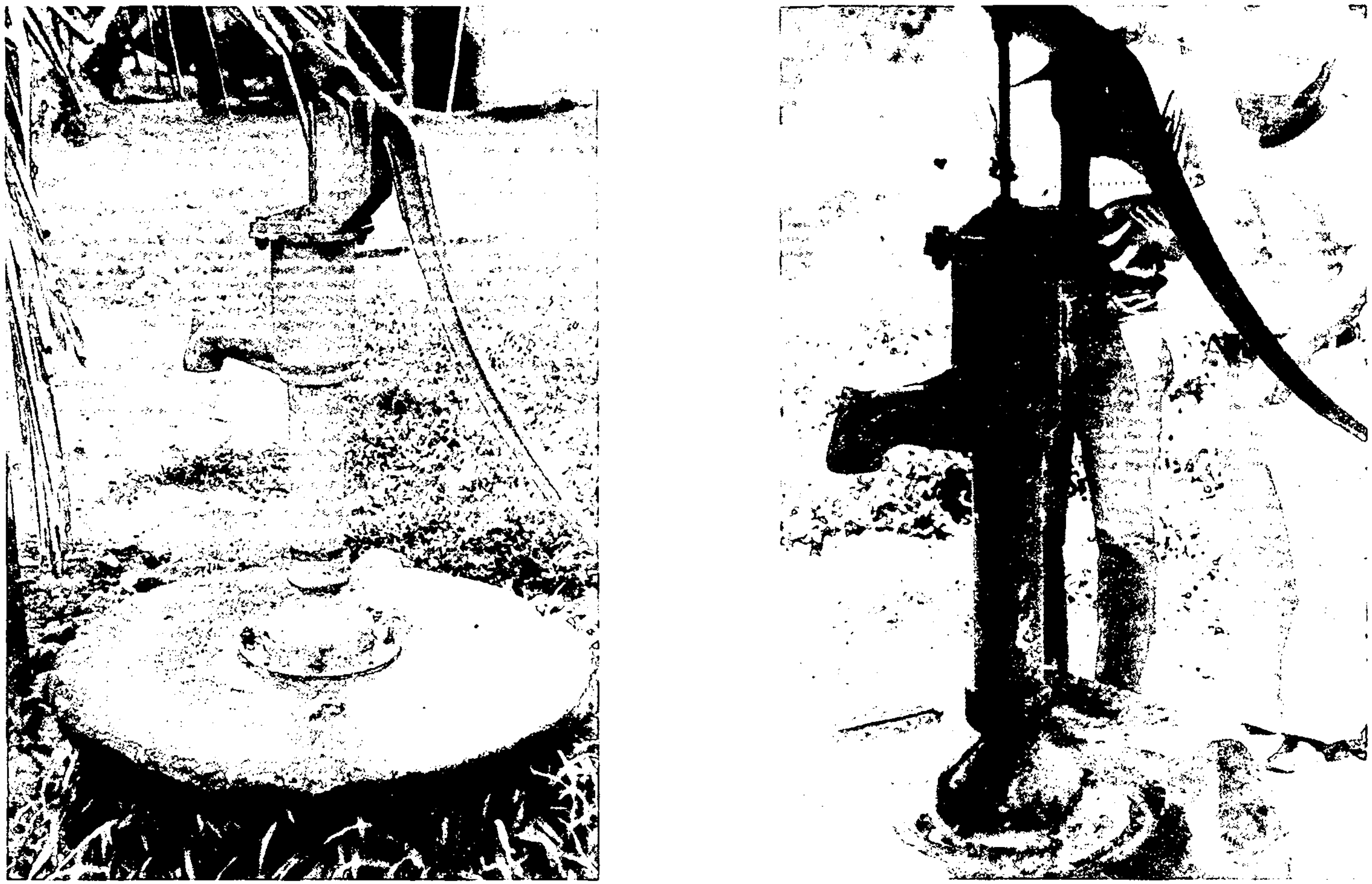
5. Needed design changes and future utilization.

6. Public acceptance and marketability.

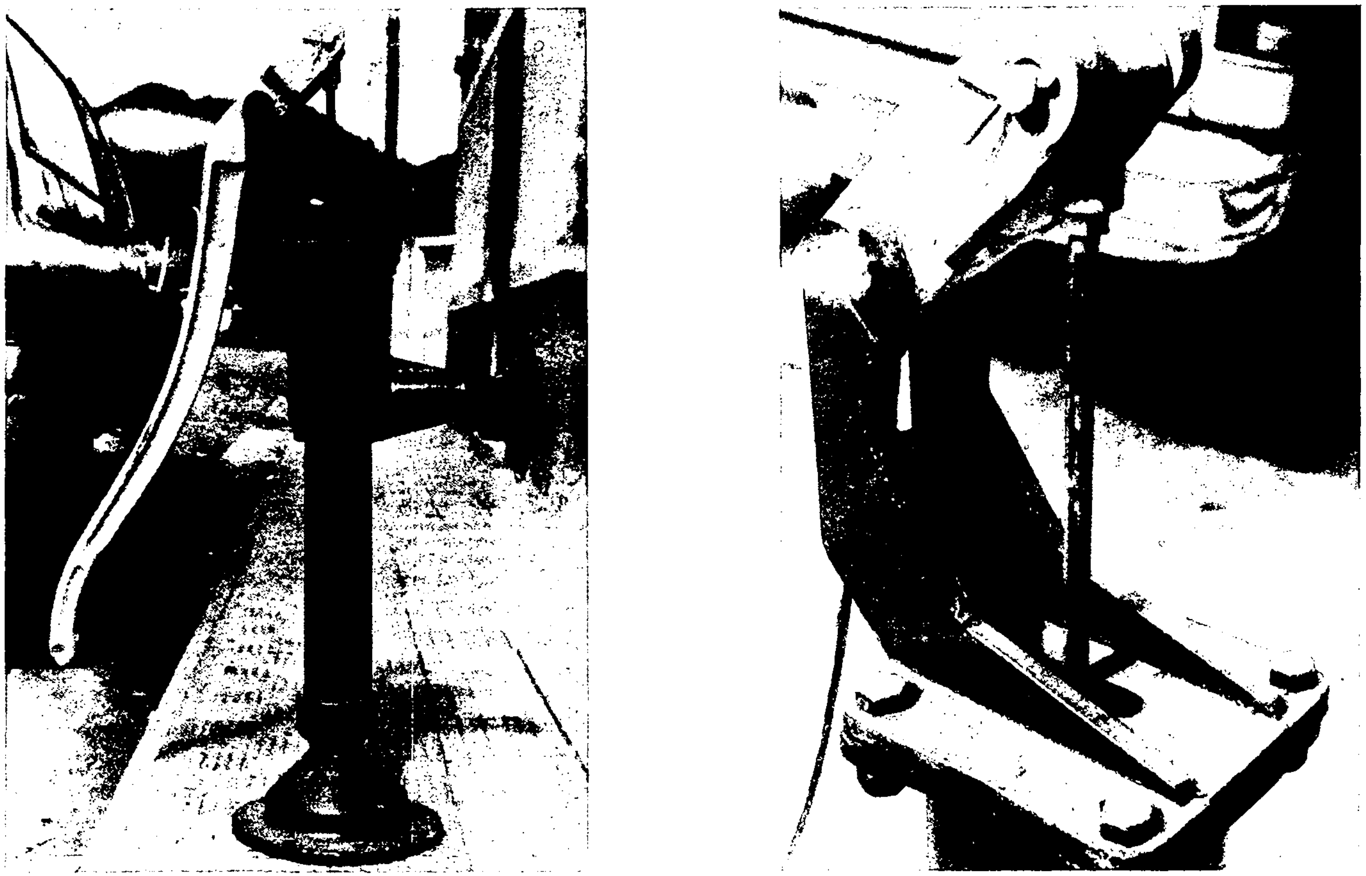
7. AID pump design characteristics and specifications.

The program has shown that the AID hand pump is very adaptable to local manufacture in many developing countries and offers many benefits (spare parts availability, easy maintenance, low cost, durability, employment generation, increase of local income, and the diminution of foreign exchange outflow). The AID hand pump consists of a shallow-well version (the plunger, or piston, and its cylinder located above the water level) and a deep-well version (the plunger, or piston, and its cylinder located below the water level). Both versions are single-action, reciprocating, positive displacement type pumps. Photographs of these pumps, produced in both Costa Rica and in Nicaragua, follow.

COSTA RICA

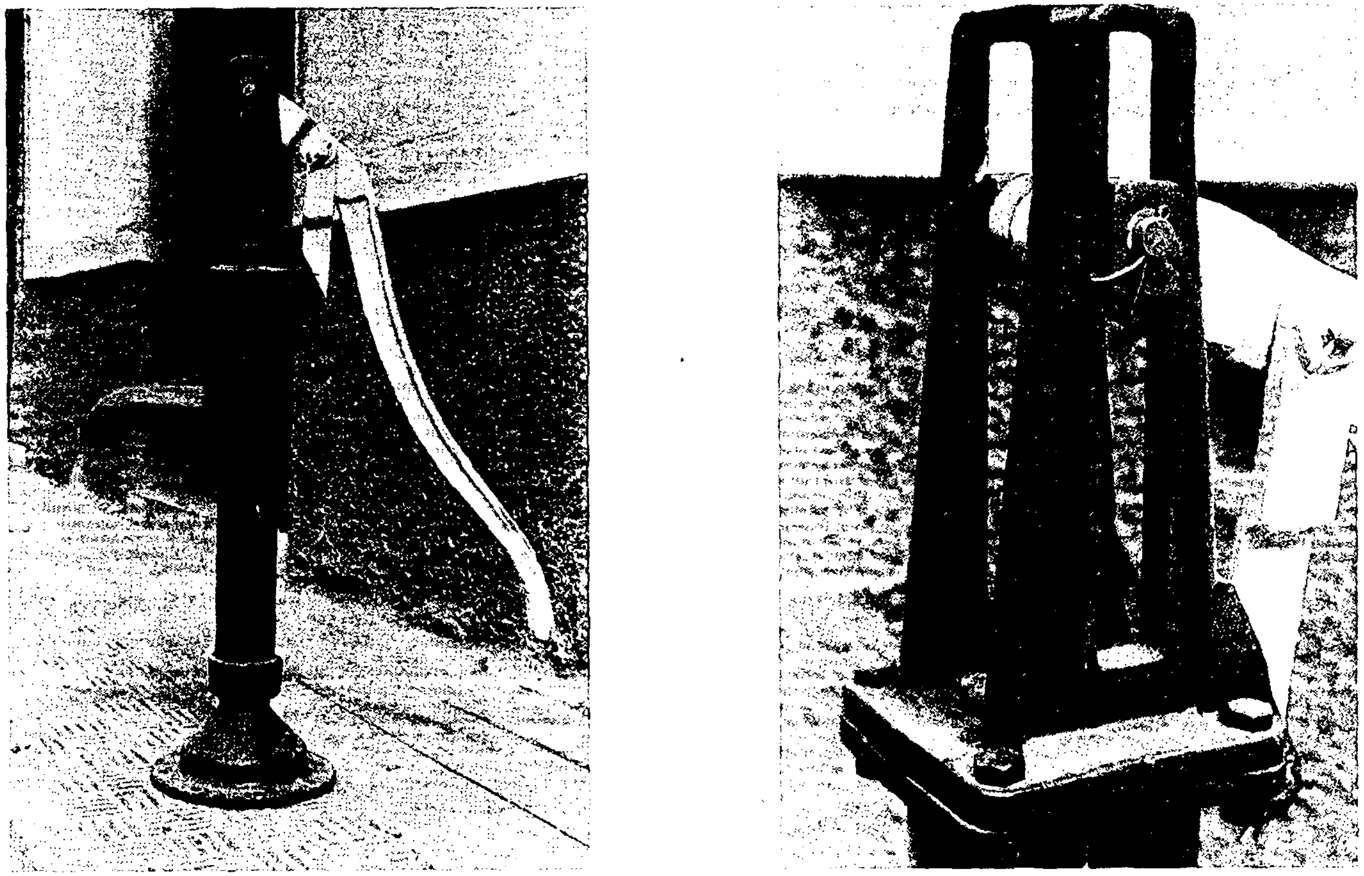


The AID shallow-well pump, left photo, and the AID deep-well pump, right photo, both manufactured in Costa Rica.



The AID shallow-well pump, manufactured in Nicaragua

NICARAGUA



The AID deep-well pump, manufactured in Nicaragua

COSTA RICA

Background

It is universally accepted that an adequate supply of water for drinking, personal hygiene, and other domestic purposes and an adequate means of waste disposal are essential to public health and well-being. Unfortunately, vast numbers of people in the developing world, most of them living in rural areas, do not have access to a safe and convenient source of water. When safe and convenient sources are available, satisfactory sewage disposal facilities normally are still unavailable.[1/]

Costa Rica was chosen as a test country because of a sizable well and hand-pump loan that had been made to that country by AID and because of the country's need for an expanded water-pump program. Provisions of the loan specifically included installation of water pumps on a large-scale basis, and it was felt that assistance in such areas as pump selection, installation techniques, and pump maintenance, as a part of this field-test program, would greatly benefit the government of Costa Rica. Costa Rican Ministry of Health and AID officials also strongly felt that a locally manufactured hand pump offered by the AID/Georgia Tech/ICAITI program had many advantages that should be included in the Costa Rican loan program (mainly employment generation, spare parts availability, and lower cost than for commercially available hand pumps).

One aspect of this project that was obvious from the beginning is that, even though Costa Rica is a developing country, it is much more developed than Nicaragua, and this shows up in the availability of rural community water supplies for the two countries. For instance, based on on-site surveys, representative test sites chosen for this project showed an average usage by approximately 60 persons in Costa Rica and 170 persons in Nicaragua. In Costa Rica, most communities of 250 inhabitants or more had some form of piped water system, while in Nicaragua, the size of the community usually exceeded 2,000 inhabitants before piped water was found. In Costa Rica, most communities had at least one well with a pump, if not piped water, and in Nicaragua, springs,

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[1/] Robert J. Saunders and Jeremy J. Warford, Village Water Supply (Baltimore, Maryland: The Johns-Hopkins University Press, 1976), p. 3.

rivers, and open, dug wells were the common sources of water. Costa Rica has a greater degree of electrification in rural areas, allowing the installation of motorized pumping systems that are not possible in many areas of Nicaragua. Further, the Ministry of Health in Costa Rica has had a limited hand-pump water program for some 15 years, while Nicaragua is just now in the beginning stages of such a program.

This does not mean that Costa Rica is without a need for improvement in its potable water delivery system. The Ministry of Health, for instance, has estimated that as many as 47,000 hand-operated water pumps are needed to provide a suitable water supply to the country's rural citizens. Further, many existing water pumps are inoperable because of a lack of maintenance and, where there are functioning pumps, most of the well structures are poorly designed and completely ineffective in sealing out contamination. There is also a great need for continued improvement in the proper governmental organization infrastructure to carry out an effective rural water supply program.

Active work began in Costa Rica in January 1977, when AID/Washington and Georgia Tech jointly agreed that Costa Rica and Nicaragua should be the test countries for the program described herein. A machine shop that purchases rough iron castings from a local foundry was contracted to manufacture 20 AID pumps (eleven deep-well and nine shallow-well). These pumps were produced and delivered to a Ministry of Health warehouse for storage and installation in April 1977. Two different kinds of pumps were chosen with which to compare the AID pump: a Dempster and a Japanese "Lucky" pump. Thirty-one sites, representative of Costa Rica, were chosen to receive the test pumps (16 AID pumps and 15 competitive pumps). (A pictorial monograph of all field-test sites in both Costa Rica and Nicaragua is contained in the Appendix of this report.)

Wells were randomly tested by chemical and bacteriological analyses prior to test-pump installation and found to contain large numbers of intestinal bacteria, indicating that contamination was not being sealed off from the water. The pumps were installed by the Ministry of Health, the wells were disinfected with a chlorine-yielding compound, and attempts were made to seal off the contamination sources. However, subsequent bacteriological testing has shown no improvement in the quality of the water, due to poor construction of the upper well structures by the rural villagers as well as their reluctance to accept an adequate amount of disinfection -- a matter that has caused great concern within the Ministry of Health. As a result, internal organizational changes have been made, and technicians and engineers are now being hired and trained in an attempt to alleviate the situation.

Field Test Sites

Table 1 shows those sites selected for the field testing in Costa Rica. They were chosen primarily because of their relative high usage (for Costa Rica) and accessibility. All sites were existing wells, all except one had been hand dug rather than drilled, and all were classified as either deep wells (as used herein, more than 25 feet in depth) or shallow wells (25 feet or less in depth). The usage at each site varied considerably, with an overall average of 60 people. Approximately half of these sites already had pumps, with the condition of the original pumps ranging from broken and inoperable to good. (The other half of the well sites had no previous pumps and, as a result, the new pumps replaced the bucket and rope system of retrieving water.)

Selection of the sites was made during the dry-season months of January, February, and March so that the water column figures would indicate annual low-water levels. However, the dry season of 1976-1977 took a disastrous toll on the sites, and, by the middle of May, many (approximately 50%) of the sites had dried up completely and had to be deepened before all pumps could be installed. In some cases, the wells had already been dug as deeply as possible, and substitute sites had to be found that were much more inaccessible and less desirable from a high-usage standpoint.

The general areas of site concentration were in the northwestern quadrant of Costa Rica in the vicinity of Nicoya, Santa Cruz, Liberia, and Las Cañas, and in the eastern area of Limon (see Map 1).

Manufacture of AID Pumps

Manufacturing Costs. A contract was signed with Mecanizados Mofama, S.A., located near San Jose, on January 28, 1977, for the manufacture of nine shallow-well type AID pumps and eleven deep-well type AID pumps. The prices of the pumps were as follows:

Table 1

SELECTED SITES FOR AID PUMP FIELD TESTS IN COSTA RICA

Site No.	Location	Well Situation	Well Type	Classification by Depth	Depth (m)	Average[1] Estimated Usage - No. People	Type of Original Pump	Condition of Original Pump	Has Water Meter	Type[2] of Pump Installed	Date Installed
1	La Palma de Abangares	Existing	Dug	Deep	11.55	70	Japanese	Broken		AID-DW	4/22/77
2	San Joaquin de Abangares	Existing	Dug	Deep	11.70	38	Dempster	Broken		AID-DW	4/22/77
3	IMAS, El Torito, Samara	Existing	Dug	Shallow	5.86	98	Dempster	Good	X	AID-SW	5/17/77
4	Hernandez de Santa Cruz	Existing	Dug	Shallow	4.30	51	Dempster	Good		Lucky	5/18/77
5	Curime de Nicoya (School)	Existing	Dug	Deep	10.35	125	Dempster	Poor		Dempster	5/19/77
6	Pijije de Bagaces (School)	Existing	Dug	Deep	10.80	38	Dempster[3]	Good		Dempster	5/19/77
7	La Javilla de Canas (School)	Existing	Dug	Shallow	6.10	91	Dempster	Poor		AID-SW	5/20/77
8	Zent #1, Matina (School)	Existing	Dug	Shallow	4.50	60	None	--	X	AID-SW	5/20/77
9	Corina, Matina	Existing	Dug	Shallow	7.60	17	Japanese	Poor		AID-SW	5/25/77
10	Bristol, Matina	Existing	Dug	Shallow	3.20	145	None	--	X	AID-SW	5/26/77
11	La Margarita, Bataan (School)	Existing	Dug	Shallow	3.85	41	None	--		Lucky	5/26/77
12	Corazon de Jesus	Existing	Dug	Deep	12.10	13	None	--		Dempster	6/1/77
13	Zent #2, Matina (Pedro Bustos)	Existing	Dug	Shallow	4.20	15	None	--		AID-SW	6/7/77
14	San Miguel de Venado	Existing	Dug	Deep	14.85	51	None	--		Dempster	6/15/77
15	Sabalito de Venado	Existing	Dug	Deep	19.10	24	None	--		Dempster	6/16/77
16	Pueblo Nuevo de Colorado (School)	Existing	Dug	Shallow	7.48	32	Dempster	Fair	X	AID-SW	6/22/77
17	San Francisco, Santa Cruz (School)	Existing	Dug	Shallow	6.30	30	Dempster	Fair		Lucky	6/23/77
18	Terciopelo de Nicoya	Existing	Dug	Deep	7.61	50	Dempster	Poor		AID-DW	6/24/77
19	Caimitalito de Nicoya (School)	Existing	Dug	Deep	10.50	34	Red Jacket	Broken		AID-DW	6/24/77
20	Judas de Chomes	Existing	Dug	Deep	9.85	118	Dempster	Broken	X	Dempster	8/12/77
21	Limonal de Abangares	Existing	Dug	Deep	9.30	30	Dominion	Broken		Dempster	9/2/77
22	Zent #3, Matina (Mariano Grijalba)	Existing	Dug	Shallow	4.90	8	None	--		Lucky	6/7/77
23	Santa Marta de Matina	Existing	Dug	Shallow	4.10	42	Dempster	Broken		Lucky	7/27/77
24	Tarcolesa de Orotina (School)	Existing	Dug	Shallow	4.30	32	Dempster	Fair		Lucky	8/4/77
25	Mesetas Abajo (School)	Existing	Dug	Shallow	6.30	15	None	--		Lucky	8/5/77
26	San Juan Grande	Existing	Dug	Deep	9.30	153	None	--		AID-DW	8/5/77
27	Sabana Grande	Existing	Dug	Deep	8.30	245	Dempster	Broken		AID-DW	8/10/77
28	Coyolito de Santa Cruz	Existing	Drilled	Deep	10.00	65	Dempster	Broken		AID-DW	8/11/77
29	La Lorena de Santa Cruz	Existing	Dug	Deep	9.60	28	None	--		Dempster	8/12/77
30	Lajas de Canas	Existing	Dug	Deep	10.00	19	None	--		AID-DW	8/29/77
31	Indiana Tres, Siquirres	Existing	Dug	Shallow	3.25	40	None	--		AID-SW	9/8/77

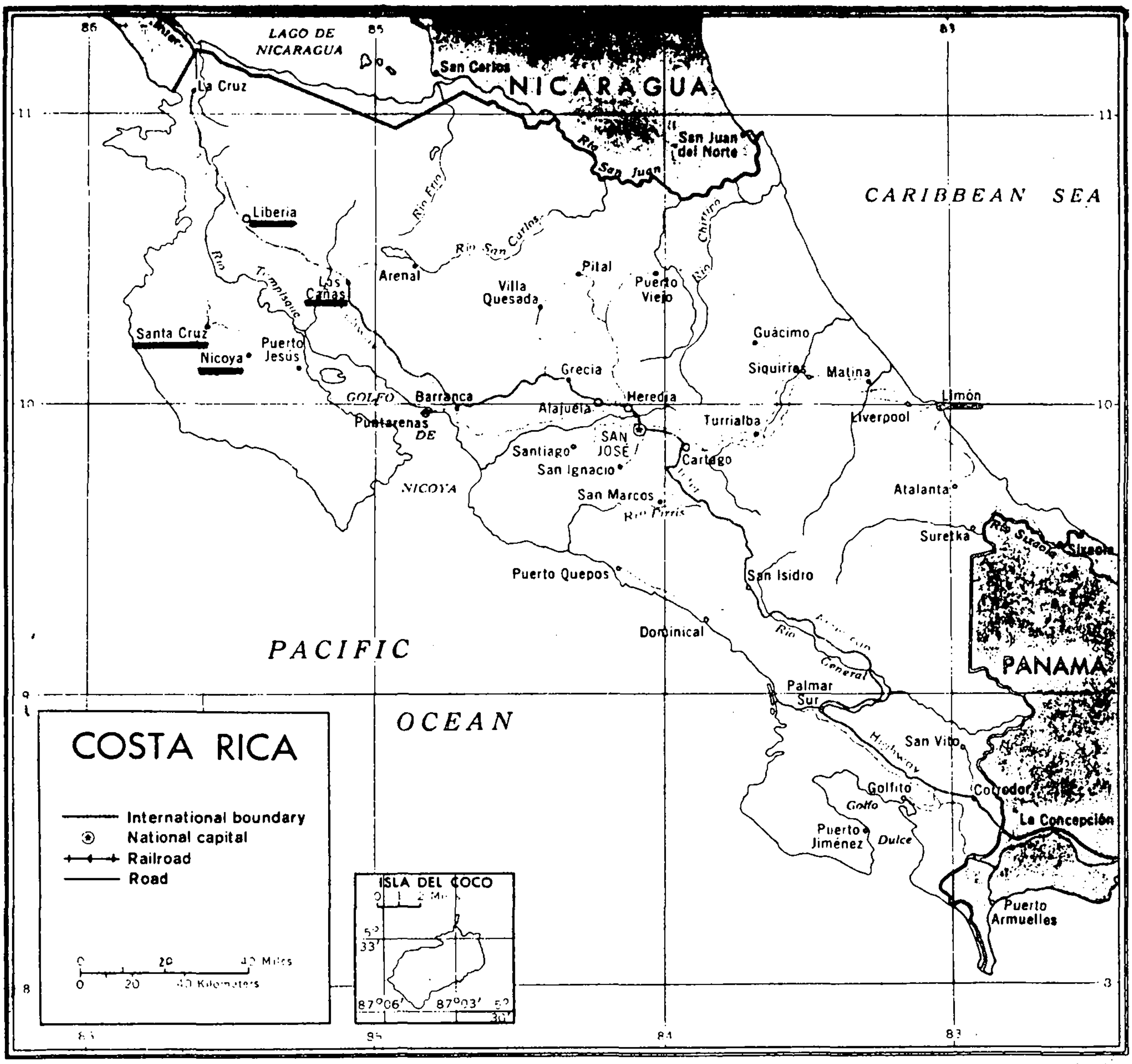
[1] Average estimated usage based upon individual user pattern surveys at each site.

[2] AID-DW: AID pump for deep well; AID-SW: AID pump for shallow well; Dempster: Dempster deep-well type pump; Lucky: Japanese-made shallow-well type pump.

[3] Pump being used for forced pumping to storage tank.

Map 1

COSTA RICAN TEST SITE AREAS



Sites in Costa Rica are concentrated in two major areas: (1) the northwestern quadrant around Nicoya, Santa Cruz, Liberia, and Las Canas, and (2) the eastern area of Limon.

Shallow-well	$ 98	(each)
Deep-well	$128	(each)
Patterns	$498	(one-time charge only)

Because an order for 20 pumps does not offer any significant economies of scale, it is extremely costly to manufacture such a small order, especially if the manufacturer is not familiar with the many components of the pump and how they relate to each other. The manufacturer broke even on the 20 pumps actually produced and has recently updated his prices to reflect larger numbers of pumps per order and inflation:

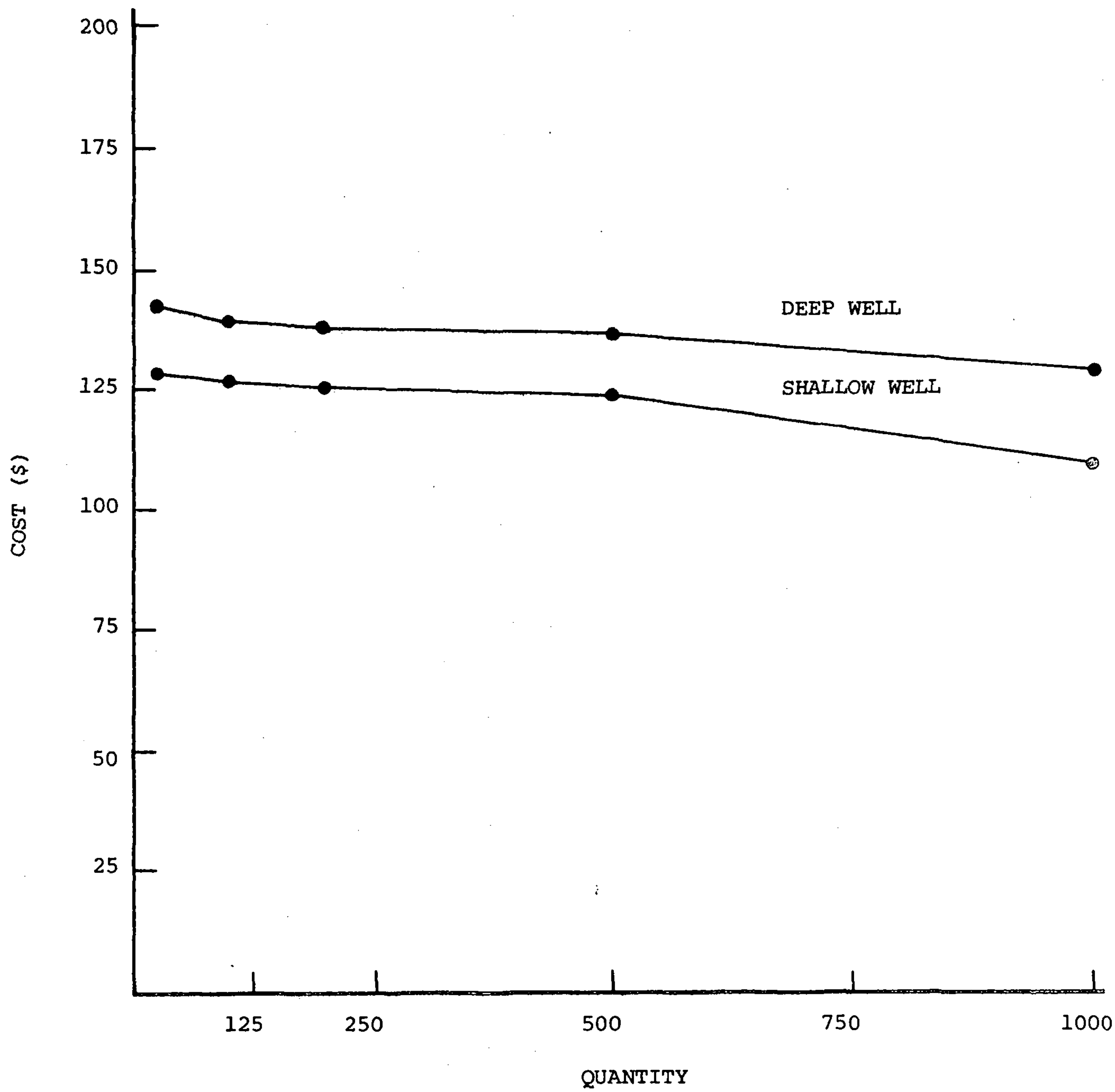
Quantity	Shallow-well ($ Price/Unit)	Deep-well ($ Price/Unit)
20	128.00	139.00
100	126.50	137.75
200	125.50	136.60
500	124.25	135.25
1,000	120.00	130.00

The above price scales are represented graphically in Figure 2. There are other foundries in Costa Rica that could be used for future orders to meet the 47,000 pump demand, mentioned earlier, and it is felt that the prices quoted by Mecanizados Mofama could be improved upon because of competitive pressures. The prices as quoted are competitive with imported pumps (Dempster, for example), and when other advantages of local pump manufacture are taken into consideration, such as spare parts availability, employment generation, local income increases and reduction of foreign exchange outflow, this possibility appears attractive to project personnel, AID officials in Costa Rica, and Ministry of Health personnel.

It should be noted that it has been very difficult during this program to arrive at a "representative" price for the AID pump because of extreme variances in manufacturing costs, especially overhead, between different countries and even between different manufacturers within the same country. For example, in Nicaragua, prior to placing an order with the manufacturer, price quotes were received from seven foundries that ranged from $69 (shallow-well) and $75 (deep-well) to $225 (shallow-well) and $250 (deep-well). During a trip to Ghana, the project director for this program discussed the AID pump with AID and Ghanaian government officials and discovered that prior investigations

Figure 2

COST BY QUANTITY TO PRODUCE
AID PUMPS IN COSTA RICA



into the use of the AID pump for that country indicated a cost of approximately $500 per pump (shallow-well or deep-well) for a relatively large order (100 pumps or more). Inquiries into the manufacture of the AID pump in the Dominican Republic have provided cost estimates ranging from $160 (shallow-well) and $200 (deep-well) to $261 (shallow-well) and $298 (deep-well), with the cost of patterns for making the castings included here in the price of the pumps, rather than as a separate cost.

To complicate matters even more, a judgment of expected quality must be balanced against the price of the pump and, in some cases, higher prices have not necessarily reflected a potential for the highest level of quality. However, various cost estimates show that the AID pump (shallow-well or deep-well) can be provided for an attractive price of below $100 (for instance, Indonesian foundries are manufacturing the deep-well pump for $60 and the shallow-well pump for $50 on orders of less than 50 pumps per order).

Manufacturing Specifications. The AID pumps were manufactured according to AID-approved Battelle drawings and with the following additional instructions:

1. The plunger rod was made from 1/2-inch diameter rod, rather than 7/16-inch, because of difficulty in locating a reliable supply of 7/16-inch stock. The pump rod nut, the rod end, and the plunger assembly also were changed to accommodate the 1/2-inch plunger rod.

2. The handle pivot pins were hardened to 40 R_C and steel bushings (60-64 R_C) were inserted in the pump handle holes. By taking this approach, the pins are expected to wear out before the handles, allowing easier repairs at the least cost.

3. For the shallow-well pump, the 3-inch support pipe was internally coated with epoxy for a smoother surfaced cylinder finish. A bolted pump cap was chosen in preference to a pin-mounted pump cap (the bolted cap was felt to be sturdier and longer lasting).

4. For the deep-well pump, a bolted pump cap was chosen in preference to a pin-mounted option. The pump cap was modified, however, because of concern by the manufacturer that he could not cast this particularly complex part. (Figures 3 and 4 are working drawings of the locally modified cap and its accompanying handle fulcrum.) The pump cylinder was constructed from Schedule 40 PVC pipe.

Figure 12

FULCRUM HANDLE FOR MODIFIED DEEP-WELL PUMP CAP IN NICARAGUA

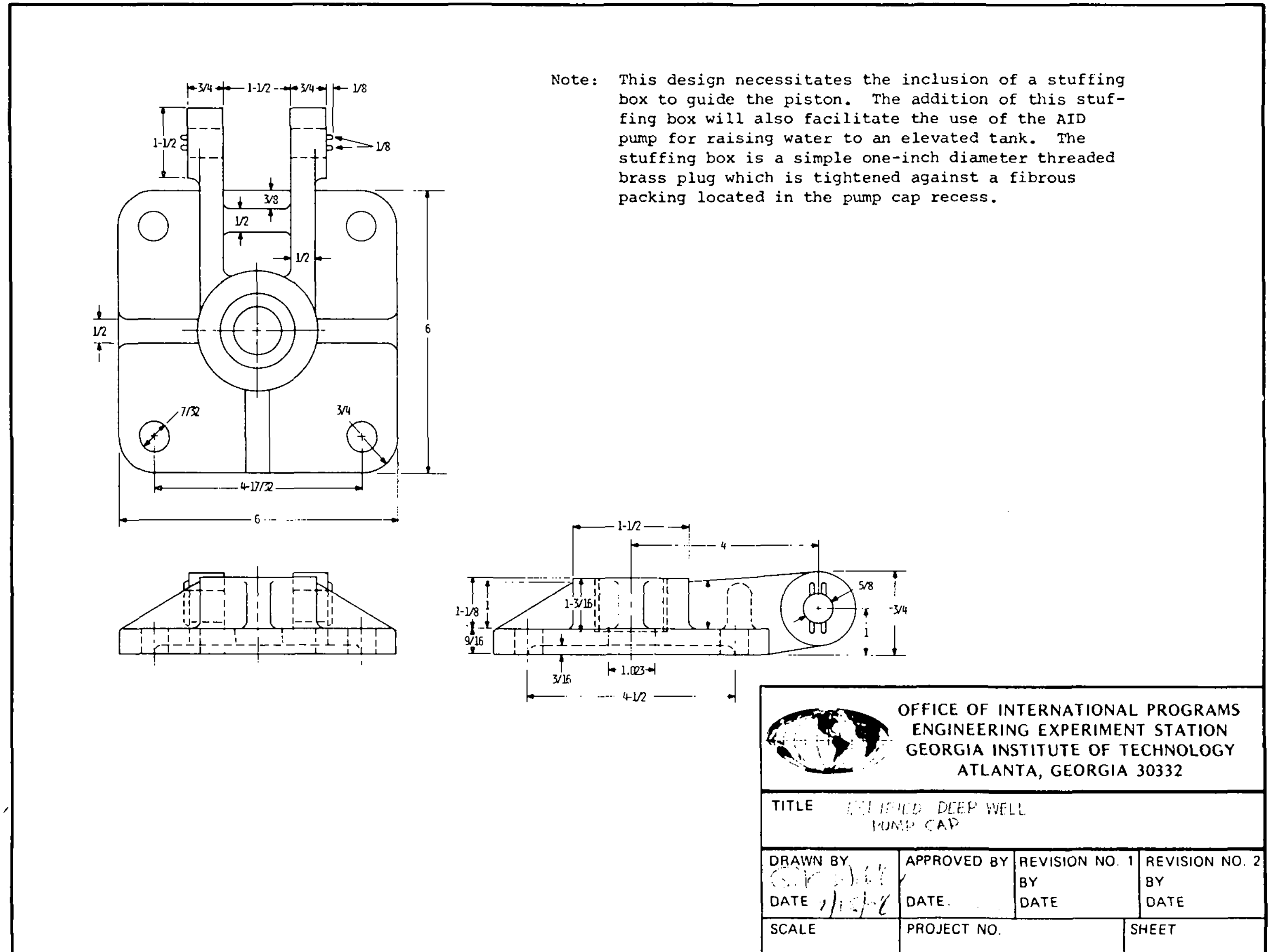
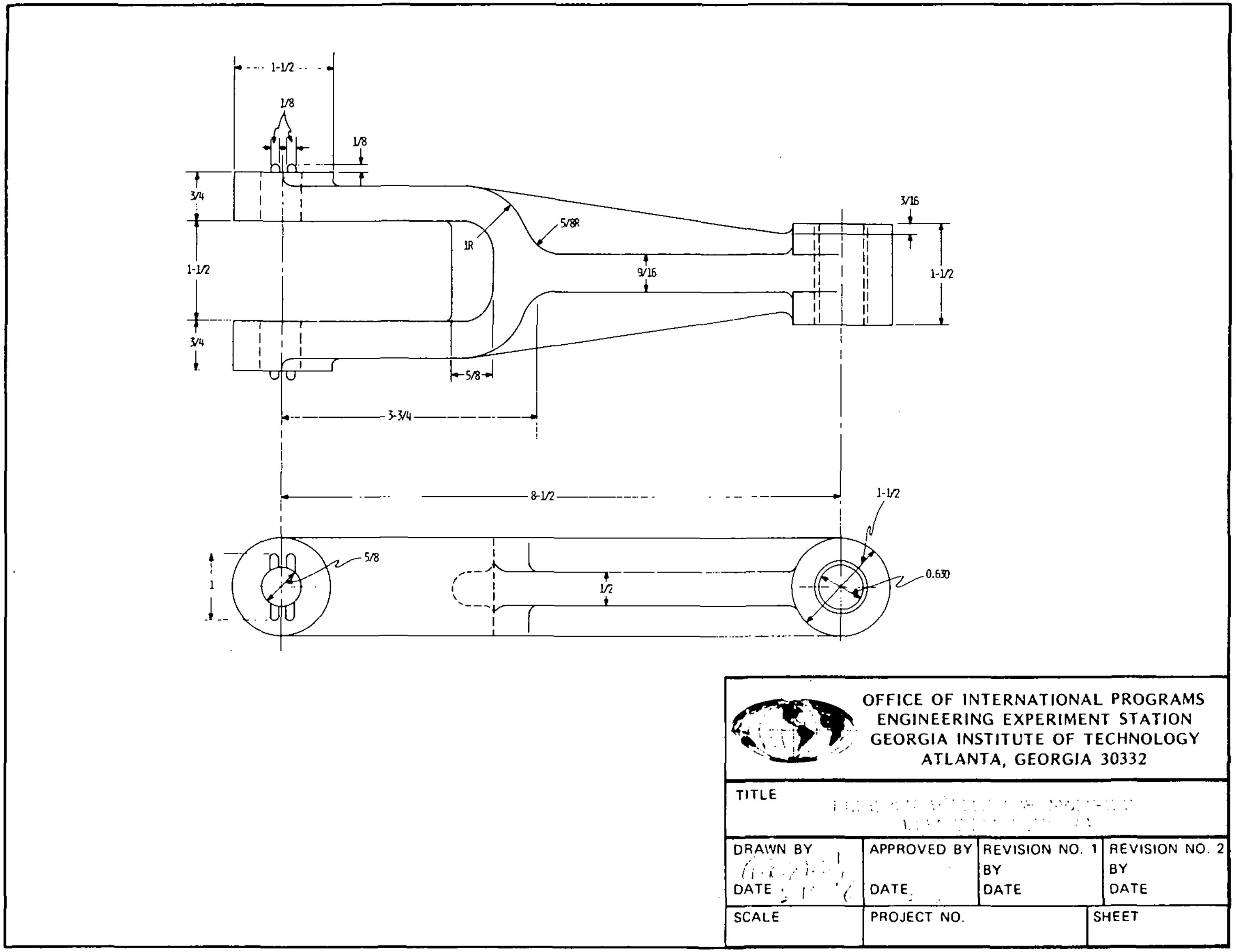


Figure 4

FULCRUM HANDLE FOR MODIFIED DEEP-WELL
PUMP CAP IN COSTA RICA



In addition to the above, all pumps were painted with an anticorrosive coating and consecutively numbered for identification purposes. In general, the manufacturing problems encountered were mostly associated with those to be expected from unfamiliarity with the pump itself on the first production order -- a prototype would have been very helpful -- and from poor castings. Visual inspection checks were carried out at periodic stages of production by Georgia Tech and ICAITI personnel, and, before acceptance of the finished pumps, all pumps were installed on a 55-gallon drum of water and checked for overall pump performance.

It should be noted that the foundry producing the castings had no laboratory facilities and used scrap metal as the source of raw materials. High-quality castings require a level of technology not generally expected to be found in developing countries and, without this technology, quality (such as degree of hardness) will vary from pump to pump and from one production order to the next. As a result, the pump castings produced in Costa Rica were rough in texture, contained voids and inclusions, and would be considered unacceptable by U.S. standards. However, subsequent castings produced for replacement parts showed significant improvement as the foundry gained experience in the production of these components.

Proper machine shop facilities and skilled machinists also are necessary for the manufacture of the AID pump. While the Costa Rican AID pump manufacturer had only a small shop (four employees) for the machining operations required, it was sufficient for small-quantity pump production. The machine shop contained a multiple-speed lathe, a vertical lathe, welding equipment, a drill press, a metal cutter, and assorted hand tools. Sandblasting equipment was not available but would have been useful in smoothing out the rough texture of the castings. Additionally, the machine shop did not have access to an oven, which was necessary for hardening the steel bushing inserts and the handle pivot pins (a competitor's oven was actually used).

Comparative Pumps

Two pumps were chosen for comparison with the AID pumps manufactured in Costa Rica -- a Dempster and a Japanese Kawamoto Daiichi "Lucky" pump. The Dempster model (see Figure 5) is considered by the authors of this report to be one of the better hand-operated water pumps in the world, has the cylinder

Figure 5

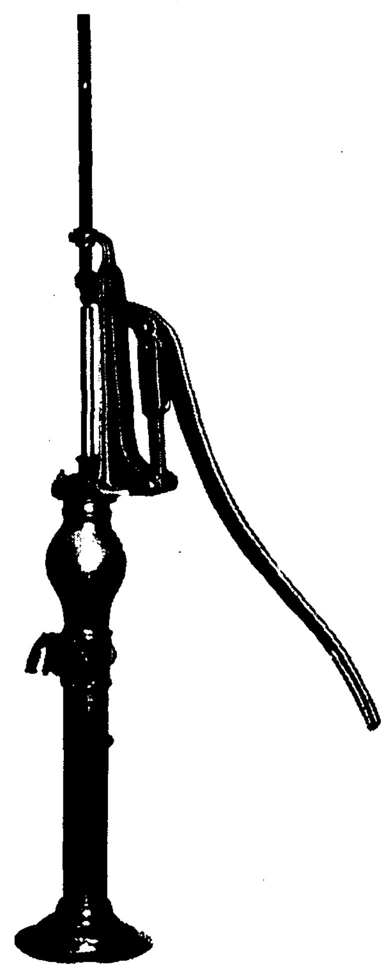
PUMPS and CYLINDERS

DEMPSTER®

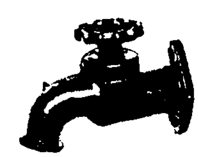
CONSTRUCTION

DATA SHEET 380-3
ISSUE DATE 1976

CAST IRON



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 36
Compression Spout
Furnished at slight Additional Cost.

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. This model is available with 2-1/2-inch tapping in the base at slight additional cost.

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 connec-*tion. 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.

below water level so that it can be used for wells of shallow or deep depth, and costs approximately $257 (1977 list prices) in Central America, delivered (the $257 includes the pump, the cylinder, and transportation). The "Lucky" pump (see Figure 6) is for shallow wells only (25 feet or less in depth), appears to be of good quality, has a porcelain-lined cylinder, and costs approximately $63 (1977 list prices) in Central America, delivered.

Monitoring System

Responsible individuals in each test community were provided with simple, printed report forms (see Form 1) designed to provide information covering community usage, pump physical condition, and functioning problems, if any. These forms were to be filled out and returned to Ministry of Health representatives every 15 days. If the returned forms showed complaints of any type concerning pump functioning or condition, a repair truck was dispatched to the site for investigation and repair of the defect. Should a serious pump failure occur that could not be corrected readily by Ministry personnel, the Ministry was instructed to request immediate assistance from Georgia Tech or ICAITI by telephone.

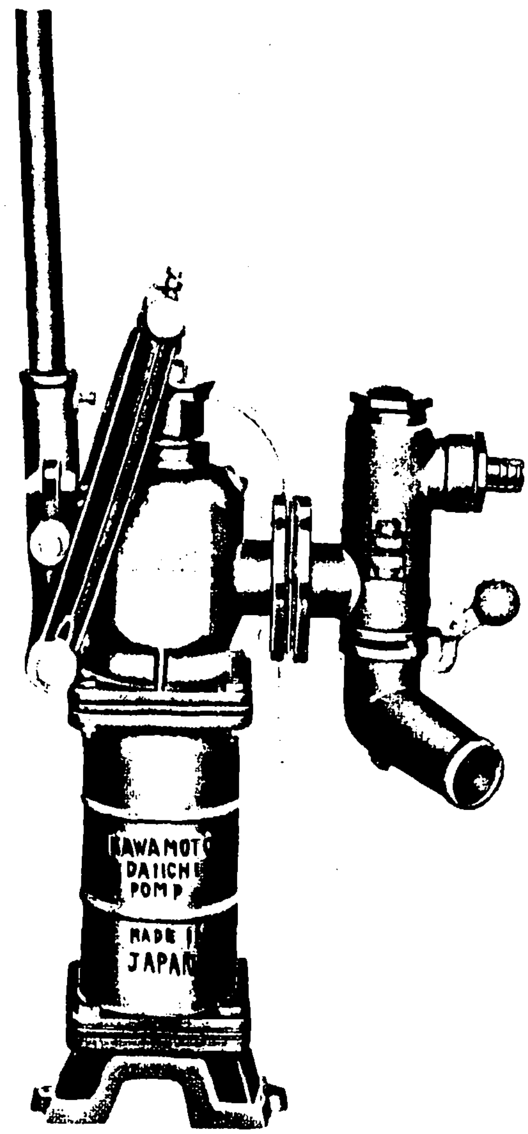
Copies of all report forms, as well as records of any repair work done on either AID or competitive pumps, were maintained at the Ministry of Health. This information was reviewed periodically by ICAITI for inclusion in pump performance control charts. In addition to the above, a periodic site-by-site inspection of all pumps was made by Georgia Tech and/or ICAITI personnel (approximately 10 times during the 12-month monitoring period).

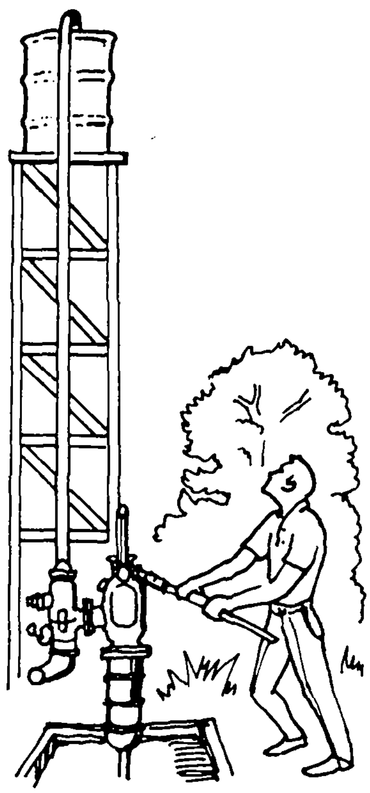
Pump Performance

In general, the functional performance and acceptance of the Costa Rican-manufactured AID pump has been satisfactory, but serious casting defects were encountered which necessitated the replacement of five handles, two shallow-well caps, and one modified handle fulcrum. In all cases, these failures were caused by a lack of quality control at the foundry, which was not possible without laboratory facilities for testing the cast iron. The foundry used for the manufacture of the AID pumps in Costa Rica was representative of what might be found in many developing countries, but was not considered by project personnel to be the best in the country. Better foundries were available; however, these

TRADE MARK LUCKY PUMP

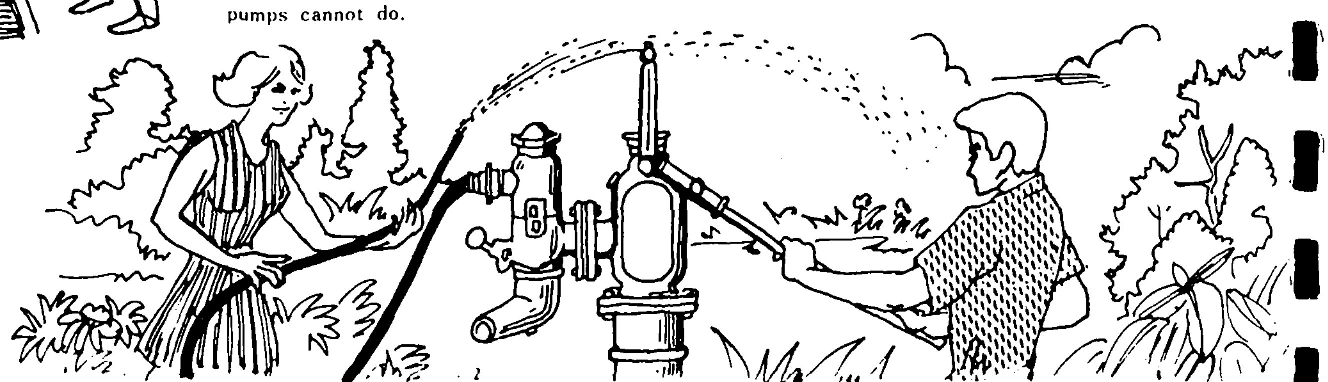
The most outstanding and unique feature of the "LUCKY" Hand Pump is the ConVertibility in its usage from an ordinary suctioning to pushing up water as illustrated.
No other brand of hand pump offers this double usage. Thus, it makes "LUCKY" a very economical buy, "TWO PUMPS FOR THE PRICE OF ONE"

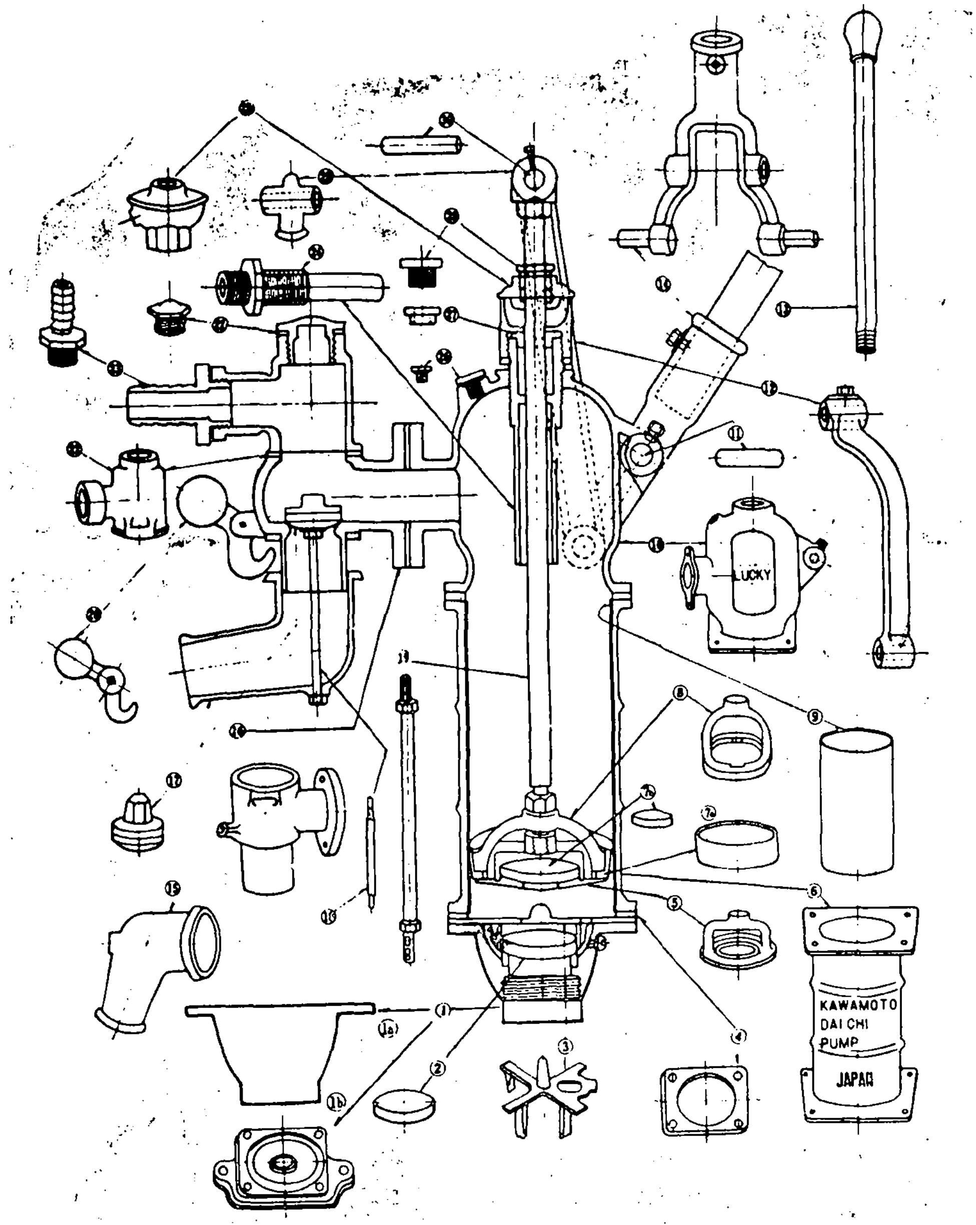




Special Features:

1. Chrome Pump Rod: A special hard chrome around the pump rod gives "LUCKY" added durability. Only gun-metal and steel used in main parts and casted with the best pig iron.
2. Porcelain Enameled Cylinder Liner: Unlike other pumps, "LUCKY" has a porcelain enameled cylinder liner which prevents rusting of the pump lining. Very little physical effort is required to get maximum amount of water in less time.
3. Leakage Impossible: A special double gland packing prevents water leakage which is very common in other kinds of pumps.
4. Vertical Pumping Motion: This kind of pumping motion makes it easy to connect the pump rod of the artesian wells, without any alteration.
5. Mud Free: The unique construction of "LUCKY" pumps eliminates mud which ordinary pumps cannot do.

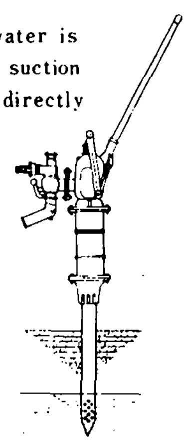




- ⓵a DRIVEN SUCTION VALVE BOX
- ⓵b DUG SUCTION VALVE BOX
- ⓶ VALVE
- ⓷ VALVE GUIDE
- ⓸ RUBBER PACKING
- ⓹ LOWER PISTON
- ⓺ CYLINDER
- ⓻a BOWL RUBBER
- ⓻b PISTON VALVE
- ⓼ UPPER PISTON
- ⓽ SLEEVE PORCELAIN ENAMELED
- ⓾ CHAMBER
- ⑪ HANDLE PIN
- ⑫ DOUBLE ROD
- ⑬ STEEL--PIPE HANDLE
- ⑭ LEVER
- ⑮ UNIVERSAL SPOUT
- ⑯ FAUCET BOX
- ⑰ FAUCET VALVE
- ⑱ VALVE SPINDLE
- ⑲ PISTON ROD
- ⑳ STOP WATER WEIGHT
- ㉑ FAUCET COVER
- ㉒ UPPER FAUCET
- ㉓ HOSE COUPLING
- ㉔ INNER GLAND BOX
- ㉕ GLAND BOX
- ㉖ LEAKAGE SPOUT
- ㉗ INNER GLAND
- ㉘ GLAND
- ㉙ ROD HEAD
- ㉚ GUIDE PIN

DRIVEN-WELL

The underground water is sucked up through a suction pipe that is driven directly underground.



Art. No.	Sort of Well pump	Inside Diameter of Suction Pipe	Suction Capacity Per Hour	More Than Suction Lift	More Than Pushing Lift	Weight
G-700	Driven	1 ¼"	1,100 imp. gallon	30 feet	50 feet	20 kg
G-701	Driven	1 ½"	1,100 imp. gallon	30 feet	50 feet	20 kg
G-702	Dug	1 ¼"	1,100 imp. gallon	30 feet	50 feet	20 kg
G-703	Dug	1 ½"	1,100 imp. gallon	30 feet	50 feet	20 kg

AVAILABILITY:
Good for every existing dug well and fit for driven wells.

USE:
General home use, sucking, pushing up to a height, fire-preventing and watering.

SPECIFICATION:
Vertical size, 85cm high, steel-pipe handle of 70cm long equipped.

Form 1

Bimonthly Inspection Report of Water Pumps

Location: ______________________________

Water pump number: ______________________________

Date of inspection: ______________________________

Name of inspector: ______________________________

1. PHYSICAL CONDITION

Indicate the condition of the following water pump parts.

	GOOD CONDITION	WORN-OUT	BROKEN
Handle:	______	______	______
Plunger Rod:	______	______	______
Pins:	______	______	______
Nuts and Bolts:	______	______	______
Pump Stand:	______	______	______

2. PERFORMANCE

Indicate if there was a fault in the water pump in the last 2 weeks. Yes ___ No ___

If there was a fault, describe the problem and action, if any, taken to correct it.

____

____

Indicate if there have been complaints about the performance of the water pump. Yes ___ No ___

If there were, describe them.

____

Form 1 (continued)

3. USAGE

Indicate how many people use this well.

Less than 30	30 to 50	50 to 100	100 to 200	More than 200
________	________	________	________	________

Indicate approximately how many times per day the pump is used.

Less than 30	30 to 50	50 to 100	100 to 200	More than 200
________	________	________	________	________

4. GENERAL OBSERVATIONS

foundries were not interested in initial small orders even though the potential for much larger orders existed for the future.

Leather cups have shown excessive wear in AID shallow-well pumps which have been manufactured with metal cylinders and coated with epoxy. The cups appeared to wear out for two reasons: first, the walls of the cylinders, even when an epoxy coating is applied, are too rough and, second, the diameter of the metal base of the plunger follower where the leather cup sits was made too small (causing the leather cup to catch between the cylinder wall and the base, literally tearing the cup apart). The roughness of the cylinder lessens as the cup hones it down, but it still presents a problem. If numerous cup replacements during the life of the pump are not acceptable, then the cylinder must have a PVC sleeve or be mechanically honed down during its manufacture -- an operation that may not be available in some developing countries. The smallness of the diameter of the plunger's metal base was easily corrected by manufacturing units that are exact size or slightly on the plus side of specifications (in other words, closer quality control).

PVC cylinders for the AID deep-well pumps performed exceptionally well, and <u>no</u> leather cups were changed in this type of cylinder (which indicates that PVC or honed-down metal cylinders should be used for future pumps). There have been <u>no</u> significant problems with the U.S.-manufactured Dempster or the Japanese-manufactured "Lucky" pumps.

Table 2 shows the corrective maintenance performed on all pumps installed in Costa Rica. In addition, Ministry personnel conducted periodic preventive maintenance, such as lubrication of moving parts, minor adjustments and tightening of nuts and bolts.

As mentioned previously, pump usage in terms of the number of people expected to use each pump site was estimated by user pattern surveys. In order to verify the validity of these estimations, water meters were installed in five sites and total consumption readings were obtained over an eight-month period. These data when applied to the survey estimations showed a variation in per capita consumption for 0.3 gallons per day to 1.6 gallons per day from one site to another, and an overall average of 1.13 gallons per day.

Considering the fact that the great majority of the pumps in Costa Rica were installed at schoolhouses and that, therefore, students during school

Table 2

FIELD TEST PUMP MAINTENANCE - COSTA RICA

Site No.	Location	Corrective Maintenance During Test Period
	A. AID DEEP-WELL PUMP WITH PVC CYLINDER	
1	La Palma de Abangares	Replaced handle (broken - casting defect)
2	San Joaquin de Abangares	NONE
19	Caimitalito de Nicoye	NONE
26	San Juan Grande	Replaced handle fulcrum (broken - casting defect)
27	Sabana Grande	NONE
28	Coyolito de Santa Cruz	NONE
30	Lajas de Canas	NONE
	B. DEMPSTER DEEP-WELL PUMP	
5	Curime de Nicoya	NONE
6	Pijije de Bagaces	NONE
12	Corazon de Jesus	NONE
14	San Miguel de Venado	NONE
15	Sabalito de Venado	NONE
20	Judas de Chomes	NONE
21	Limonal de Abangares	NONE
29	La Lorena de Santa Cruz	NONE
	C. AID SHALLOW-WELL PUMP WITH STEEL CYLINDER	
3	IMAS, El Torito, Samara	Replaced handle (broken - casting defect) 2 cup changes (excessive wear)
7	La Javilla de Cañas	Replaced handle (broken - casting defect) 6 cup changes (excessive wear)
8	Zent #1, Matina (school)	Replaced pump cap (broken - casting defect) Replaced handle (broken - casting defect) 1 cup change (excessive wear)
9	Corina, Matina	2 cup changes (excessive wear)
10	Bristol, Matina	3 cup changes (excessive wear)
13	Zent #2, Matina	1 cup change (excessive wear)
16	Pueblo Nuevo de Colorado	Replaced pump cap (broken - casting defect)
18	Terciopelo de Nicoya	1 cup change (excessive wear)

Table 2 (continued)

Site No.	Location	Corrective Maintenance During Test Period
31	Indiana Tres, Siquirres	Replaced handle (broken - casting defect) 2 cup changes (excessive wear)
		D. LUCKY SHALLOW-WELL PUMP
4	Hernandez de Santa Cruz	NONE
11	La Margarita, Bataan	NONE
17	San Francisco, Santa Cruz	NONE
22	Zent #3, Matina	NONE
23	Santa Marta de Matina	NONE
24	Tarcolesa de Orotina	NONE
25	Mesetas Abajo	NONE

Note: All AID pump components that broke during the test period were from the initial production order. No subsequently produced replacement parts failed during the test period (because of improved quality control by the manufacturer).

It is also interesting to note that the AID deep-well pump with PVC cylinder and leather cup required no cup replacement during the 12-month monitoring period in communities of as many as 245 users per day. Further, at the end of the test period, AID deep-well pumps were disassembled and inspected with no evidence of wear to the cylinder or to the leather cup itself.

hours wer the principal consumers, the relatively low average per capita consumption shown above appears reasonable. The variation between sites may reflect errors in the survey estimates; therefore, in any future programs of this type, water meter readings would be the preferred method for determining usage.

All pump defects requiring corrective maintenance were due to known causes (poor castings, rough steel cylinders, etc). Maintenance problems, as could be expected, occurred randomly rather than at those sites with the highest usage. Therefore, no correlation could be shown between usage and corrective maintenance.

In order to further determine the durability of the different test pumps, attempts were made to correlate the different well depths with the amount of total stress exerted on the test pumps, assuming that the greater the depth of the well as well as the greater the distance to the water level, the greater the pump is stressed in pumping water over a given period of time.

Under normal operating conditions, a pump is never uniformly stressed, that is, the force per unit area varies throughout the structure of the pump. Due to the difficulty in calculating total stress for the entire pump, both theoretical and actual force (in Newtons) was determined on the delivery system of the pump. The theoretical force depended upon the volume of water being lifted from the well's water level plus the weight of the plunger rod and plunger assembly, while the actual force depended not only upon all the above, but also on friction and flow losses. Even though theoretical force and actual force are both directly proportional to stress, theoretical force generally increased with increasing well depth, while actual on-site force measurements randomly varied with depth (see Table 3).

Little correlation could be made between depth and actual force. These data indicate that friction plays a dramatic role in the amount of work required to pump water. If a water pump is kept in a well-lubricated state, has a smooth cylinder, has a cup that fits snugly but not too tightly inside the cylinder, and has no surfaces that grind against each other, the amount of actual force required to produce water will approach the theoretical force figure. If any of the above conditions are not met (which is almost always the case), the friction factor increases drastically and, as seen in Table 3, a pump operating from a depth of 3.8 meters (Site No. 11) can require three times as much work as a pump bringing up water from a well two times as deep (Site No. 9).

Table 3

FORCE EXERTED ON FIELD-TEST PUMPS (COSTA RICA)
AS A FUNCTION OF WELL DEPTH

Depth (m)	Site No.	Actual Force[1] Newtons	Actual Force[1] lb_f	Theoretical Force[2] Newtons	Theoretical Force[2] lb_f	AF/TF*	Type of Pump
3.2	10	117.9	26.5	52.5	11.8	2.2	AID-SW
3.3	31	80.1	18.0	52.9	11.9	1.5	AID-SW
3.8	11	350.1	78.7	50.7	11.4	6.9	Lucky
4.1	23	140.1	31.5	52.5	11.8	2.7	Lucky
4.2	13	420.4	94.5	53.4	12.0	7.9	AID-SW
4.3	4	280.2	63.0	54.3	12.2	5.2	Lucky
4.5	8	280.2	63.0	55.6	12.5	5.0	AID-SW
4.9	22	294.0	66.1	65.4	14.7	4.5	Lucky
6.1	7	264.7	59.7	74.7	16.8	3.5	AID-SW
6.3	17	419.5	94.3	69.8	15.7	6.0	Lucky
7.6	9	117.9	26.5	86.3	19.4	1.4	AID-SW
9.6	29	303.8	68.3	187.7	42.2	1.6	Dempster
10.0	28	382.4	86.0	190.7	42.9	2.0	AID-DW
10.0	30	235.3	52.9	190.7	42.9	1.2	AID-DW
10.8	6	303.8	68.3	199.7	44.9	1.5	Dempster

1/ Calculations for Actual Force. Actual force figures were ascertained, on-site, by measurement with a heavy-duty spring scale of the force required to stroke the handle on each individually installed pump. This force was then multiplied by the length of the handle (from the fulcrum point to where the spring scale was attached) and divided by the distance between the plunger rod and the fulcrum point of the handle. The final result was the force required to lift water with no mechanical advantage. The equation used was the following:

$$F = \frac{(f)(d)}{D}$$

where

F = Actual force where no mechanical advantage is required to lift water from a well (Newtons).

*Note: Ratio of Actual Force to Theoretical Force.

f = Force exerted on the handle of the pump in order to lift water (Newtons)

d = Distance from the fulcrum point on the pump to where a person's force is exerted to stroke the handle (m)

D = Distance between the plunger rod and the fulcrum point of the handle (m).

For example, at Coyolito de Santa Cruz (Site No. 28) in Costa Rica, the variables are as follows:

$f = 47.8$ Newtons

$d = 0.8$ m

$D = 0.1$ m

Applying the above equation

$$F = \frac{47.8\ (0.8)}{0.1}$$

$F = 382.4$ Newtons

2/ Calculations for Theoretical Force. When calculations are made to determine the amount of theoretical force required on a hand pump in order to make it lift water, the total number of cubic meters of water in the drop pipe (from the pump base to the wells water level) and inside the pump must be determined. The equation used is the following:

$$V = \pi H\ [(R)^2 - (R^1)^2] + \pi h\ [(r)^2 - (r^1)^2]$$

where

V = Total volume (m^3)

H = Depth of the well from the pump base to the well's water level (m)

R = Radius of the drop pipe (m)

R^1= Radius of the plunger rod inside the drop pipe (m)

h = Height of the water inside the pump assembly (m)

r = Radius of the pipe inside the pump assembly (m)

r^1= Radius of the plunger rod inside the pump assembly (m)

When V is determined, it is converted into kilograms of water, assuming that one kilogram of water is equal to 1.00×10^{-3} cubic meters. The total number of kilograms of water is then added to the weight of the plunger rod and the plunger assembly. When multiplied by the gravity constant (9.807 m/sec^2), the total amount of force is the result. For example, at Coyolito de Santa Cruz (Site No. 28) in Costa Rica, variables are as follows:

$H = 9.0$ m

$R = 1.6 \times 10^{-2}$ m

$R^1 = 6.3 \times 10^{-3}$ m

$h = 5.5 \times 10^{-1}$ m

$r = 3.8 \times 10^{-2}$ m

Therefore,

$$V = \pi(9.0)\ [(1.6 \times 10^{-2})^2 - (6.3 \times 10^{-3})^2] + \pi(5.5 \times 10^{-1})\ [(3.8 \times 10^{-2})^2 - (6.3 \times 10^{-3})^2]$$

$$V = 6.1 \times 10^{-3} + 2.4 \times 10^{-3}$$

$$V = 8.5 \times 10^{-3}\ m^3$$

The total number of kilograms of water is:

$$\frac{1\ kg}{1.00 \times 10^{-3} m^3} = \frac{x\ kg}{8.5 \times 10^{-3} m^3}$$

$x = 8.5$ kg of H_2O

The total weight of the plunger rod and plunger assembly is 10.9 kg. The total force is thus:

$$F = (8.5\ kg + 10.9\ kg)\ (9.807\ m/sec^2)$$

$$F = 190.7\ kg - m/sec^2$$

$$F = 190.7\ \text{Newtons}$$

Water Quality -- Bacteriological and Chemical

Water samples were taken from 13 Costa Rican locations prior to installation of pumps to determine the level of bacteriological contamination in the water being used by rural villagers. (Three of the locations were subsequently dropped as test sites because of poor accessibility and infrequent use.) All but one location contained Escherichia coli in concentrations ranging from 3.6 to 1,100 per 100 milliliter (ml.) sample, as shown in Table 4.

Inasmuch as the presence of E. coli indicates probable fecal contamination, ideally none should be present. It was not surprising to find this existing condition, however, due to the poorly constructed wells. While the wells were disinfected at the time of their construction, imperfect sealing of the top, seepage of surface water and inadequate disinfection led to subsequent contamination. Bacterial quantity is subject to considerable variability, and frequent analysis of each site would have been required to provide definitive data; it is noteworthy, on the other hand, that there was only one location free of coliforms. (World Health Organization water quality standards for total coliforms and for E. coli consider 10/100 ml and 0/100 ml, respectively, as the highest permissible levels.)

Table 4

SUMMARY OF BACTERIOLOGICAL ANALYSIS, COSTA RICA
(BEFORE PUMP INSTALLATION)

Site No.	Location	Total Coliforms per 100 ml @ 35°C	E. coli per 100 ml @ 44°C
1	La Palma de Abangares	1,100	460.0
2	San Joaquin de Abangares	460	21.0
3	Conjunto IMAS, El Torito, Samara	290	290.0
5	Curime de Nicoya	43	3.6
6	Pijije de Bagaces	150	3.6
7	La Javilla de Canas	93	3.6
16	Pueblo Nuevo de Colorado	1,100	290.0
18	Terciopelo de Nicoya	0	0.0
19	Caimitalito de Nicoya	1,100	120.0
20	Judas de Chomes	210	150.0
--	San Buena Ventura de Colorado	460	240.0
--	Penas Blancas de Colorado	1,100	1,100.0
--	Nicoya (Barrio San Martin)	210	20.0

Note: All tests performed in accordance with Standard Methods for the Examination of Water and Waste Water, 13th Edition APHA, 1971.

Water disinfection has been a routine matter in Costa Rica during the installation of pumps, but there has been no laboratory analysis to reveal the extent of assumed contamination in the wells. Because many of the sites in Costa Rica had been disinfected in the past only to result in continued contamination, the sites were tested again after pump installation to measure the effectiveness of pump programs such as this one now being carried out in Costa Rica and Nicaragua.

The bacteriological analyses, shown in Table 5, indicate that all waters involved in the second sampling were polluted to some extent, and some were grossly polluted. The presence of E. coli was taken as an indication of fecal contamination, and thus, the possible presence of pathogens associated with the intestinal tract of humans or other mammals. Persistent failure to improve the qualities of these waters should, as a general rule, lead to condemnation of the water supply.

It should be stressed that existing, poorly constructed Costa Rican structures were used for this field test of the installation and operational performance of the AID hand pump, not improved structures such as was the case in Nicaragua, and, in addition, project personnel experienced a serious reluctance

Table 5

SUMMARY OF BACTERIOLOGICAL ANALYSIS, COSTA RICA
(AFTER PUMP INSTALLATION)

Site No.	Location	Total Coliforms per 100 ml @ 35°C	E. coli per 100 ml @ 44°C
1	La Palma de Abangares	23	3.6
2	San Joaquin de Abangares	39	3.6
4	Hernandez de Santa Cruz	1,100	150.0
5	Curime de Nicoya	more than 1,100	210.0
6	Pijije de Bagaces	1,100	23.0
7	La Javilla de Canas	more than 1,100	1,100.0
9	Corina	more than 1,100	93.0
10	Bristol	more than 1,100	210.0'
11	La Margarita	1,100	53.0
12	Corazon de Jesus de Kutru	1,100	35.0
13	Zent #2 (Sr. Pedro Bustos)	more than 1,100	1,100.0
14	San Miguel de Venado	1,100	460.0
15	Sabalito de Venado	1,100	1,100.0
16	Pueblo Nuevo de Abangares	1,100	43.0
18	Terciopelo de Nicoya	93	93.0
19	Caimitalito de Nicoya	more than 1,100	more than 1,100
--	San Fernando de Santa Cruz	1,100	28.0
--	La Pastora de Quepos	1,100	120.0
--	Santa Domingo de Quepos	290	35.0

Note: All tests performed in accordance with Standard Methods for the Examination of Water and Waste Water, 13th Edition APHA, 1971.

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on the part of rural villagers and Ministry of Health personnel to accept an adequate level of disinfection, all contributing factors to the poor improvement in the water quality of the wells. These factors have caused great concern to the Ministry of Health and, as pointed out earlier, the Ministry of Health is now making internal organizational changes to allow the hiring and training of qualified technicians and engineers in an attempt to correct the situation.

Because data were needed on chemical quality of the water represented by the field-test sites, further sampling of the water was carried out soon after pump installation (the results are shown in Table 6). This sampling was performed by the Ministry of Health and, with few exceptions, the characteristics of these waters were quite similar.

Future Potential for AID Pump in Costa Rica

As a result of the confidence and interest by AID/Costa Rica and Costa Rican Ministry of Health personnel in the AID pumps, it has been reported to Georgia Tech project personnel that 500 deep-well and 500 shallow-well type pumps will be purchased in the near future for installation in Costa Rica. The purchase of these 1000 pumps is out for bid to local manufacturers and delineates the importance of a cost effective, durable, locally manufactured hand pump where rural water supply programs are needed in developing countries.

Table 6

SUMMARY OF CHEMICAL ANALYSES OF WATERS -- COSTA RICA[a/]

Site No.	Location	Color	Total Solids	Dissolved Solids	Hardness $CO_3^=$	Hardness Non-$CO_3^=$	Hardness Total	Alkalinity	Fe	Mn	$SO_4^=$	NO_3^-	Observed pH	Saturation pH	Saturation Index[c/]
2	San Joaquin de Abangares	5	285.0	256.0	150.0	150.0	150.0	170.0	0.0	0.0	24.0	<1	6.6	11.5	-4.9
3	El Torito de Samara	5	196.0	163.0	112.5	0.0	112.5	120.0	0.0	0.0	38.4	<1	6.5	11.0	-4.5
4	Hernandez de Santa Cruz	5	234.0	231.0	170.0	0.0	170.0	172.5	0.5	0.0	24.0	<1	7.2	11.0	-3.8
5	Curime de Nicoya	5	267.0	223.0	100.0	47.5	147.5	100.0	0.10	0.0	19.2	<1	8.2	11.0	- .25
6	Pijije de Bagaces	5	262.0	231.0	105.0	0.0	105.0	152.5	0.0	0.0	24.0	<1	6.9	11.2	-4.2
7	La Javilla de Canas	5	352.0	316.0	190.0	0.0	190.0	230.0	0.0	0.0	29.0	1	6.7	11.0	-3.3
8	Zent #1	5	166.0	166.0	104.0	16.0	120.0	104.0	0.1	0.0	29.0	1	6.4	11.9	-5.5
9	Corina	5	210.0	172.0	160.0	7.0	167.0	160.0	0.1	0.0	25.0	<1	7.5	11.9	-4.4
10	Bristol	5	230.0	226.0	176.0	4.0	180.0	176.0	0.0	0.1	27.0	<1	6.6	11.9	-5.3
11	La Margarita	7	204.0	197.0	120.0	10.0	130.0	120.0	0.2	0.3	19.2	<1	6.5	11.9	-5.4
13	Zent #2	5	172.0	171.0	69.0	26.0	95.0	69.0	0.1	0.0	19.2	<1	6.4	11.9	-5.5
14	San Miguel de Venado	5	178.0	162.0	97.0	8.0	105.0	97.0	0.0	0.0	0.0	<1	6.7	11.9	-5.2
15	Sabalito de Venado	5	180.0	171.0	49.0	35.0	84.0	49.0	0.0	0.0	4.8	<1	6.5	11.9	-5.4
16	Pueblo Nuevo de Abangares	5	462.0	428.0	380.0	5.0	385.0	380.0	0.0	0.0	43.2	<1	7.1	11.7	-4.6
17	San Francisco de Santa Cruz	5	214.0	196.0	150.0	2.5	152.5	150.0	0.0	0.0	28.0	<1	6.9	11.6	-4.7
18	Terciopelo de Nicoya	5	412.0	411.0	350.0	5.0	355.0	350.0	0.0	0.0	29.0	<1	7.1	11.3	-4.2
19	Caimitalito de Nicoya	5	261.0	252.0	180.0	0.0	180.0	180.0	0.0	0.0	24.0	<1	7.0	11.2	-4.2
22	Zent #3	5	230.0	229.0	146.0	4.0	150.0	146.0	0.1	0.1	25.0	<1	6.6	11.8	-5.2
	WHO Limits:														
	Highest Desirable		500.0		100.0			--	0.10	0.05	200.0	(b)	7.0-8.5		
	Maximum		1,500.0		500.0			--	1.00	0.50	400.0	(b)	6.5-9.2		

a/ All Values mg/l except pH.
b/ Values above 45 mg/l considered potentially harmful, especially to children.
c/ Negative values indicate waters corrosive to metal.

NICARAGUA

Background

Data from 1975 show that 56% of the total population of Nicaragua has relatively easy access to piped water supplies; however, when this figure is broken down into urban and rural areas, it is seen that 100% of the urban population has easy access to this type of water system, while only 14% of the rural population has easy access. Comparative figures for Costa Rica are 72% (total), 100% (urban), and 56% (rural).[1/]

Nicaragua was chosen as a test country because of a rural water supply and hand-pump program loan by AID to that country involving the installation of hand-operated water pumps. The loan provisions included potable water systems that will construct 300-340 wells by the end of 1979. The AID/Georgia Tech/ ICAITI program has complemented this program by providing technical assistance in pump selection, installation techniques, and pump maintenance, and has enabled the Ministry of Health in Nicaragua to take advantage of locally manufactured hand pumps that can be produced at a cost lower than commercially available pumps. This local program increases spare parts availability, reduces foreign exchange outflow, and stimulates local employment, as well as provides all other benefits of the AID pump mentioned in the introduction to this report.

As in Costa Rica, program activities began in Nicaragua in January 1977. A local foundry was chosen to manufacture 20 AID pumps (eleven deep-well and nine shallow-well), which were produced and delivered to a Ministry of Health warehouse for storage and installation in May. Two kinds of locally available pumps were chosen for comparison with the AID pump: a Dempster and a Brazilian "Marumby" pump. A pump developed by the International Development Research Centre (IDRC) of Ottawa, Canada, also was used for comparison. Thirty sites, representative of Nicaragua, were approved to receive the test pumps (16 AID pumps and 14 comparative pumps), and all of the sites required extensive preparatory work before pumps could be installed. Pumps were installed by a Ministry of Health installation team, and the wells were disinfected with a

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[1/] World Health Statistics Report, Water and Sanitation, Volume 29, No. 10, published by the World Health Organization, Geneva, 1976.

chlorine-yielding substance. As in Costa Rica, the sites had chemical and bacteriological testing prior to installation of test pumps and showed excessive amounts of intestinal bacteria.

Field Test Sites

Table 7 shows the sites selected for field testing in Nicaragua. All of the wells were in existence at the beginning of the project, and one spring, Site No. 10 (El Naranjo), was adapted to support a pump. The sites consisted of 16 shallow wells and 14 deep wells equipped with 16 AID pumps and 14 comparative pumps. Usage was quite high for the sites, averaging 170 persons, and all wells required site improvement work of some kind (well deepening, application of a lining to the well, slab and drainage concrete work, and cleaning and disinfecting of the well). Seven originally selected sites posed problems that necessitated a search for substitute wells. The problems included the striking of hard rock during excavation, wells caving in, water sources polluted beyond the ability to correct quickly, and villagers deciding that they would prefer an electric pump and storage tank to a hand-operated water pump (even if the villagers had to pay for the electric pump and storage tank). The general areas of site concentration were in the northern section of Nicaragua in the vicinity of Condega, Esteli, and Matagalpa (see Maps 2 and 3).

It was the original intent of this project to use existing wells with pumps that were inoperable or in a state of disrepair and to merely replace the broken pumps with the test pumps. However, this approach was impractical in Nicaragua because there were few existing hand-pump installations; therefore, it was necessary to deepen 24 wells, provide linings for 12 wells, construct slabs for 30 well structures, and disinfect all 30 wells to complete installation of the pumps. The construction improvements were provided and supervised by PLANSAR, an impressive unit of the Ministry of Health.

Manufacture of AID Pumps

Manufacturing Costs. In manufacturing the AID pumps in Nicaragua, a somewhat surprising situation was encountered -- foundries were plentiful, but pattern makers, a very necessary requirement for local production, were almost nonexistent. A foundry was located that appeared to have the resources, including pattern makers, to manufacture a quality AID pump, and a contract was signed

Table 7

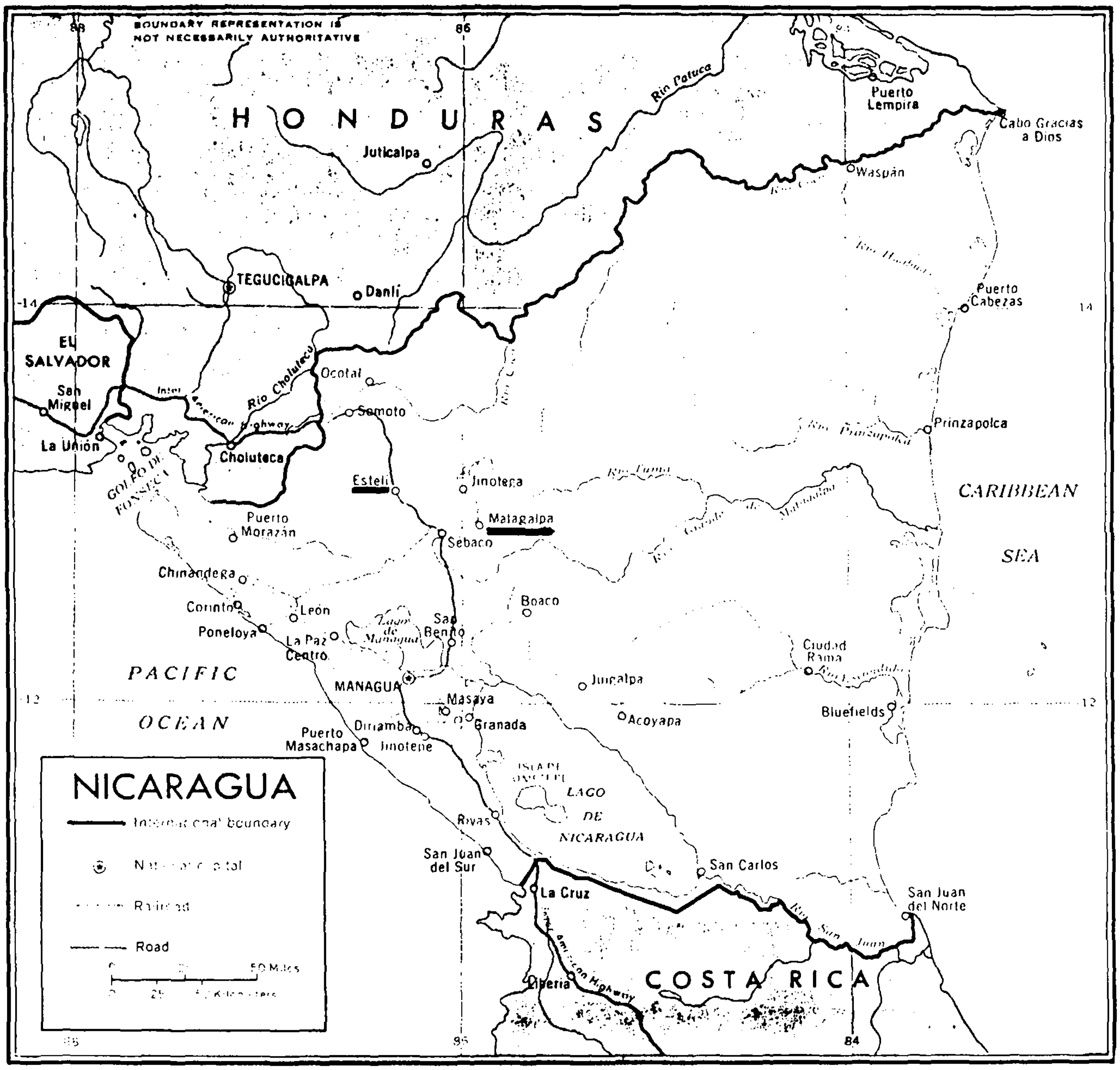
SELECTED SITES FOR AID PUMP FIELD TESTS IN NICARAGUA

Site No.	Location	Well Situation	Well Type	Classification by Depth	Depth (m)	Estimated Usage - No. People	Type of Original Pump	Condition of Original Pump	Has Water Meter	Type of Pump Installed	Date Installed
1	La Garita (Schoolhouse)	Existing	Dug	Deep	8.98	150	None	--		Dempster	4/27/77
2	Las Lajitas	Existing	Dug	Shallow	5.85	160	None	--	X	Marumby	5/12/77
3	La Lamilla	Existing	Dug	Deep	15.38	100	None	--		Dempster	5/12/77
4	San Antonio	Existing	Dug	Deep	10.42	100	None	--	X	Dempster	5/13/77
5	Las Mesas	Existing	Dug	Shallow	5.70	150	None	--		Marumby	5/16/77
6	Las Mangas	Existing	Dug	Deep	14.66	400	None	--		AID-DW	6/16/77
7	Llane Grande	Existing	Dug	Shallow	3.97	150	None	--		CAN-SW	5/28/77
8	San Diego	Existing	Dug	Shallow	5.03	100	None	--		Marumby	5/28/77
9	Mechapa	Existing	Dug	Deep	18.75	190	None	--		Dempster	6/4/77
10	El Naranjo	Existing	Spring	Shallow	3.12	210	None	--		AID-SW	5/28/77
11	Isidrillo	Existing	Dug	Deep	26.10	360	None	--		Dempster	6/11/77
12	La Concepcion	Existing	Dug	Shallow	2.85	280	None	--		AID-SW	6/8/77
13	El Rodeo	Existing	Dug	Deep	17.05	75	None	--		Dempster	6/17/77
14	Los Calpules (Stream)	Existing	Dug	Shallow	3.75	150	None	--		AID-SW	6/22/77
15	Los Calpules (Schoolhouse)	Existing	Dug	Deep	9.45	150	None	--		Dempster	6/22/77
16	Paso Hondo	Existing	Dug	Shallow	7.55	75	None	--		Dempster	6/23/77
17	Quebrada Arriba	Existing	Dug	Shallow	4.73	150	None	--		Marumby	7/21/77
18	Las Lajas	Existing	Dug	Shallow	6.65	90	None	--		AID-SW	7/26/77
19	Los Hatillos (Plaza)	Existing	Dug	Deep	17.19	100	None	--		AID-DW	7/26/77
20	Los Hatillos	Existing	Dug	Deep	17.25	100	None	--		AID-DW	7/27/77
21	Musuli	Existing	Dug	Deep	10.16	50	Dempster	Broken		AID-DW	7/27/77
22	Los Rincones	Existing	Dug	Deep	9.46	150	Dempster	Broken		AID-DW	7/28/77
23	Santa Rosa	Existing	Dug	Deep	17.60	656	Dempster	Broken	X	AID-DW	7/29/77
24	El Jocote	Existing	Dug	Deep	15.00	150	None	--		AID-DW	7/28/77
25	Mechapa - La Conception	Existing	Dug	Shallow	2.95	54	None	--		AID-SW	7/29/77
26	Licoroy	Existing	Dug	Shallow	5.00	50	None	--		AID-SW	7/30/77
27	Tomabu	Existing	Dug	Shallow	2.50	250	None	--		AID-SW	7/29/77
28	El Espinal #1	Existing	Dug	Shallow	3.50	360	None	--	X	AID-SW	7/30/77
29	El Espinal #2	Existing	Dug	Shallow	5.95	300	None	--	X	AID-SW	7/30/77
30	Sabana Grande	Existing	Dug	Shallow	2.80	75	None	--		Marumby	8/9/77

Note: AID-DW: AID pump for deep well; AID-SW: AID pump for shallow well; Dempster: Dempster deep-well type pump; Marumby: Brazilian shallow-well type; CAN-SW: Canadian pump for shallow well.

Map 2

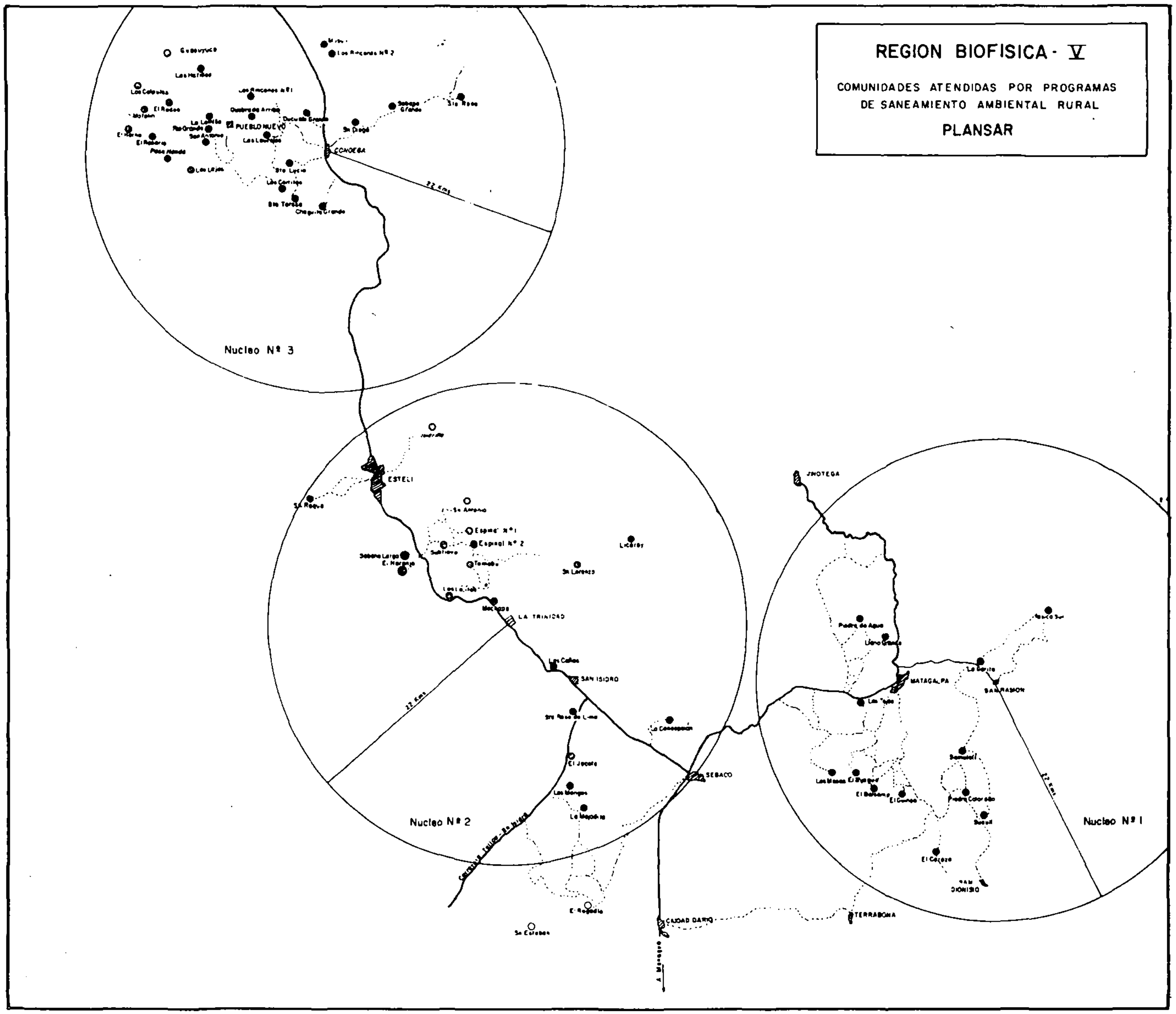
NICARAGUAN TEST SITE AREAS



Sites in Nicaragua are concentrated in the northern part of the country, near Condega (not shown on this map), Esteli, and Matagalpa.

Map 3

NICARAGUAN TEST SITE AREAS



on January 22, 1977, between Georgia Tech and Complejo Metalurgico Especializado, S.A. (Cometales) for the manufacture of eleven deep-well pumps and nine shallow-well pumps. The prices of the pumps, for an order of 20, were as follows:

Shallow-well	$ 69	(each)
Deep-well	$ 75	(each)
Patterns	$1,000	(one-time charge only)

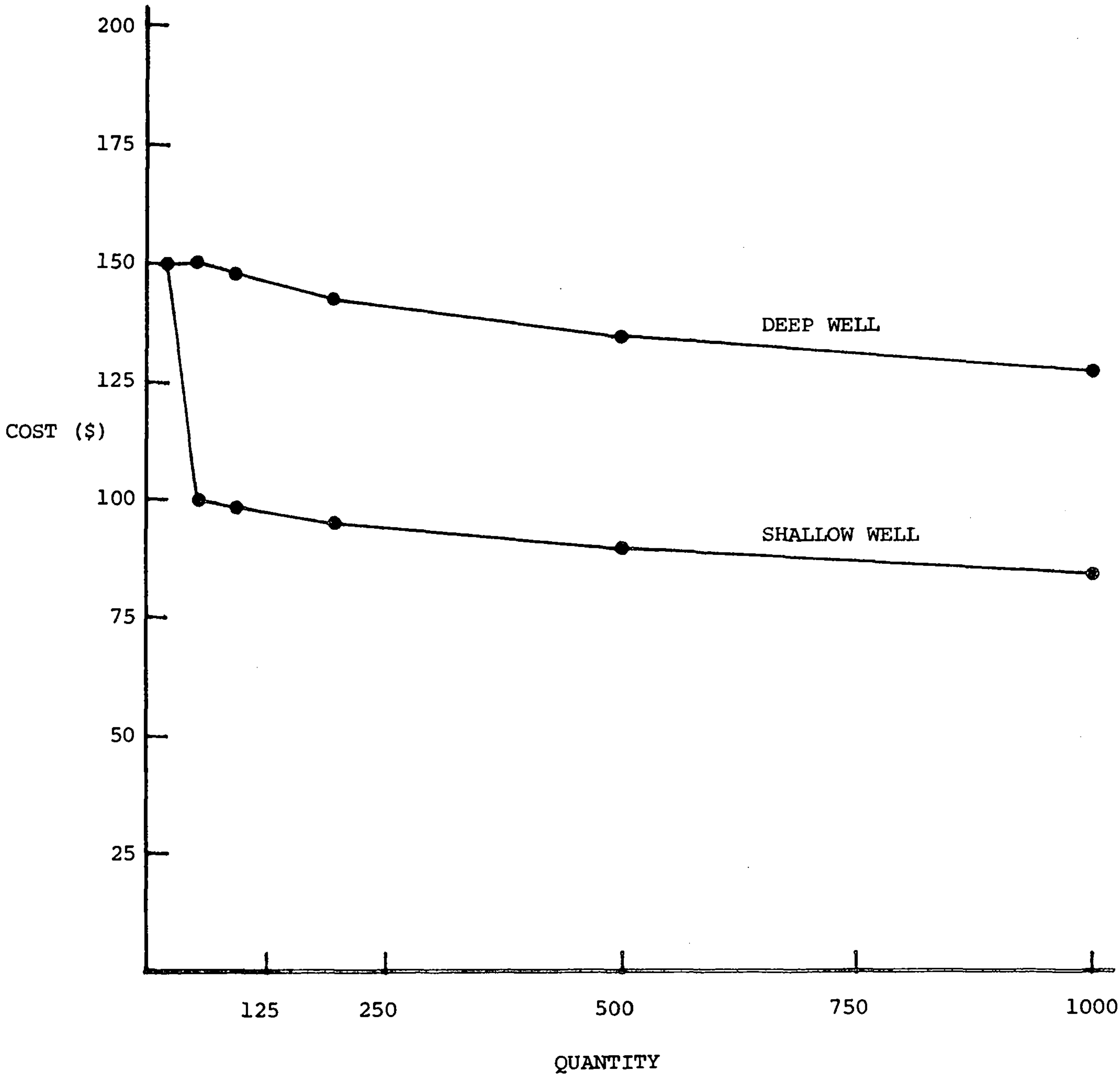
Based on the manufacturer's experiences with the first production run of the pumps, the following prices have been formally quoted for future orders, and are presented graphically in Figure 7.

Quantity	Shallow-Well ($ Price/Unit)	Deep-Well ($ Price/Unit)
20	150	150
50	100	150
100	98	147
200	95	142
500	90	135
1000	85	127

As was the case in Costa Rica, an order for only 20 pumps offered no significant economies of scale, and start-up costs were higher than originally expected because the manufacturer was totally unfamiliar with the working components of water pumps. The manufacturer encountered many unforeseen problems that increased his costs, such as the inability to cast the deep-well pump cap as specified and to obtain correctly sized PVC (3-inch inside diameter) for the deep-well cylinder, as well as a severe drought that struck Nicaragua which restricted the supply of hydroelectric power to the point that the manufacturer was allowed only four hours per day of electricity to run his plant. As a result of the manufacturer's experiences with the first production run of the AID pump, much higher price quotes have been submitted to the Ministry of Health for future orders. It is felt that the increased prices are over-inflated and, considering the weight of the AID pump (approximately 75 lbs.) versus a general foundry pricing guideline for Central America of between one and two dollars per pound (depending on complexity of the product), a more realistic pricing structure would allow the AID pump (both shallow-well and deep-well) to be manufactured and sold for less than $100 with reasonable profit to the manufacturer.

Figure 7

COST BY QUANTITY TO PRODUCE
AID PUMPS IN NICARAGUA



Manufacturing Specifications. AID pumps in Nicaragua also were manufactured according to AID-approved Battelle drawings with the following modifications:

1. The plunger rod was made from 1/2-inch diameter rod, rather than 7/16-inch stock. The pump rod nut, the rod end, and the plunger assembly also were changed to accommodate the 1/2-inch plunger rod.

2. The handle pivot pins were hardened to 40 R_C, and steel bushings (60-64 R_C) were inserted in the pump handle holes.

3. For the shallow-well pump, the 3-inch support pipe was internally coated with epoxy for a smoother-surfaced cylinder finish. A bolted pump cap was chosen in preference to a pin-mounted pump cap.

4. For the deep-well pump, a bolted pump cap also was chosen in preference to a pin-mounted pump cap.

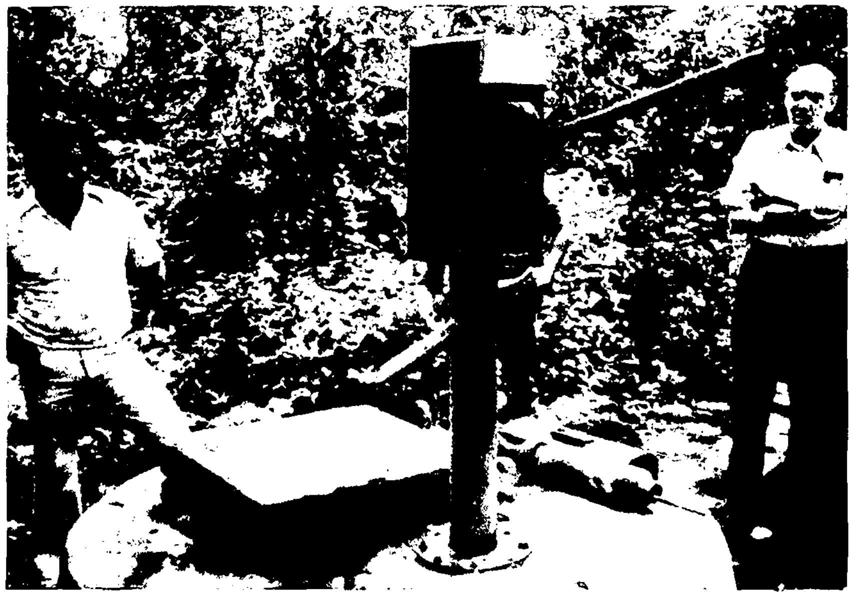
The AID pump manufacturer in Nicaragua had a complete, integrated foundry and machine shop with trained metallurgists in the day-to-day management of the facilities for the casting process, a quality control ingredient that is not normally expected to be found in developing countries. While it appears that the AID pump is adaptable to local manufacture in Nicaragua, the requirement of available casting facilities will restrict the use of the pump in some developing countries.

Comparative Pumps

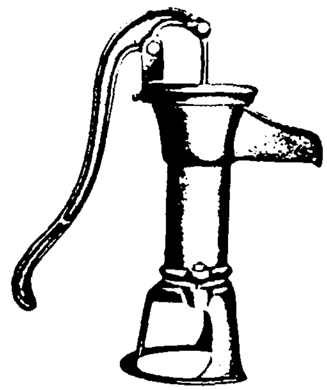
Two pumps that were locally available to the people of Nicaragua were chosen for comparison with the AID pump. These pumps were the Dempster (for shallow or deep wells) and a Brazilian "Marumby" pump (for shallow wells only). A pump developed by IDRC (for shallow or deep wells) also was used for comparison purposes (see Figure 8). The Dempster is designed for heavy-duty use in both shallow and deep wells, has either a brass-lined or PVC cylinder, is made of cast iron, and has a very good worldwide reputation, as pointed out earlier. The Brazilian pump (see Figure 9) uses a 1 1/4-inch drop pipe (as do the Dempster and AID pumps) and has a cylinder of smooth cast iron with an internal diameter of slightly over three inches (3.1"). The pump developed by IDRC uses a 3-inch diameter PVC drop pipe that is unique in that it also serves as the cylinder for the piston assembly (which can be inserted into or withdrawn from the cylinder while the cylinder and drop pipe are attached to the pump that is secured to the well's upper structure).

Figure 8

THE IDRC PUMP



The above photo is of the IDRC-developed pump that was installed at Llano Grande (Site No.7), in Nicaragua. The pump is made of indigenous materials (wood, galvanized iron pipe, and PVC pipe) and represents a design that simplifies hand pumps mechanically by substituting plastic pipe for traditional steel and cast iron. The casing is three-inch PVC pipe that serves as the drop pipe and the cylinder housing the piston assembly (this allows the piston and check valve to be brought up for inspection by pulling up the plunger rod without disassembling the drop pipe). Both piston and check valve are made of the same interchangeable components: perforated plastic discs with flapper valves covering the holes. The pump handle is made of standard galvanized iron pipe and the pivot points use oil-impregnated wooden bearings.



BOMBA SIMPLES

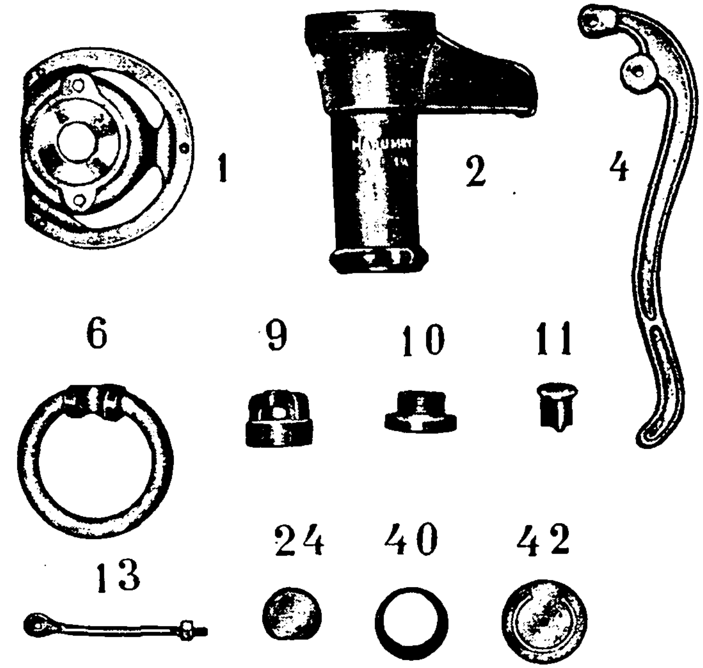
(BICA DE JARRO)

Tipo BJ

Para cano de 1¼" com pistão de ferro Cr$..

ESPECIFICAÇÕES:

Sucção cano de (Suction tube)	1¼"	
Altura do corpo (Height of body)	280	mm.
Diâmetro interno do cilindro (ID of cylinder)	80	mm.
Rendimentos em 55 movimentos do pistão por minuto (Flowrate/min.)	22	L.
Sucção até (Suction depth)	7	m.
Pêso líquido (Weight of liquid)	13	kg.



Peca n.° 1 - Prato (Plate)
2 - Corpo (Body)
4 - Alavanca (Handle)
6 - Anel suporte alavanca (Support ring)
9 - Corpo do pistão (Piston body)
10 - Porca do pistão (Piston nut)
11 - Válvula do pistão (Piston valve)
13 - Haste do pistão (Piston rod)
24 - Pêso da válvula (Valve weight)
40 - Manga de couro (Leather sleeve)
42 - Válvula de couro p/ prato (Leather valve for plate)

Figure 9

MARUMBY (BRAZILIAN) PUMP

In addition to the above-mentioned comparative pumps, six U.S.-manufactured Robbins and Myers "Moyno" hand pumps were purchased and installed in Nicaragua during July 1978. The "Moyno" rotary, rotor and stator, positive-displacement pump has been developed just recently and shows considerable potential for use in rural developing countries. The "Moyno" pump is advertised as a positive-displacement, steady-flow, self-priming, simple-design, abrasion-resistant, and energy-efficient pump that requires minimal maintenance and has many components that could be locally manufactured in a developing country. (See following pages for "Moyno" brochure information in more detail.)

The "Moyno" pumps installed in Nicaragua were installed in deep wells of between 40 and 70 feet with usage by between 300-500 villagers. The cost of the six pumps was $400 each, plus packing and shipping, for an average total unit cost of $470. Specific locations of the installed pumps were as follows:

1. Santa Teresa
2. Laguna de Los Hernandez
3. Valle de Santa Rosa
4. El Quebracho
5. Las Delicias
6. Los Pozos

Unfortunately, because of serious civil disorder that began during the latter months of this project and is still continuing in Nicaragua, project personnel were unable to install, inspect, or monitor these pumps, and thus, only limited information is available. It is known that the pumps were installed and initially performed well. However, in recent telephone calls to the Ministry of Health, it has been learned that five of the six "Moyno" pumps are inoperative. In one of the five cases, the villagers had operated the pump handle in a counterclockwise direction, which had loosened the rotor and stator from the plunger rod. In the other four cases, Ministry of Health personnel reported that the pumps had been "incorrectly installed," but did not give details as to what had been incorrectly done. Robbins and Myers states that the plunger rod and drop pipe must be of equal lengths, and this could possibly be the incorrect installation procedure to which they refer.

The Dempster pump used in the field test cost approximately $257 in Central America, the Brazilian "Marumby" approximately $45, and the IDRC pump about $70 (this estimated $70 cost was for comparison only and can vary widely,

Figure 10

THE MOYNO PUMP

Robbins & Myers
Fluids Handling Products

Bulletin 678

Hand Pumps for Rural Water Systems

Easy operation, minimum maintenance, maximum life

Minimum maintenance, maximum life per unit of cost

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.

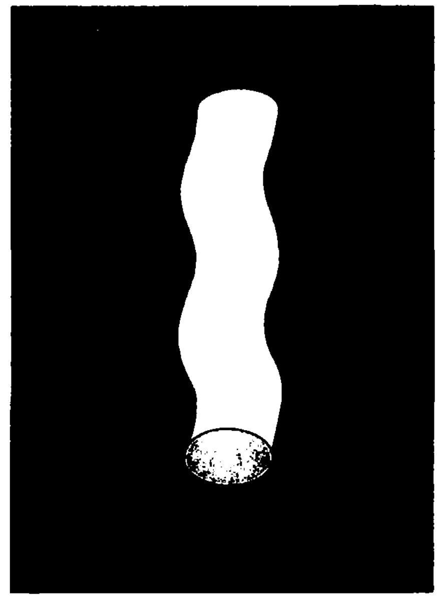
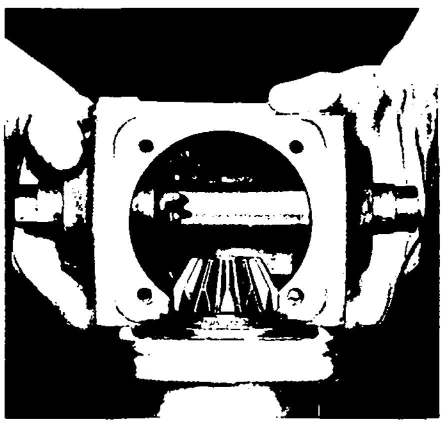


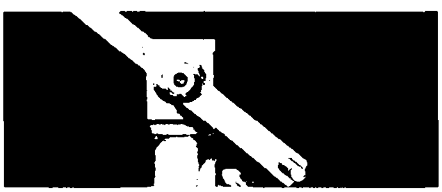
Figure 10 (continued)

Designed for long life

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.



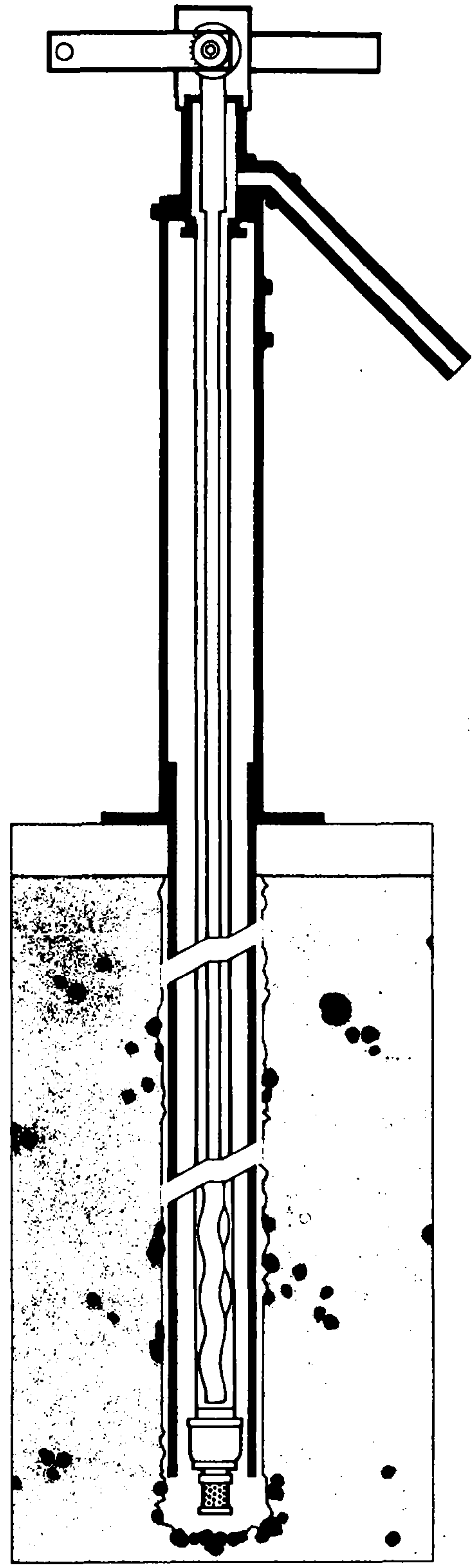
Heavy duty gearbox incorporates a right angle gear arrangement in a rugged housing. Gears are machined and hardened steel, mounted on high strength steel shafts. Tapered roller bearings provide precise gear alignment and long life. Sealed housing along with double lip seals on both handle and output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



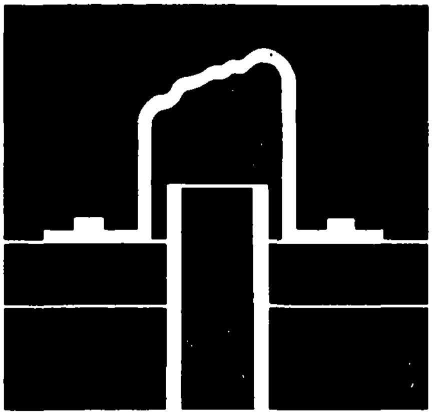
Rugged steel handle arms are keyed and bolted to the handle shaft. ⅞″ diameter handles permanently attached to handle arms.

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

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.

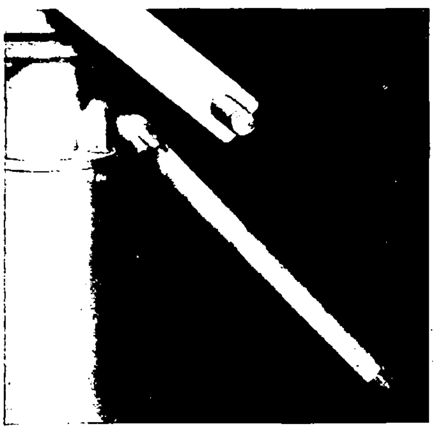


Sanitary design; easy installation



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.



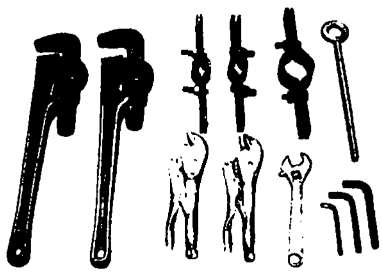
Long, angled discharge spout prevents possibility of sticks and stones being dropped or forced into the well by mischievous children.

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.

Figure 10 (continued)

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)

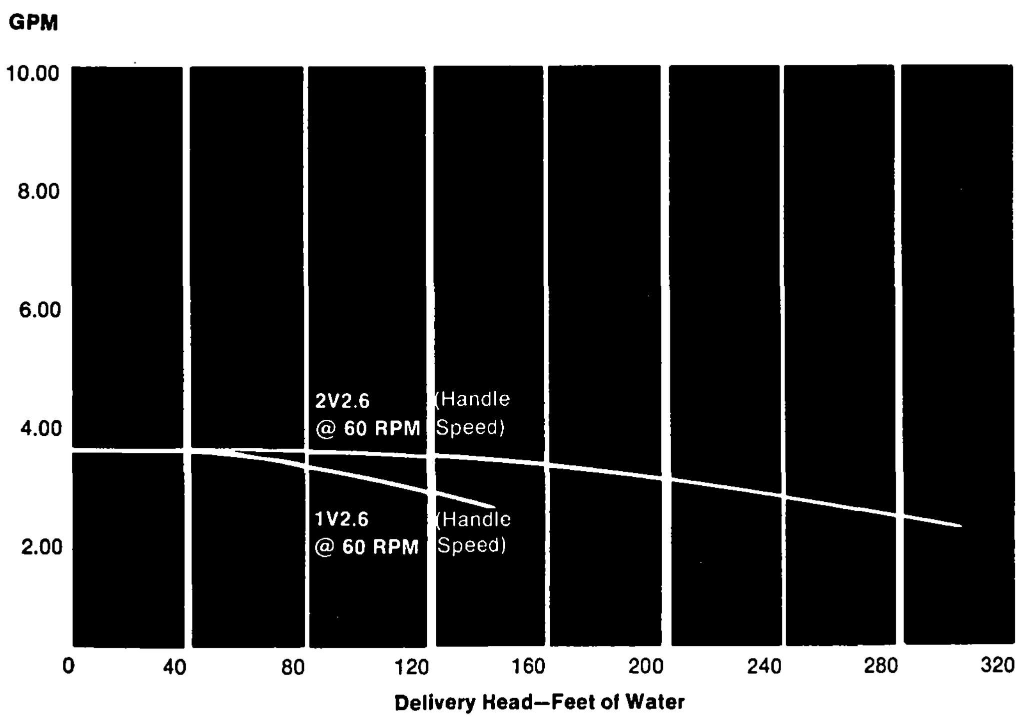
10′ Well Extension Assembly—23 lb. (10.4kg)

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, ½″ diameter steel rod with ½″-13 threads.

Performance curves

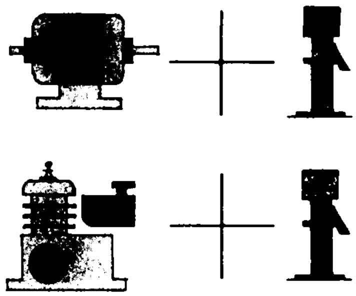


Designed for quality

Robbins & Myers
Fluids Handling Products

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.



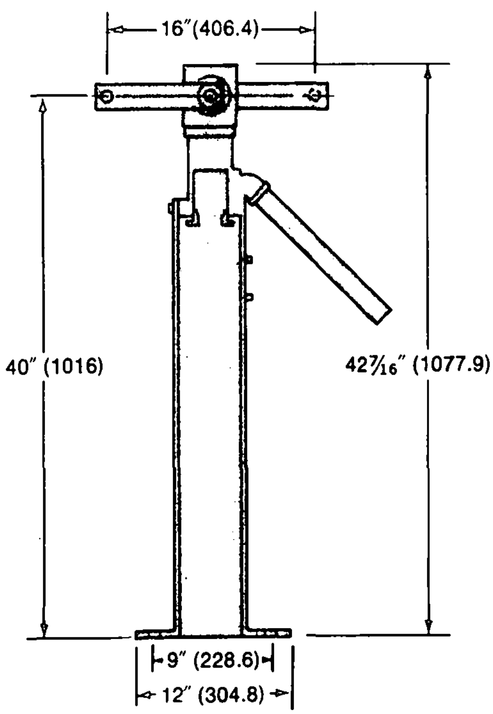
The Robbins & Myers Hand Pump can be converted to alternate power sources such as electric motors and gasoline engines. Please consult the factory for recommended conversions.

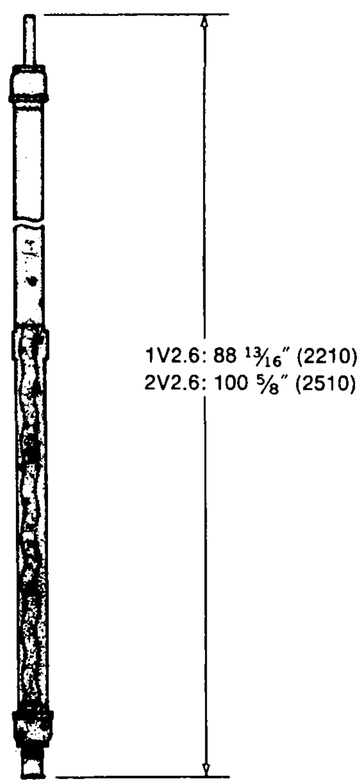
Pumps and Components manufactured in . . .

Springfield, Ohio U.S.A.
Columbia, South Carolina U.S.A.
Brantford, Ontario, Canada

Robbins & Myers, Inc.
Springfield, Ohio 45501
U.S.A.
Phone: (513) 327-3553

The Robbins & Myers Co. of Canada Ltd.
Brantford, Ontario N3T 5N6
Canada
Phone: (519) 752-5447





Bulletin 678 Litho in U.S.A.
2M-PS-878

depending on the materials and the pricing systems used by the fabricating shop). It is interesting, at this point, to recap all pumps included in the field testing of the AID pump, noting, as explained earlier, that price estimates for the manufacture of the AID pump vary greatly from country to country as well as from manufacturer to manufacturer within the same country.

		Costa Rica	Nicaragua
1.	AID Shallow-Well (for shallow wells only)	$ 98	$ 69
2.	Japanese "Lucky" (for shallow wells only)	63	--
3.	Brazilian "Marumby" (for shallow wells only)	--	45
4.	AID Deep-Well (for deep and shallow wells)	128	75
5.	Dempster (for deep and shallow wells)	257	257
6.	IDRC PVC Cylinder (for deep and shallow wells)	--	70
7.	Robbins and Myers "Moyno" (for deep and shallow wells)	--	470

Another approach to analyzing the relative costs of the field-test pumps was to consider the total estimated material cost of installing each pump complete with drop pipe (average price @ $.70 per foot), plunger rod (average price @ $.71 per foot), drop pipe connectors (average price @ $.91 each), and plunger rod connectors (average price @ $1.06 each) at various depths. The Brazilian "Marumby" shallow-well pump extended to $63 for a 25-foot well. The Japanese "Lucky" shallow-well pump, when installed in a 25-foot well, cost $81. The AID shallow-well pump, installed at 25 feet, cost $87 in Nicaragua and $116 in Costa Rica. The Dempster pump for shallow or deep wells is a very good pump, but is expensive at $294 for a 25-foot well. The IDRC pump for shallow or deep wells was competitive in cost with the AID pumps used for deep wells (or shallow wells, if so desired). However, the cost data on the IDRC pump for this report are based on only one pump and do not give enough information for reliable conclusions. The "Moyno" pump is also expensive, ranging from a material installation cost of $515 (25-foot well) to $830 (200-foot well).

	25 ft.	50 ft.	75 ft.	100 ft.	150 ft.	200 ft.
AID Shallow-Well (C.R.)*	$116	$ --	$ --	$ --	$ --	$ --
AID Shallow-Well (Nic.)*	87	--	--	--	--	--
Japanese "Lucky"*	81	--	--	--	--	--
Brazilian "Marumby"*	63	--	--	--	--	--
AID Deep-Well (C.R.)	135	172	210	251	324	398
AID Deep-Well (Nic.)	106	143	181	222	295	369
Dempster	294	331	369	410	483	557
IDRC (three-inch PVC cylinder)**	123	167	212	254	355	452
Robbins and Myers "Moyno"	515	560	605	650	740	830

*Cannot be used for depths of more than 25 ft.
**PVC priced @ $1.20 per foot.

Monitoring System

In Costa Rica, designated, responsible individuals in each test community were provided with simple, printed report forms designed to provide information covering community usage, pump physical condition, and functioning problems, if any. These forms were filled out every 15 days and mailed to an AID engineer in San Jose for analysis, who then reproduced them and turned the copies over to Ministry of Health representatives. If any of the returned forms indicated that repairs were necessary, a maintenance team was dispatched to correct the problems.

The monitoring system in Nicaragua was similar to that in Costa Rica, except that all pumps were inspected every 15 days by Ministry of Health engineers who were permanently stationed in the field and were responsible for the completion of the report forms as well as initiating any necessary repairs. Information included in the report forms was reviewed periodically by ICAITI and recorded on pump performance charts. All Nicaraguan test sites also were inspected by Georgia Tech and/or ICAITI approximately 10 times during the 12-month monitoring period.

Pump Performance

The Nicaraguan-manufactured AID pumps have been well received by the people installing, operating, and maintaining them. Because of confidence that the Ministry of Health has in the future potential of the AID pumps, an additional 100 have been ordered by the Ministry from the manufacturer for installation.

Two major maintenance problems with the AID pump (see Table 8) became apparent when installation of the pumps began. The most critical problem was that the deep-well pump cap's weakest point was where maximum stress was being applied by the handle fulcrum upon the pivot arm of the cap, causing the pivot arm to break off from the cap. This problem was partly the fault of the design and partly the fault of the manufacturer. Because of an indented contour of the top plate of the pump body, it was not possible to cast the pump body as specified by the drawings (the patterns for the pump could not be removed from the molding sand without destroying the mold). Therefore, the manufacturer eliminated the indented contour of the top plate of the pump and then did not have enough clearance between the pivot arm of the cap and the top of the pump body. In order to obtain a better fit between the pump cap and the pump body, the manufacturer milled away a fillet on the pivot arm, thereby leaving a notch at the point of maximum stress. To alleviate the entire problem, the pump cap was redesigned by lifting the pivot arm up and away from the pump body and positioning it so that it does not absorb so much of the stress caused by the downward force of the pump handle (the fulcrum handle also had to be shortened). (See Figures 10 and 11.) The redesigned cap was put into production at the manufacturer's foundry, installed on the pumps in the field, and has presented no additional problems.

The second major maintenance problem encountered with the AID pump in Nicaragua evolved when the manufacturer could not find 3-inch (inside diameter) PVC pipe for the deep-well cylinders. As a result, the manufacturer used 3-inch (outside diameter) PVC pipe and expanded it, by heating, to a 3-inch inside diameter. Quality control for such an approach was most difficult, and the results were unacceptable. While several of these PVC cylinders were installed in the field, it was decided that metal cylinders coated internally with epoxy (a Battelle option) would have to be used until the correct size PVC could be made available locally or imported from another country. In July (1978) the correct size PVC pipe was obtained from a local manufacturer and cylinders were produced according to specifications to be used for future pump installations.

Table 8

FIELD TEST PUMP MAINTENANCE - NICARAGUA

Site No.	Location	Corrective Maintenance During Test Period
		A. AID DEEP-WELL PUMP WITH METAL CYLINDER
6	Las Mangas	Battelle design cap broken -- replaced with modified version 1 cup change (excessive wear) Cylinder replaced (excessive cup wear)
19	Los Hattillos	1 cup change (excessive wear) Cylinder replaced (excessive cup wear)
20	Los Hattillos	Battelle design cap broken -- replaced with modified version 1 cup change (excessive wear) Cylinder replaced (excessive cup wear)
22	Los Rincones	Battelle design cap broken -- replaced with modified version 1 cup change (excessive wear) Cylinder replaced (excessive cup wear)
23	Santa Rosa	4 cup changes (excessive wear)
24	El Jocote	3 cup changes (excessive wear)
		B. DEMPSTER DEEP-WELL PUMP -- BRASS CYLINDER
1	La Garita	NONE
3	La Lamilla	NONE
4	San Antonio	Worn out pin connecting handle to plunger rod
9	Mechapa	NONE
11	Isidrillo	Broken piston rod union
13	El Rodeo	NONE
15	Los Calpules	NONE
16	Paso Hondo	NONE
		C. AID SHALLOW-WELL PUMP WITH METAL CYLINDER
10	El Naranjo	1 cup change (excessive wear)
12	La Concepcion	Pump cap replaced (broken -- casting defect) 3 cup changes (excessive wear)
14	Los Calpules	Pump cap replaced (broken -- casting defect) 5 cup changes (excessive wear)
18	Las Lajas	1 cup change (excessive wear)
26	Liconoy	Handle replaced (broken -- casting defect)

Table 8 (continued)

Site No.	Location	Corrective Maintenance During Test Period
27	Tomabu	Pump cap replaced (broken -- casting defect)
28	El Espinal	2 cup changes (excessive wear)
29	El Espinal	Pump cap replaced (broken -- casting defect)
	D. "MARUMBY" SHALLOW-WELL PUMP -- HONED METAL CYLINDER	
2	Las Lajitas	1 cup change (excessive wear)
5	Las Mesas	Cap replaced (broken)
8	San Diego	1 cup change (excessive wear)
17	Quebrada Arriba	Pump cap replaced (broken) 1 cup change (excessive wear)
30	Sabana Grande	Pump cap replaced (broken) 1 cup change (excessive wear)
	E. IDRC EXPERIMENTAL PUMP	
7	Llano Grande	NONE -- foot valve has tendency to stick and cause pump to lose its prime

Figure 11

MODIFIED DEEP-WELL PUMP CAP IN NICARAGUA

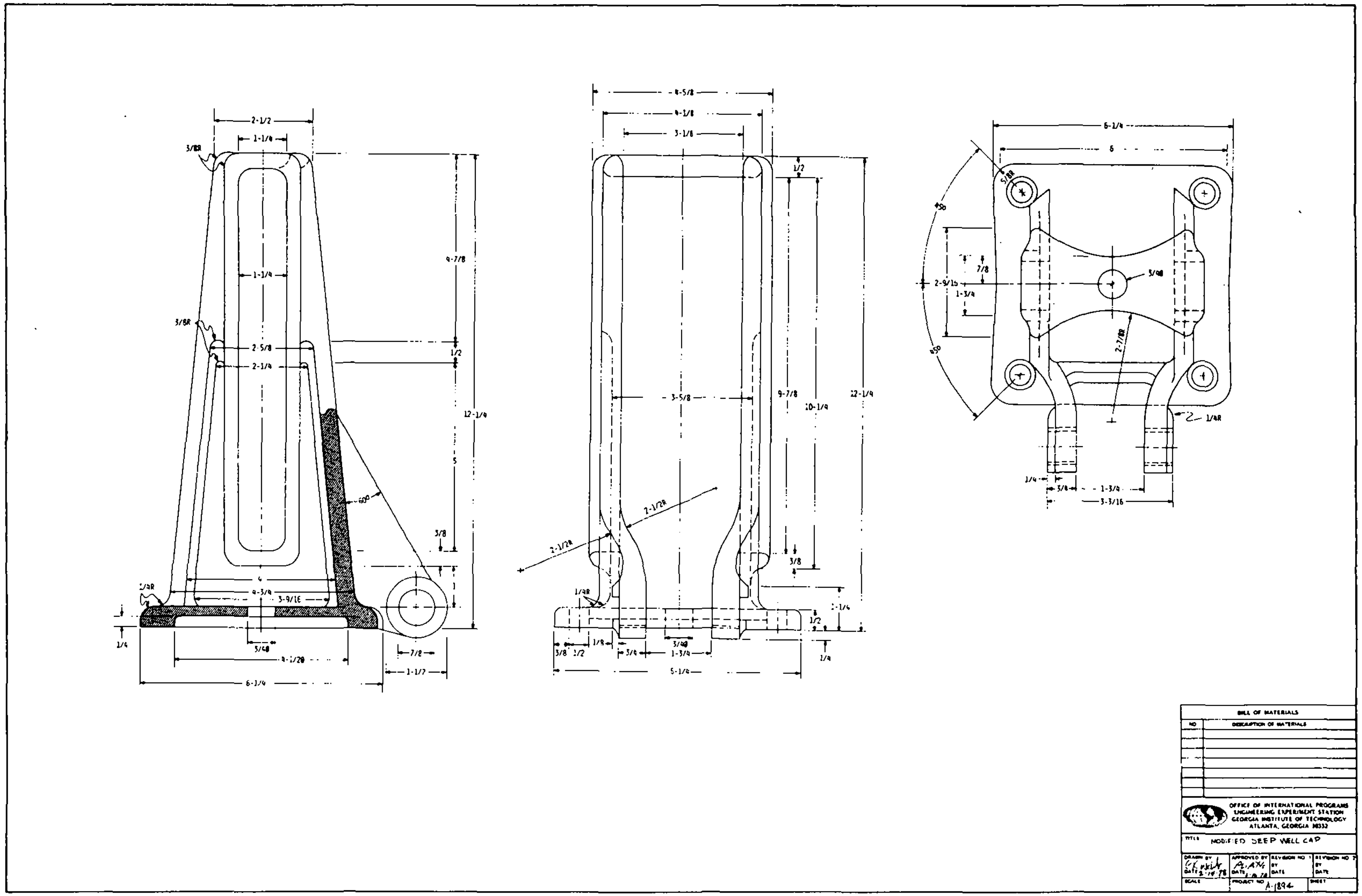
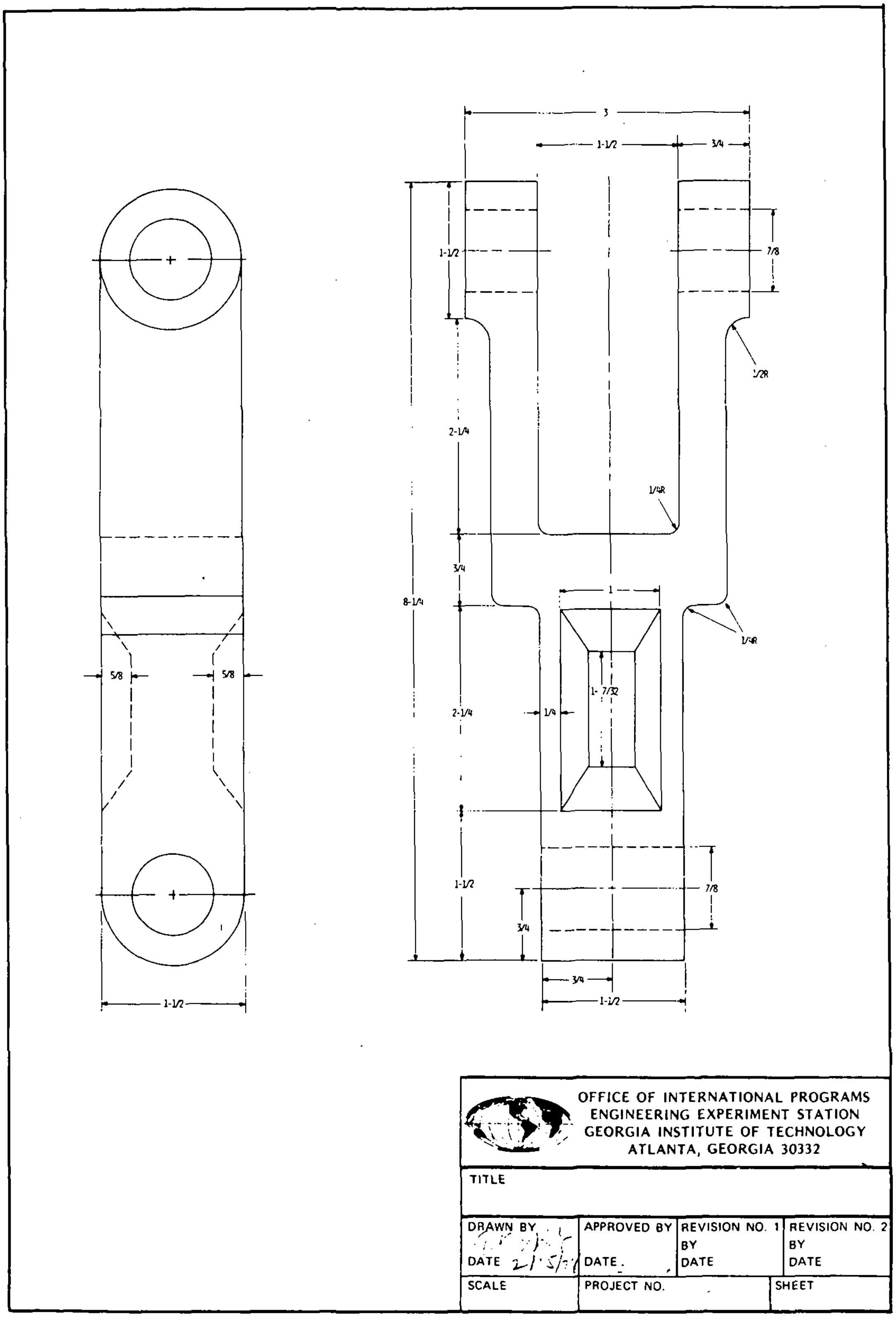


Figure 12

FULCRUM HANDLE FOR MODIFIED DEEP-WELL
PUMP CAP IN NICARAGUA



Excessive wearing of leather cups has also presented problems for the AID pump in Nicaragua principally because of insufficiently smooth cylinders and oversized cups. Battelle drawings specify a 3-inch diameter leather cup for a 3-inch cylinder, which would be satisfactory if leather did not expand when wet. To allow for expansion, the dry cups should have been made approximately 1/16-inch undersized. A replacement order for the original oversized cups was filled by the pump manufacturer, and the wearing of these new cups has been considerably less due to the use of a blanking tool that improves the quality controls of the manufacturer. The blanking tool has proven to be very beneficial and is being modified to resemble a method suggested by Dr. Eugene McJunkin in a recent publication:

> For "mass production," wooden forms can be used. To make the forms, use wooden boards about 3/4-inch (approx. 19mm) in thickness, having holes of the same diameter as the pump cylinders, and nailed to a stiff backboard. Cylindrical blocks, 3/8-inch (approx. 9.54mm) less in diameter, are bolted concentrically within the circular openings. The bolts should be long enough so that . . . wet and pliable leather, laid over the holes, can be drawn down by the bolts and blocks, forcing the leathers into position . . . let dry, remove and trim the wrinkled edge with a sharp knife (including the center hole), soak for 12 hours in a edible oil (preferably neat's-foot), wax, and lightly apply graphite grease to the wearing surface.[1/]

The Brazilian "Marumby" pump presented major problems. The weakest point of the pump appeared to be where the handle and the pump cap are connected. In three of the five pumps tested, the pump cap had to be replaced due to breakage at this point. Spare parts were also difficult to find for this pump, and the local distributor did not carry a large inventory of extra pumps for replacement purposes -- a factor that enhances the argument for locally manufacturing pumps so that spare parts can be made readily available.

The Dempster pumps in Nicaragua, as in Costa Rica, have had no major problems. The IDRC pump has performed relatively well, but has had some difficulty with its foot valve sticking in the open position (allowing the pump to lose its prime).

[1/] F. Eugene McJunkin, Handpumps for Use in Drinking Water Supplies in Developing Countries (The Hague, Netherlands: International Reference Center for Community Water Supply, 1977), p. 196.

Attempts also were made in Nicaragua to correlate the different well depths and the number of people using the wells with the amount of total stress exerted on the pumps. A direct correlation was made between actual force on the pump and the depth of the wells when the distance to the water level was taken into account. This was especially true when comparing the depth and forces of a particular pump (i.e., the Dempster). As in Costa Rica, friction obviously plays a tremendous role on the performance of the pumps (see Table 9).

In Nicaragua, water meters were installed in five sites to check the validity of usage estimates in a manner similar to that used in Costa Rica. Results indicated an average per capita consumption of approximately two gallons per person per day. This figure is almost twice as great as the per capita consumption determined for Costa Rica, probably due to the higher incidence of true community well sites in Nicaragua as opposed to the schoolhouse sites in Costa Rica. As was the case in Costa Rica, maintenance problems occurred randomly, and no correlation could be established between usage and corrective maintenance requirements.

Water Quality -- Bacteriological and Chemical

The results of chemical analyses of 19 potential sites prior to pump installation are given in Table 10. For comparison, the limits established by the World Health Organization are also included.[1/] An examination of the bacteriological data (Table 11) shows that all sites were significantly contaminated with common intestinal bacteria prior to pump installation. Salmonella was initially reported at Los Laureles, and this point was rechecked and found to be negative.

Because of the high level of bacteria found in the water in Nicaragua, all sites were to be analyzed further during the latter part of the project. This was to be done to provide more insight into whether or not contamination was being sealed off from the water by the preparation of the wells and the installation of the pumps. However, as reported earlier, Nicaraguan civil disorder during the latter part of 1978 prohibited such analysis.

[1/] International Standards for Drinking Water, Third Edition, published by the World Health Organization, Geneva, 1971.

Table 9

FORCE EXERTED ON FIELD-TEST PUMPS (NICARAGUA) AS A FUNCTION OF WELL DEPTH

Depth (m)	Site No.	Actual Force Newtons	Actual Force lb_f	Theoretical Force+ Newtons	Theoretical Force+ lb_f	AF/TF*	Type of Pump
2.5	27	77.4	17.4	50.3	11.3	1.5	AID-SW
2.8	30	298.9	67.2	37.8	8.5	7.9	Marumby
2.9	12	129.0	29.0	45.4	10.2	2.8	AID-SW
3.1	10	129.0	29.0	54.3	12.2	2.4	AID-SW
3.5	28	258.0	58.0	51.6	11.6	5.0	AID-SW
3.8	14	129.0	29.0	57.4	12.9	2.2	AID-SW
4.7	17	199.3	44.8	48.9	11.0	4.1	Marumby
5.0	8	124.6	28.0	51.2	11.5	2.4	Marumby
5.0	26	77.4	17.4	66.7	15.0	1.2	AID-SW
6.0	29	311.4	70.0	74.7	16.8	4.2	AID-SW
6.7	18	206.4	46.4	64.1	14.4	3.2	AID-SW
6.9	2	154.8	34.8	144.6	32.5	1.1	AID-DW
7.6	16	587.2	132.0	148.1	33.3	4.0	Dempster
9.0	1	667.2	150.0	184.6	41.5	3.6	Dempster
9.5	15	667.2	150.0	187.7	42.2	3.6	Dempster
9.5	22	1083.6	243.6	181.5	40.8	6.0	AID-DW
10.2	21	645.0	145.0	188.2	42.3	3.4	AID-DW
10.4	4	693.9	156.0	205.5	46.2	3.4	Dempster
14.7	6	516.0	116.0	216.2	48.6	2.4	AID-DW
15.0	24	722.4	162.4	268.2	60.3	2.7	AID-DW
15.4	3	907.4	204.0	274.0	61.6	3.3	Dempster
17.1	13	800.7	180.0	288.2	64.8	2.8	Dempster
17.2	19	645.0	145.0	298.5	67.1	2.2	AID-DW
17.3	20	1057.8	237.8	309.6	69.6	3.4	AID-DW
18.8	9	1494.6	336.0	341.2	76.7	4.4	Dempster
26.1	11	1494.6	336.0	461.7	103.8	3.2	Dempster

*Note: Ratio of Actual Force to Theoretical Force.

+Theoretical force is related to the distance to the water level as well as the depth (the latter for only deep wells). For this reason, theoretical force in many cases is not directly proportional to well depth.

Table 10

SUMMARY OF WATER CHEMICAL ANALYSES[(a)] -- NICARAGUA
(BEFORE PUMP INSTALLATION)

Site No.	Location	pH	Hardness as $CaCO_3$	Alka-linity as HCO_3^-	Total Solids	Fe	Mn	Ca	NO_3^-	F	Cl	$SO_4^=$
1	La Garita	7.0	350	26	218	0.07	0.05	70.0	3.76	0.30	22.5	2.0
2	Las Lajitas	7.5	200	190	225	0.02	0.40	50.0	4.43	0.35	5.0	2.0
4	San Antonio	7.9	240	270	404	0.01	0.00	68.0	2.65	0.50	19.5	11.0
6	Las Mangas	6.4	100	100	38	0.02	0.00	20.0	2.21	0.50	15.0	2.0
7	Llano Grande	6.4	200	120	161	0.07	0.00	30.0	9.96	0.70	12.5	3.0
8	San Diego	7.6	260	290	398	0.10	0.00	56.1	2.35	0.40	25.0	15.0
9	Mechapa	7.7	325	30	330	0.06	0.00	80.0	13.10	0.40	12.5	8.0
10	El Naranjo	6.9	400	420	426	0.05	0.00	100.1	3.54	0.70	15.0	3.0
11	Isidrillo	7.6	400	180	100	0.07	0.00	90.0	306.50	0.35	62.5	10.0
14	Los Calpules (Stream)	7.9	290	330	394	0.01	0.10	80.0	0.00	0.55	10.0	2.0
15	Los Calpules (School)	7.9	210	200	237	0.01	0.00	50.0	5.10	0.60	12.5	4.0
17	Quebrada Arriba	7.5	180	280	360	0.10	0.28	44.1	1.76	0.20	15.0	8.3
22	Los Rincones	8.1	70	445	608	0.01	0.00	20.0	16.60	0.25	20.0	20.0
	Los Rastrojos	7.6	840	260	1,600	0.27	0.58	292.0	0.66	1.62	20.0	67.5
	Santa Teresa	8.1	240	265	383	0.01	0.00	62.0	9.52	0.35	15.5	11.0
	Los Laureles	7.7	250	265	340	0.01	0.00	64.0	6.42	0.60	15.0	6.0
	Rio Grande	8.0	190	250	336	0.25	0.28	52.1	4.80	0.20	25.0	10.5
	Motolin	8.2	240	250	298	0.05	0.00	62.0	22.40	0.65	14.0	4.0
WHO limits:												
	Highest desirable	7.0-8.5	100	--	500	0.10	0.05	75.0	(b)	(c)	200.0	200.0
	Maximum permissible	6.5-9.2	500	--	1,500	1.00	0.50	200.0	(b)	(c)	600.0	400.0

(a) All values mg/l except pH.
(b) Values above 45 mg/l considered potentially harmful, especially to children.
(c) Limit depends on daily air temperature. Upper limits range from 0.8 to 1.7 mg/l.

Table 11

SUMMARY OF BACTERIOLOGICAL ANALYSIS -- NICARAGUA
(BEFORE PUMP INSTALLATION)

Site No.	Location	Coliforms per 100 ml	Salmonella Presence	Shigella Presence	Comments
1	La Garita	2.4	Negative	Negative	Positive Enterobacter
2	Las Lajitas	150.0	Negative	Negative	Positive Enterobacter
3	La Lamilla	350.0	Negative	Negative	Positive Escherichia coli
4	San Antonio	120.0	Negative	Negative	Positive Escherichia coli
7	Llano Grande	430.0	Negative	Negative	Positive Enterobacter and Citrobacter
9	Mechapa	1,100.0	Negative	Negative	Positive Proteus and Citrobacter
10	El Naranjo	1,100.0	Negative	Negative	Positive Enterobacter
11	Isidrillo	1,100.0	Negative	Negative	None
13	El Rodeo	540.0	Negative	Negative	Positive Escherichia coli
14	Los Calpules (stream)	23.0	Negative	Negative	Positive Escherichia coli
15	Los Calpules (school)	920.0	Negative	Negative	None
22	Los Rincones	54.0	Negative	Negative	Positive Pseudomonas
--	Rio Abajo (Santa Teresa)	24.0	Negative	Negative	Positive Enterobacter
--	*Rio Abajo (Los Laureles)	64.0	Positive	Negative	Positive Salmonella sp, Enterobacter, and Citrobacter
--	*Rio Abajo (Los Laureles)	350.0	Negative	Negative	Positive Escherichia coli
--	La Majadita	64.0	Negative	Negative	Positive Escherichia coli

* This site (Los Laureles) was retested because of earlier findings of positive Salmonella. (Note: all tests performed in accordance with Standard Methods for the Examination of Water and Waste Water, 13th Edition APHA, 1971.)

INSTALLATION OF AID PUMPS

Installation of the AID shallow-well and deep-well hand pump is very similar to that of most reciprocating, single-action, positive-displacement shallow-well or deep-well hand pumps (for example, the Dempster, the Brazilian "Marumby," the Japanese "Lucky," and the IDRC pumps used in this program for comparative purposes). A three-man team that has installed a traditional, commercially available pump would most likely not have significant problems in the installation of the AID pump. Further, a three-man team that has never before installed a hand pump should become fairly proficient enough after installing five to ten AID pumps to install the AID pump in four hours, provided it has basic tools and expertise in cutting and threading pipe.

The AID shallow-well pump is installed by merely inserting 1 1/4-inch drop pipe into the well platform opening, attaching the threaded drop pipe to the base of the pump, and then securing the pump to the well platform. The length of the required drop pipe is determined by measuring the depth of the well with a weight and string from the well platform, allowing approximately two feet for mud at the bottom of the well if it is new or one foot if it is an older well where the mud has settled.

The AID deep-well pump is somewhat more difficult to install. The following steps are necessary:

1. Determine the length of required drop pipe by measuring the depth of the well from the well platform, allowing for the length of the cylinder which must be connected to the drop pipe and approximately two feet at the bottom for a new well or one foot for an older well.

2. Attach a six-inch section of drop pipe to the bottom portion of the cylinder.

3. Attach a full length of plunger rod to the plunger assembly inside the cylinder and replace the cylinder cap; then attach a full length of drop pipe to the cylinder.

4. Alternate the attaching of full-length plunger rod and drop pipe until the required length of drop pipe is secured (pay no attention to the length of the plunger rod).

5. Shove plunger rod entirely up through pump body, adding additional plunger rod if necessary, and attach the drop pipe to the pump stand.

6. With the plunger assembly resting at the bottom of the cylinder, there should be approximately three inches of plunger rod left sticking up through the pump cap to be threaded and attached to the pump cap.

7. Secure the pump stand to the well platform.

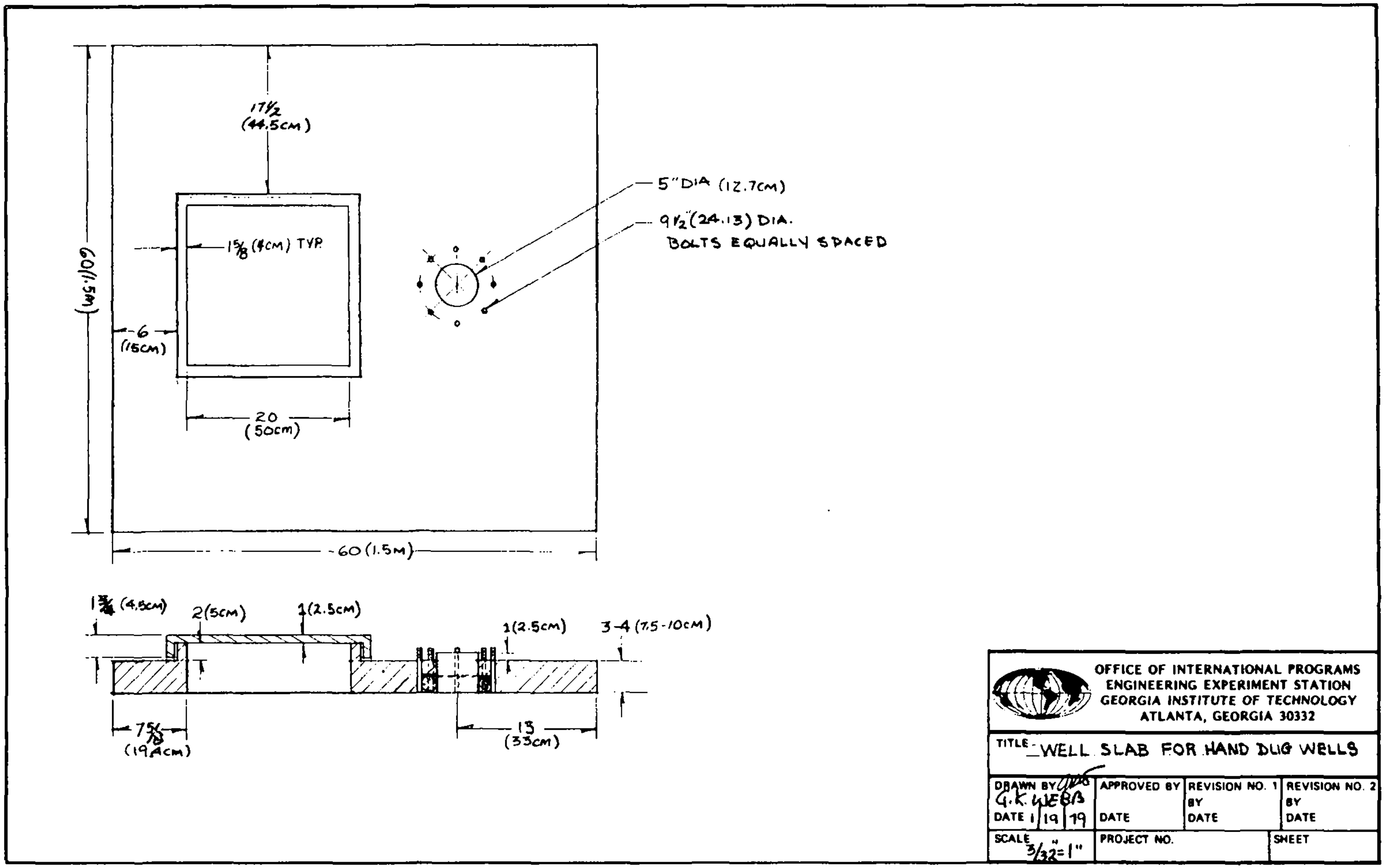
In regard to maintenance and repair, any water system, including one using hand pumps, must include a field maintenance support system, for no pump can last indefinitely without proper maintenance. Project personnel have seen numerous examples where good pumps are in excellent condition after many years (up to 10 years or more) of hard usage if minimally maintained, yet the same make and model pump can also be seen to be completely worn out in less than one year and unsalvageable if not properly taken care of. There is no such thing as a maintenance-free pump.

This field maintenance support system requires the training of technicians at a fairly sophisticated level where regional or centralized maintenance teams with adequate logistics, personnel, and budgets can support a hand-pump program. Training also is needed at a lower level of expertise to enable local villagers to handle simple, but important, tasks such as lubricating pumps on a weekly basis, repairing concrete well structures as necessary, painting exposed pump parts to prevent rust, and reporting to the regional or centralized maintenance teams if major problems exist.

The importance of a proper well structure cannot be overemphasized. The structure must not only be strong enough to support the pump and its users, but it also must be capable of keeping out all sources of possible contamination of the well water. (The following drawing depicts a suggested structure for hand-dug wells.) In addition, the structure should have a sloping apron at least 10 feet in diameter with raised edges and a drainage trough at least one foot in width to drain excess water at least 20 feet away from the apron to a natural drainage point.

Figure 13

WELL SLABS FOR HAND DUG WELLS



CONCLUSIONS AND RECOMMENDATIONS

Monitoring of pump performance has been conducted by Ministry of Health, AID, ICAITI, and Georgia Tech personnel. Despite many field test problems with the AID hand pump, field test results indicate that the AID pump can be manufactured with a high degree of quality in many less developed countries (LDCs). The test results, further, would most definitely encourage the manufacture, installation, and use of the AID hand pump in LDCs as a cost effective option.

The AID pump can be manufactured in a developing country at a competitive, profitable price and at an acceptable level of quality if adequate facilities (foundries, pattern makers, machine shops and skilled machinists, raw materials, etc.) are available; however, the availability of adequate foundry facilities with acceptable pump prices and quality controls must be determined for each individual developing country. Public acceptance by rural villagers has been good, in terms of both aesthetics and ease of use by men, women and children. Further, the AID pump should have a positive impact in LDCs on the health of rural people, employment generation, and foreign exchange requirements. In addition, the demonstration of local capabilities for manufacturing a rather complicated product instead of importing it should enhance the national pride of the people.

While numerous manufacturing problems, especially quality control, have been encountered in both Costa Rica and Nicaragua, the majority of these problems have been such as to be expected when a technological product like the AID pump is introduced into LDC production for the first time. As subsequent orders are processed through the manufacturer's plant and as personnel become more familiar with the pump itself, quality control should be refined to the point where the orders are considered to be normal production. All manufacturing problems were satisfactorily overcome as a result of adaptation and modification designs which ultimately proved to be workable in the LDC environment.

Pump Performance -- Costa Rica

Casting defects from the original order processed through the Costa Rican manufacturing plant for AID pumps caused shallow-well pump caps, handles, and one handle fulcrum to break. As subsequent orders for replacement parts were filled, these casting defects lessened in severity and no replacement part broke during the 12-month monitoring period. Even with serious casting defects in the modified deep-well caps, there were no breakages of this component, and project personnel (Ministry of Health, AID, ICAITI, and Georgia Tech) have agreed that the deep-well cap, including the stuffing box, also should be used on the shallow-well pump. (The stuffing box guides and prevents leakage around the plunger rod. The latter characteristic gives the pumps greater versatility, as it can then be used to lift water to an elevated storage location.)

The shallow-well pump in Costa Rica has consistently worn out leather cups because of the roughness of the walls of the metal cylinder. Since the Costa Rican deep-well pump with its PVC cylinder has worn out no leather cups during the 12-month monitoring period, project personnel recommend that the shallow-well pump should have a PVC-lined cylinder.

As a result of the above, Costa Rican Ministry of Health personnel have agreed to convert all existing shallow-well test pumps to deep-well pumps so that these pumps will give minimal maintenance problems in years to come.

Pump Performance -- Nicaragua

Problems with the AID pumps in Nicaragua have been numerous. The deep-well cap was originally manufactured as specified by Battelle drawing 2027 but with a positive draft angle on the front of the cap. The back of the pump cap then had to be notched out in order to fit the cap onto the pump body. Since this is the point where maximum stress is applied to the cap, breakage occurred when the pump was field tested. Subsequently, a redesigned pump cap was manufactured which has performed in a completely satisfactory manner.

Metal cylinders also have consistently worn out leather cups in both the deep-well and shallow-well Nicaraguan pumps. Replacement parts produced in Nicaragua have included PVC cylinders for the deep-well pumps, which should minimize cup wearing for this type pump. A formal recommendation has been made to Nicaraguan AID and Ministry of Health officials that all shallow-well pumps be modified to include PVC-cylinder liners and deep-well caps or changed to deep-well pumps complete with PVC cylinders. (Civil disorder within Nicaragua during final stages of this project has prohibited Georgia Tech/ICAITI personnel from personally implementing these suggestions.) These recommendations were made because of shallow-well cap breakage, even under relatively good casting conditions, and because of the excessive wearing of leather cups.

Recommendations for Future Use of the AID Pump

Based on experience in the field, the following specific recommendations are made for future use of the AID pump:

1. The AID deep-well pump should be equipped with either the modified Costa Rican deep-well cap (including stuffing box) or, preferably, the modified Nicaraguan deep-well cap. The Costa Rican deep-well cap has shown no signs of breakage or wear in over 12 months of testing, is simple in design and easy to manufacture, is lighter in weight than the Nicaraguan deep-well cap, but is not as sturdy. The Nicaraguan modified deep-well cap also has shown no signs of breakage or wear in over 12 months of testing, but is fairly complicated in design and, thus, more difficult to manufacture. It is heavier than the Costa Rican deep-well cap, and is extremely sturdy (a requirement necessary for wells where the water level approaches 75 feet or more below the top of the well or where daily usage of the pump is by more than 200 people).

2. The breakage problem of the Battelle-specified shallow-well pump caps can be eliminated in the future by merely using a deep-well cap on the shallow-well pump (either the Costa Rican or the Nicaraguan deep-well cap, neither of which has shown any breakage or wearing problems). Additional advantages of using the deep-well cap on the shallow-well pump are (1) it guides the plunger rod down in a straight motion that wears the leather cups evenly on all sides rather than in an arc that wears the cups, more or less, on two sides only, and (2) it eliminates the large, slotted opening of the shallow-well cap that seems to be a natural attraction for children to fill with rocks and small sticks.

3. It is imperative that cups of good quality and correct size be used and that the tendency to make oversized cups be avoided. Battelle specifications call for a 3-inch diameter leather cup for use inside a 3-inch inside diameter cylinder, which leads to an oversized cup when the leather becomes wet. The diameter should be reduced by at least 1/16 inch.

4. The use of hardened steel bushings in the pump handle holes that house hardened pivot pins is encouraged. The bushings should be at least

1/8 inch in thickness and hardened to approximately 60-64R_C. The pins should be hardened to approximately 40-45R_C.

In addition to the above, Battelle drawings specify that the holes in the handle pivot pin (where cotter pins hold the pump handle to the pump cap) should be 3 3/16 inches apart, plus 1/16 or minus zero inches; this specification should be 3 1/4 inches, plus 1/16 or minus zero inches, to ease insertion of the cotter pin and to prolong its use. Battelle drawings specify that the holes in the plunger rod pivot pin be 4 3/4 inches apart, plus 1/16 or minus zero inches; for the same reasons, this specification should be 4 13/16 inches, plus 1/16 or minus zero inches.

5. All cylinders should be PVC-lined. For the deep-well pump, this is no problem. However, the shallow-well pump should be modified by adding a PVC liner to the specified 3-inch inside diameter metal cylinder and <u>decreasing the diameter of the plunger assembly proportionately to fit the reduced inside diameter of the liner</u>.

6. Battelle drawings state: "Double cup plunger to be used when water level is more than 50 feet below surface." McJunkin reports, "A common practice is to use multiple cups in wells deeper than 100 feet (30 meters), adding a new cup every 50 to 100 feet (15 to 20 meters). The added head increases the slip (back flow) rate which multiple cups counteract by creation of a labyrinth type seal."[1/] The authors of this report randomly installed double cup plungers at various sites in Nicaragua and Costa Rica. In each instance where the double cup arrangement was used, cup life was extended. This appears to be feasible for wells of any depth; therefore, <u>all</u> future AID hand pumps should be installed with a double cup plunger assembly. For wells where the water level is more than 100 feet below the surface, an additional cup should be added to the plunger assembly every 50 feet.

Adding a PVC liner to the specified 3-inch inside diameter (galvanized iron) metal cylinder is relatively simple. The liner can be made from PVC pipe especially extruded to fit the metal cylinder snugly (no dimensions are given here because PVC and metal pipe vary slightly from one manufacturer to another and from one country to another). An easier method is to use PVC

[1/] <u>Handpumps for use in Drinking Water Supplies in Developing Countries</u> (The Hague, Netherlands: International Reference Center for Community Water Supply), 1977, p. 917.

with an outside diameter slightly larger than 3 inches (for instance, 3 1/4 inches) and an inside diameter slightly smaller than 3 inches (for instance, 2.95 inches), then to turn the outside diameter down to the desired size on a lathe. (The latter is being done in Indonesia for a program similar to the one described herein for Costa Rica and Nicaragua. It again should be noted that the change in the inside diameter of the cylinder caused by adding a PVC liner will require a proportionate change in the size of the leather cup and the plunger assembly.)

Appendix 3 shows working drawings of the recommended final design for the AID hand pump with modifications that have come about during the field-testing period. The drawings contain no patent limitations and are for the use of the general public.

Economies of the AID Pump

From an economic standpoint, the AID pump can be competitive in price with foreign imports into a developing country. It offers stimulation of small-scale industry (employment generation) as well as a contribution to a favorable balance of trade for the developing country. During this program, for a 25-foot well, the AID shallow-well pump cost $87 (including drop pipe, plunger rod, and connectors) in Nicaragua and $116 in Costa Rica. The AID deep-well pump cost $106 in Nicaragua and $135 in Costa Rica. The Japanese "Lucky" pump cost $81 in Costa Rica (not available in Nicaragua). The Brazilian "Marumby" pump cost $63 in Nicaragua (not available in Costa Rica). The IDRC pump cost $123 (installed only in Nicaragua). The Dempster cost $294 in both Nicaragua and Costa Rica, while the "Moyno" pump cost $465 in Nicaragua (not installed in Costa Rica).

Comparative Pumps

Comparative pumps used in the field test were originally chosen because they were expected to hold up well during the test period and because they were locally available. The Dempster pump is an excellent pump and has performed remarkably well, but is rather expensive when compared with the cost for which an AID pump can be locally manufactured. The Brazilian "Marumby" pumps have performed in an unsatisfactory manner and have been disappointing in their durability. The IDRC pump has good points that represent a lower level of manufacturing technology than that required of the AID pump, and is especially useful where foundry facilities are not available but local manufacturing is desirable. The Japanese "Lucky" pump has performed extremely well but, with no spare parts available in Costa Rica, undoubtedly will present maintenance problems as the components begin to wear. The "Moyno" pump is relatively expensive, but has the potential for a significantly positive impact on the health of developing countries. It appears to be capable of performing for a long period of time with little maintenance and has components that perhaps can be manufactured locally.

General Observations

The following general observations are offered from the experience of field testing the AID pump:

1. No matter how well a water pump is designed and manufactured, precise care and attention also must be accorded to the preparation of the well structure, the disinfection of the well water, pump installation techniques, training of local caretakers and follow-up maintenance.

2. A proper local governmental infrastructure must exist if a rural water system program is to be effective. This infrastructure requires people qualified to plan, organize, finance, purchase, engineer, install, maintain, monitor the use of the components of the system and train local community personnel in simple maintenance techniques.

3. There is no substitute nor shortcut to proper pump testing before starting on large operational programs. The world is full of broken pumps that have been hurriedly designed and placed into mass production without sufficient, if any, laboratory testing, field testing, and redesign, if necessary. While it is believed that the AID pump design is sound, each country considering the use of the pump should first investigate the local resources for manufacturing it and then carry out a brief program to field test the capabilities of the manufacturer and to work out unforeseen manufacturing problems.

4. Much is published about the necessity for maintenance of pumps. However, little information has been made available concerning maintenance of water quality in rural situations. The authors would like to see more research into bacteriological analysis of well waters over long periods of time to determine how effectively properly designed well structures seal out

contamination and how often wells should be redisinfected (different wells obviously should require more, or less, frequent disinfection, depending on their individual environment). This matter has been discussed with various AID and local government officials, but no evidence has been found where periodic redisinfection is carried out after a pump is installed (except, perhaps, when a pump is pulled from the well for maintenance and then reinstalled) even if chlorine is available.

5. The advantages and benefits of using a locally manufactured pump (like the AID hand pump) should not be underestimated. It is often quicker and easier to import a pump from another country, but this approach ignores in-country employment generation, readily available spare parts, savings in transportation, flexibility in design to meet local conditions, probable lower purchasing costs, and reduced foreign exchange requirements which free in-country money for other priority needs.

Final Evaluation

The Georgia Institute of Technology evaluation team finds the AID modified hand pump designs to be low in manufacturing cost and locally manufacturable in most LDCs. The pumps exhibited excellent operation and maintenance characteristics in Nicaraguan and Costa Rican field tests, and the designs proved to be readily usable and culturally acceptable in all field situations where they were introduced.

Much detailed work is involved in initiating local manufacture of a pump such as the AID model in LDCs which are not currently producing similar items. The manufacturer must be assisted in reaching a satisfactory level of quality control, and LDC implementing organizations must be made fully aware of the hand pump's capabilities and problems. This requires patient, prolonged and understanding work with personnel of a variety of private, governmental, and international organizations.

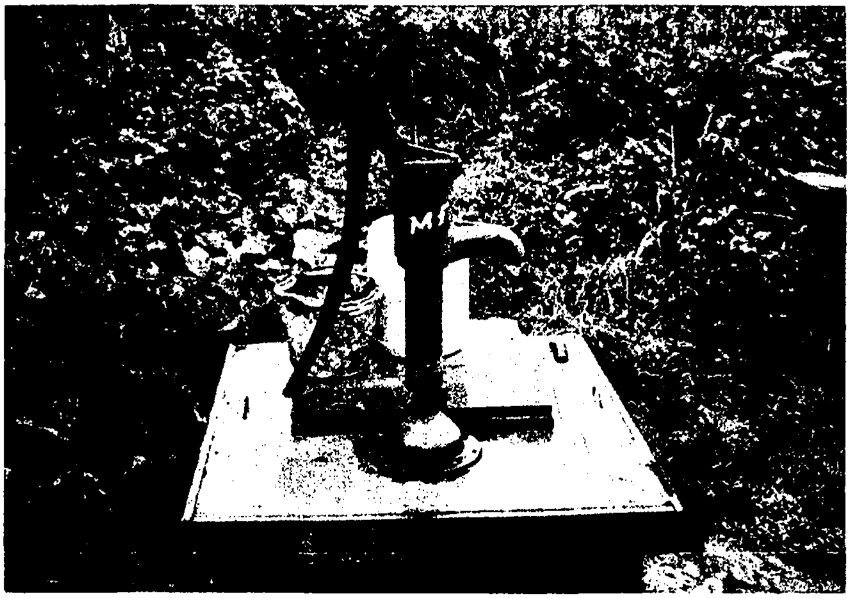
This project represents the application to LDCs of technology transfer in its most complete form. A methodology for working with indigenous manufacturers and cooperating organizations to stimulate the local fabrication, installation, and monitoring of the AID pump and other pumps has been devised and thoroughly tested. This successful methodology can easily be applied in a variety of countries interested in better hand pump equipment for their water supply and sanitation projects.

Appendix 1

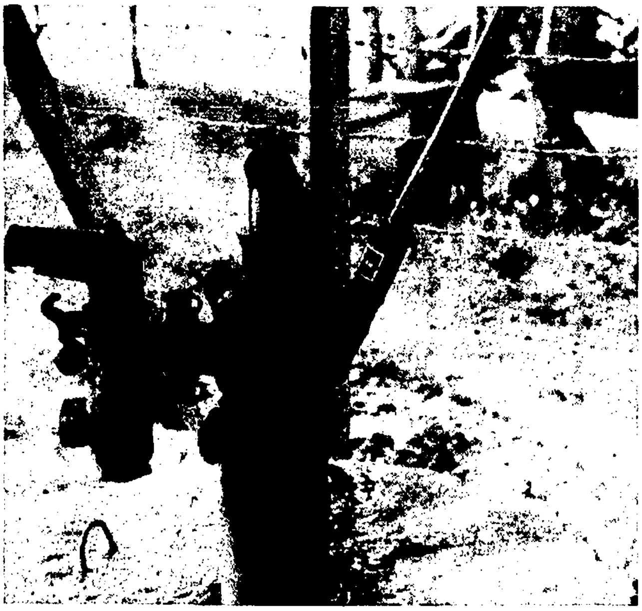
COSTA RICAN TEST SITES

Site No. 1, located at La Palma de Abangares (AID deep-well pump).

Site No. 2, located at San Joaquin de Abangares (AID deep-well pump).



Site No. 3, located at IMAS, El Torito, Samara (AID shallow-well pump).

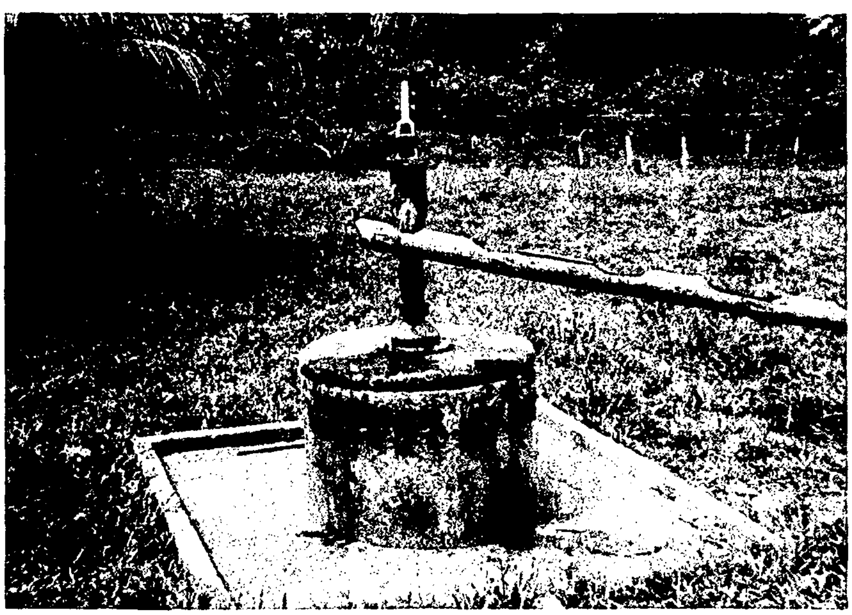


Site No. 4, located at Hernandez de Santa Cruz (Lucky shallow-well pump).

Site No. 5, located at Curime de Nicoya (Dempster pump).

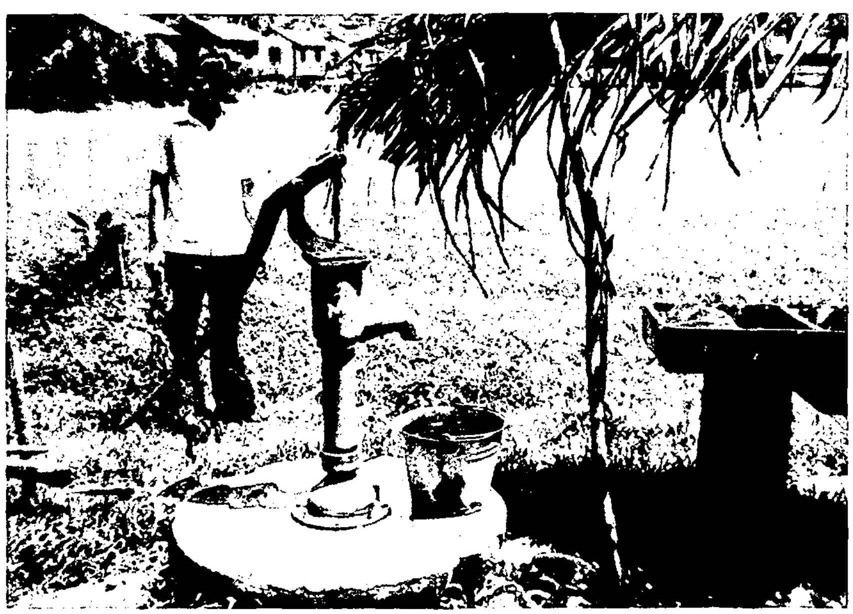
Site No. 6, located at Pijije de Bagaces (Dempster pump).

Site No. 7, located at La Javilla de Canas (AID shallow-well pump).

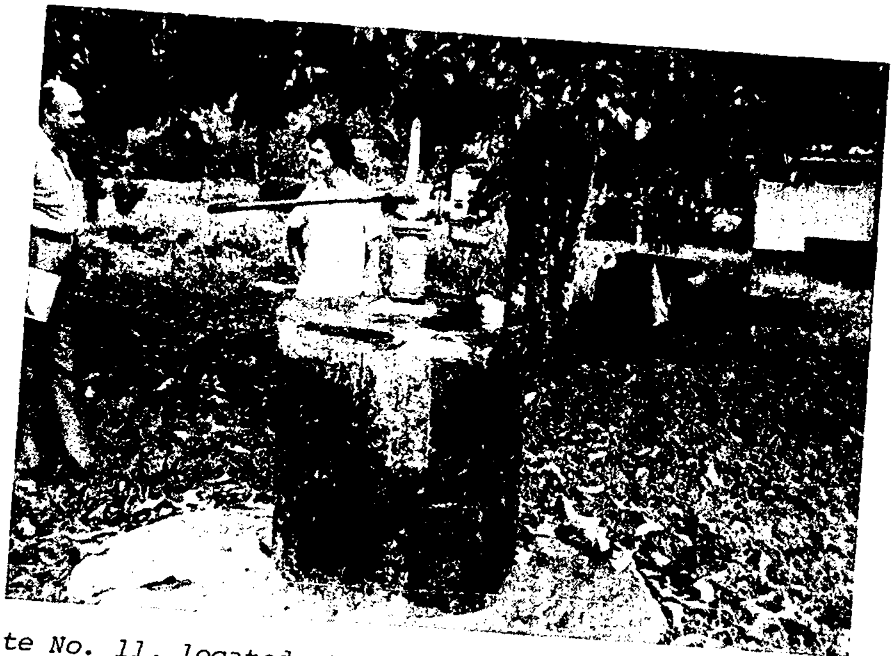


Site No. 8, located at Zent, Matina school (AID shallow-well pump).

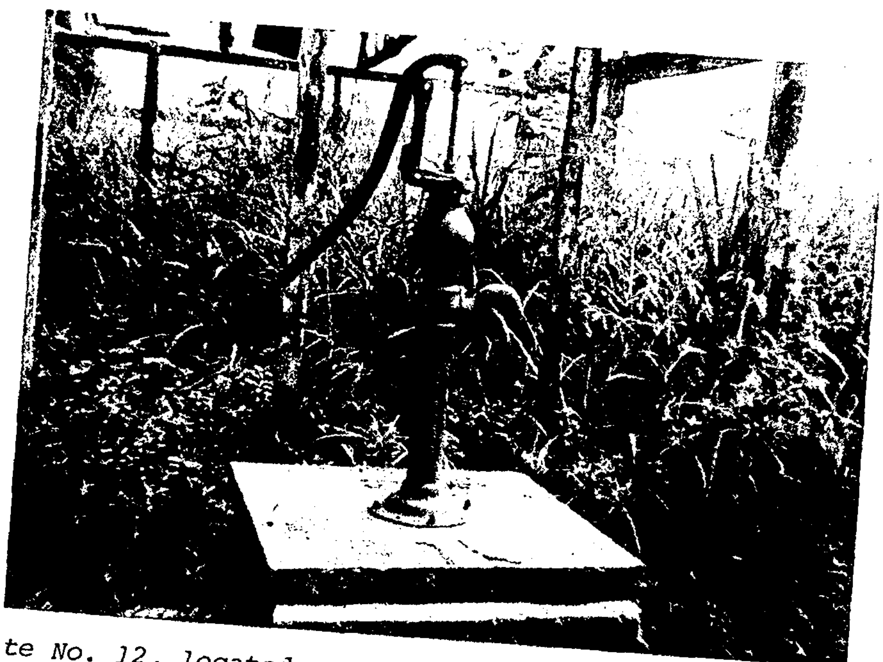
Site No. 9, located at Corina, Matina (AID shallow-well pump).



Site No. 10, located at Bristol, Matina (AID shallow-well pump).



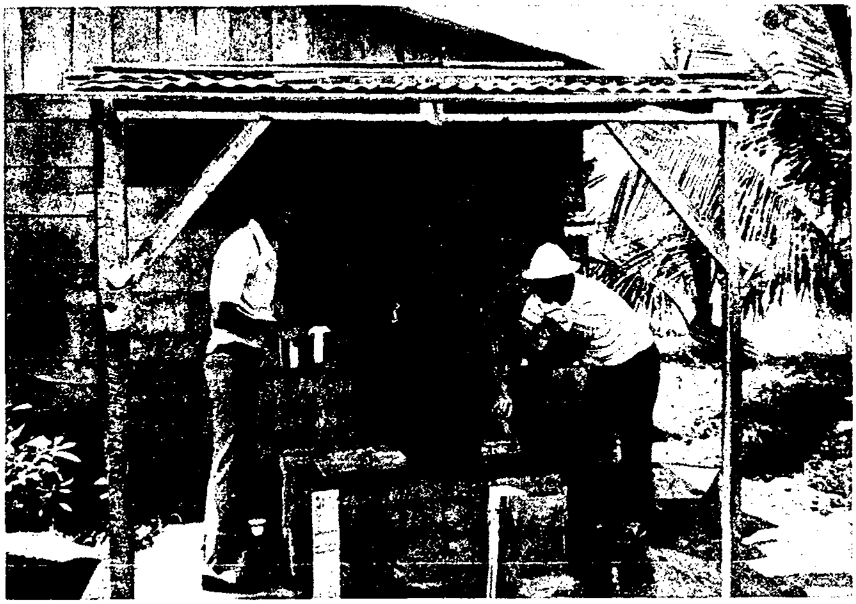
Site No. 11, located at La Margarita, Bataan (Lucky pump).



Site No. 12, located at Corazon de Jesus (Dempster pump).

Site No. 13, located at Zent, Matina (Lucky pump).

Site No. 14, located at San Miguel de Venado (Dempster pump).



Site No. 15, located at Sabalito de Venado (Dempster pump).

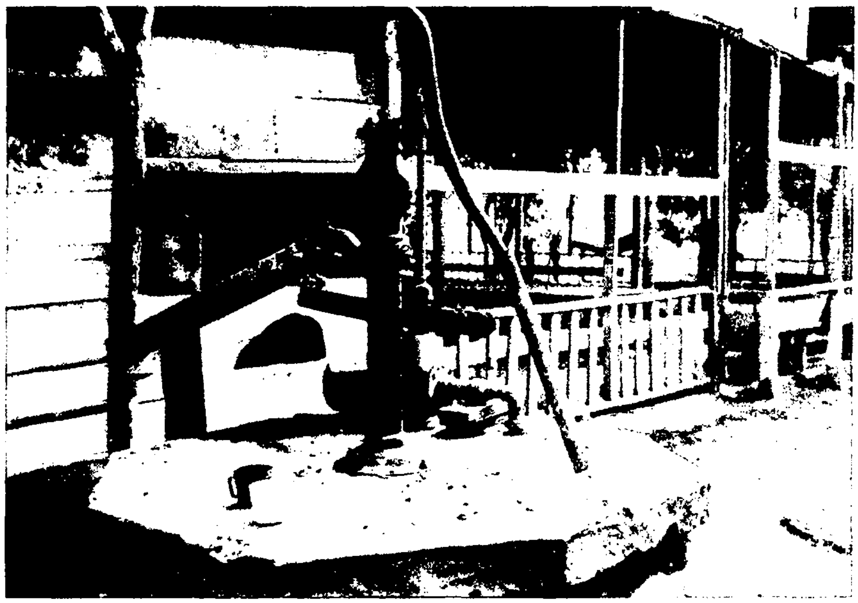
Site No. 16, located at Pueblo Nuevo de Colorado (AID shallow-well pump).

Site No. 17, located at San Francisco de Santa Cruz (Lucky pump).

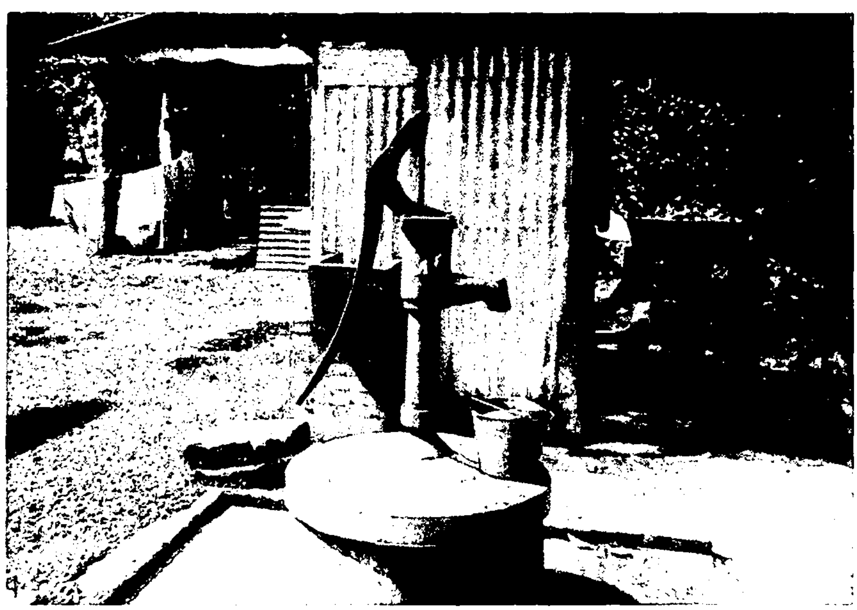
Site No. 18, located at Terciopelo de Nicoya (AID deep-well pump).

Site No. 19, located at Caimitalito de Nicoya (AID deep-well pump).

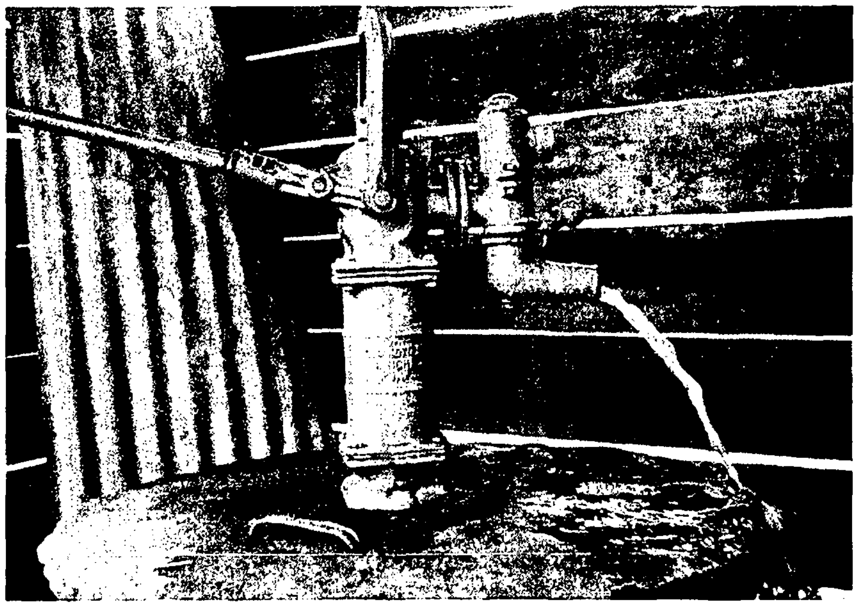
Site No. 20, located at Judas de Chomes (Dempster pump).



Site No. 21, located at Limonal de Abangares (Dempster pump).



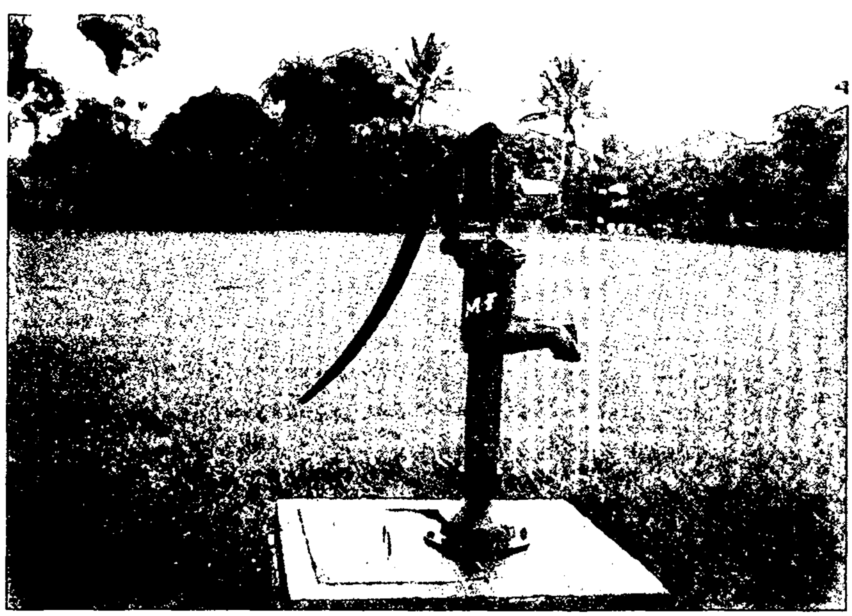
Site No. 22, located at Zent, Matina (AID shallow-well pump).



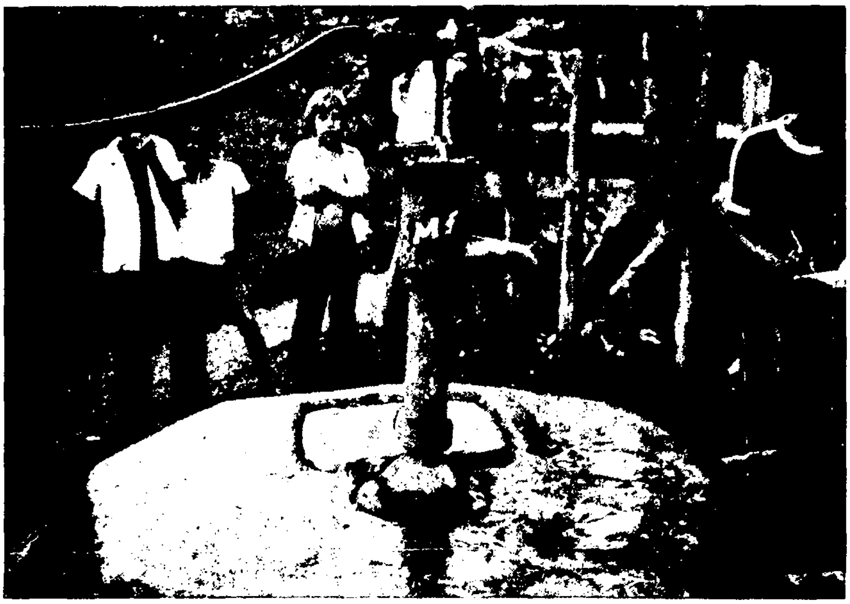
Site No. 23, located at Santa Marta de Matina (Lucky pump).

Site No. 24, located at Tarcolesa de Orotina (Lucky pump).

Site No. 25, located at Mesetas Abajo (Lucky pump).



Site No. 26, located at San Juan Grande (AID deep-well pump).



Site No. 27, located at Sabana Grande (AID deep-well pump).

Site No. 28, located at Cuyolito de Santa Cruz (AID deep-well pump).

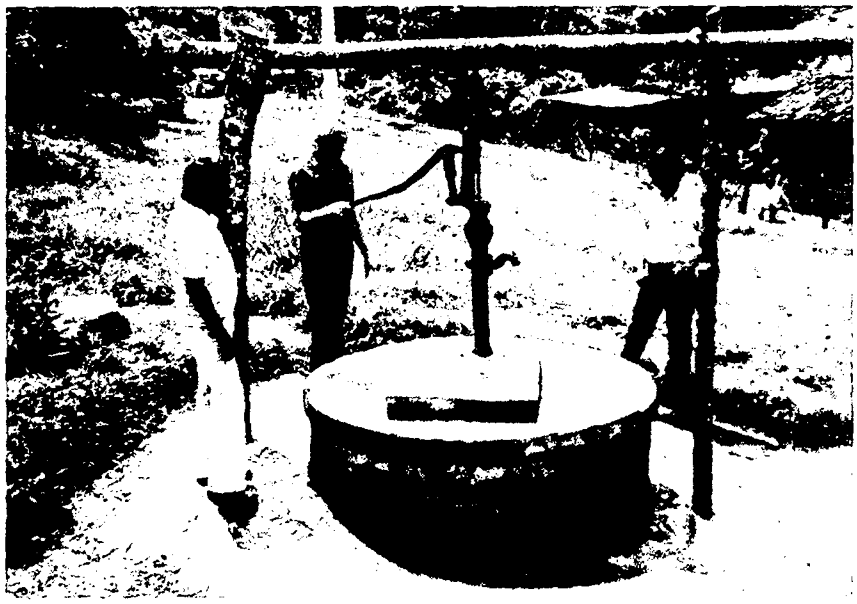
Site No. 29, located at La Lorena de Santa Cruz (Dempster pump).

Site No. 30, located at Lajas de Canas (AID deep-well pump).

Site No. 31, located at Indiana Tres-Siquirres (AID shallow-well pump).

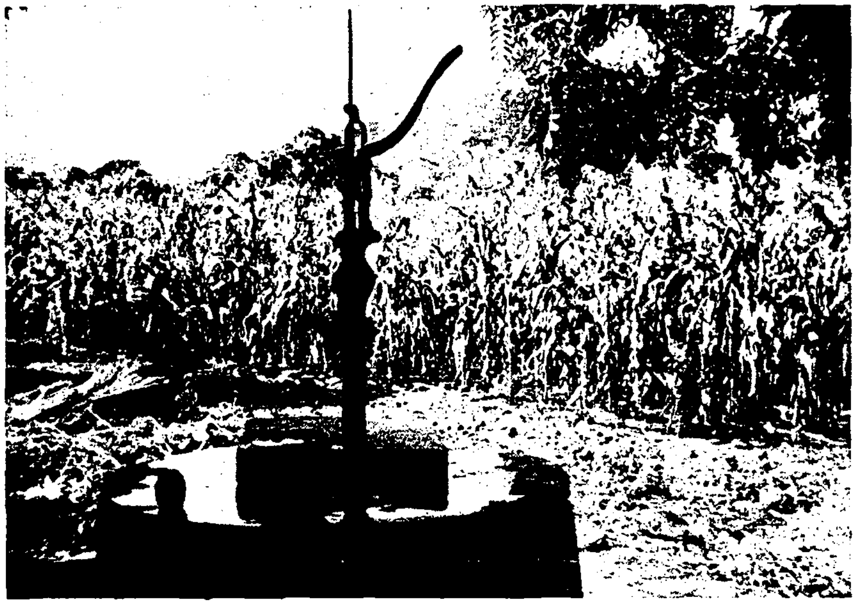
Appendix 2

NICARAGUAN TEST SITES



Nicaragua Site No. 1, located at La Garita (Dempster pump).

Nicaragua Site No. 2, located at Las Lajitas (Marumby shallow-well pump).

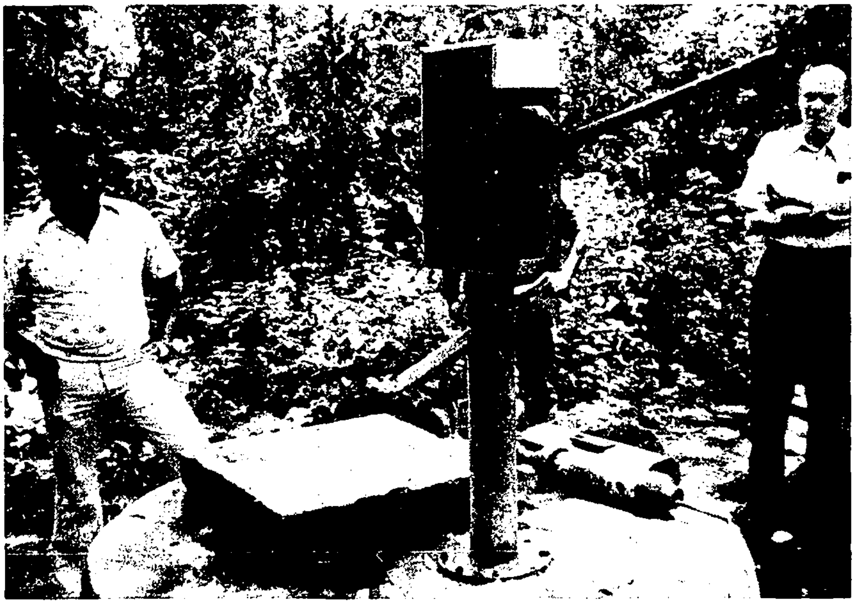


Nicaragua Site No. 3, located at La Lamilla (Dempster pump).

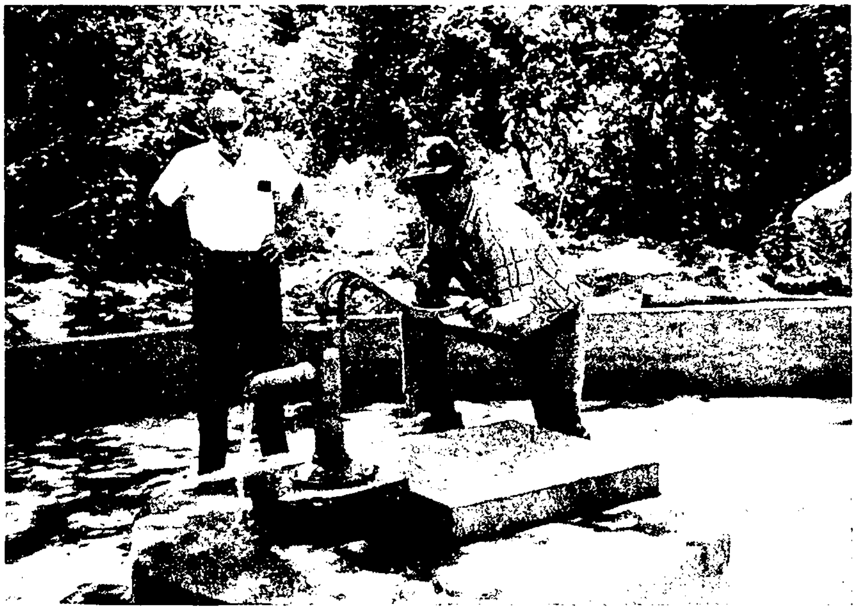
Nicaragua Site No. 4, located at San Antonio (Dempster pump).

Nicaragua Site No. 5, located at Las Mesas (Marumby shallow-well pump).

Nicaragua Site No. 6, located at Las Mangas (AID deep-well pump).



Nicaragua Site No. 7, located at Llano Grande (IDRC pump).



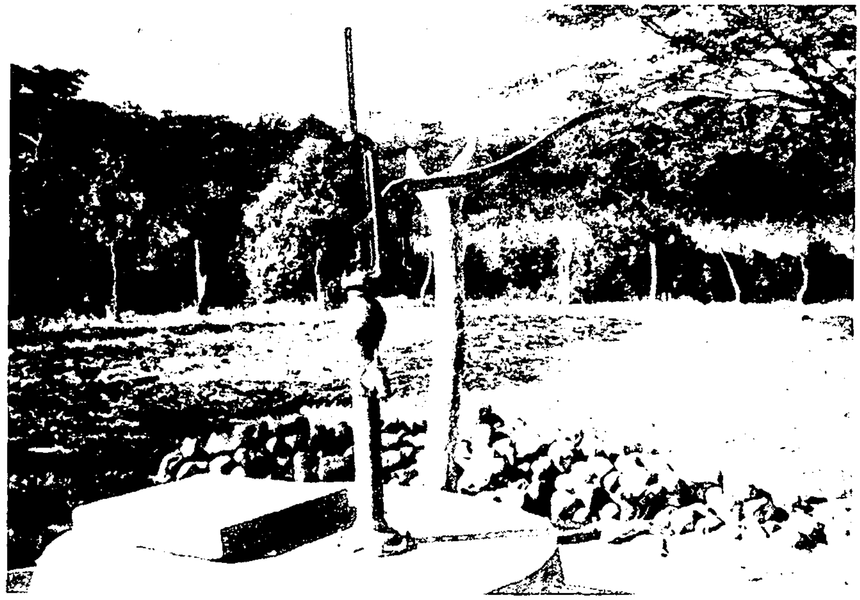
Nicaragua Site No. 8, located at San Diego (Marumby shallow-well pump).

Nicaragua Site No. 9, located at Mechapa (Dempster pump).

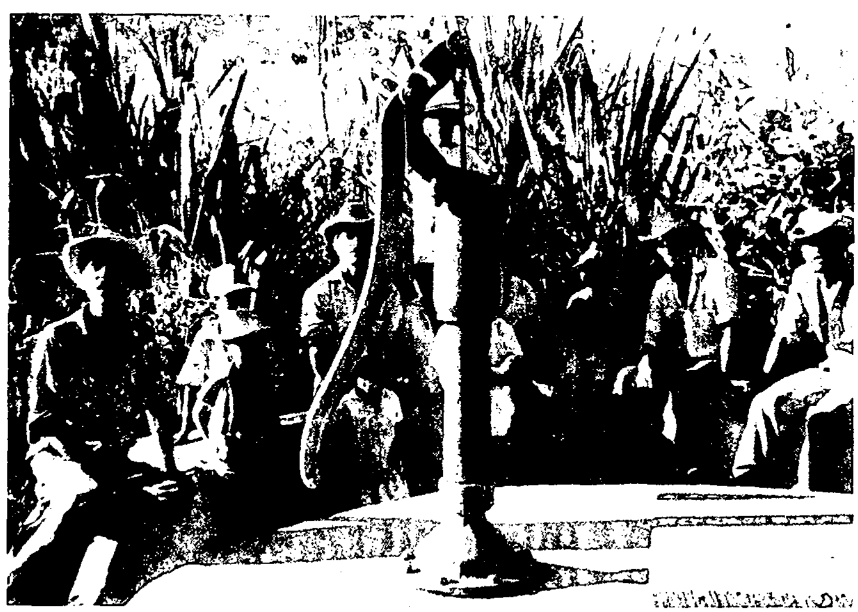
Nicaragua Site No. 10, located at El Naranjo (AID shallow-well pump).

Nicaragua Site No. 11, located at Isidrillo (Dempster pump).

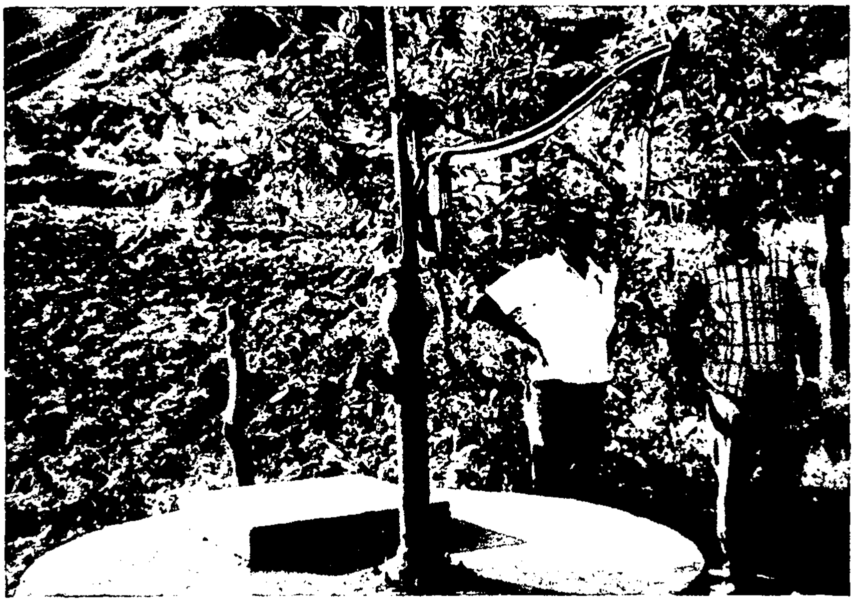
Nicaragua Site No. 12, located at La Concepcion (AID shallow-well pump).



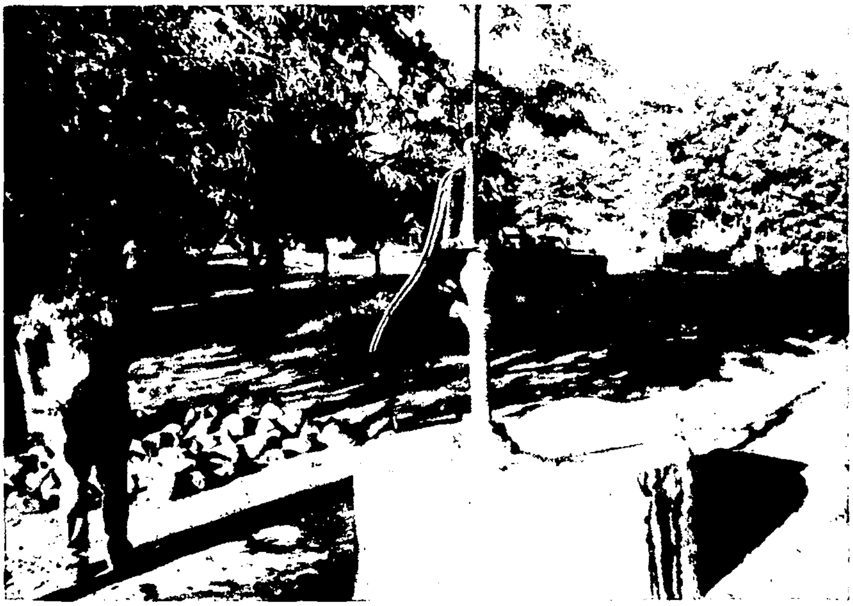
Nicaragua Site No. 13, located at El Rodeo (Dempster pump).



Nicaragua Site No. 14, located at Los Calpules stream (AID shallow-well pump).



Nicaragua Site No. 15, located at Los Calpules school (Dempster pump).



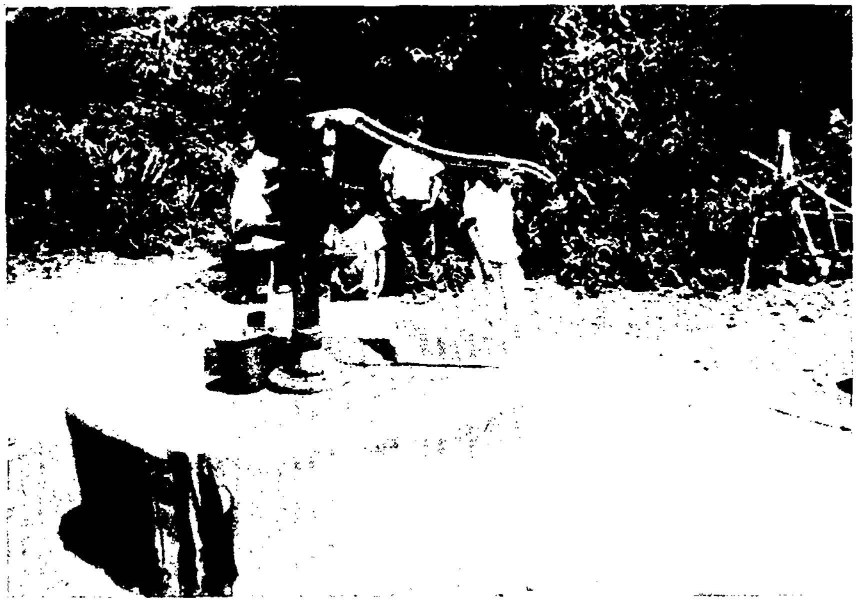
Nicaragua Site No. 16, located at Paso Hondo (Dempster pump).

Nicaragua Site No. 17, located at Quebrada Ariba (Marumby shallow-well pump).

In order to better understand water consumption patterns of the users of test pumps, water meters have been installed at representative sites in both Nicaragua and Costa Rica. These water meters will accurately record the amount of water, in gallons, that passes through the pumps during a given period of time and will provide data to complement user figures based on village population. Sites having water meters, in Nicaragua, are Las Lajitas (Site No. 2), San Antonio (Site No. 4), Santa Rosa (Site No. 23) and El Espinal (Sites No. 28 and 29).

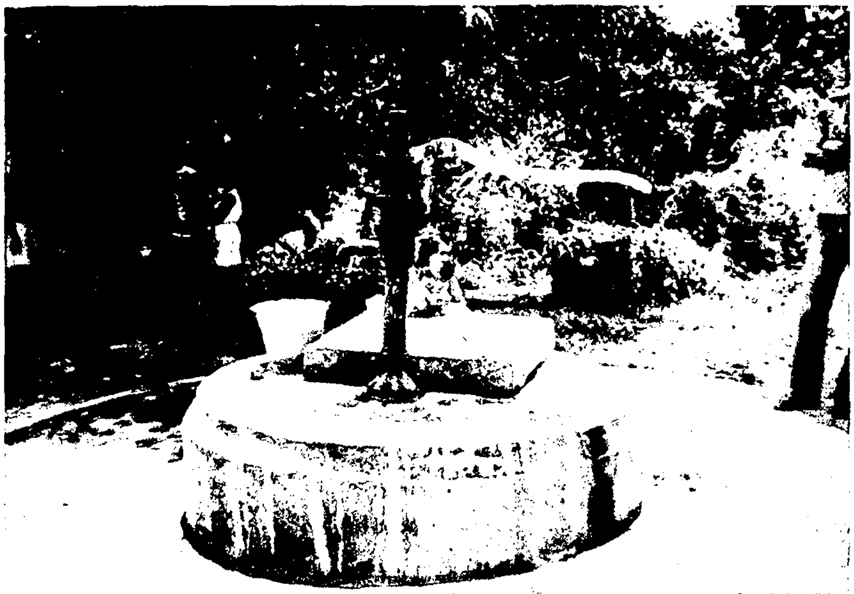
Nicaragua Site No. 18, located at Las Lajas (AID shallow-well pump).

Nicaragua Site No. 19, located at Los Hatillos community plaza (AID deep-well pump).



Nicaragua Site No. 20, located at Los Hatillos (AID deep-well pump).

Nicaragua Site No. 21, located at Musuli (AID deep-well pump).

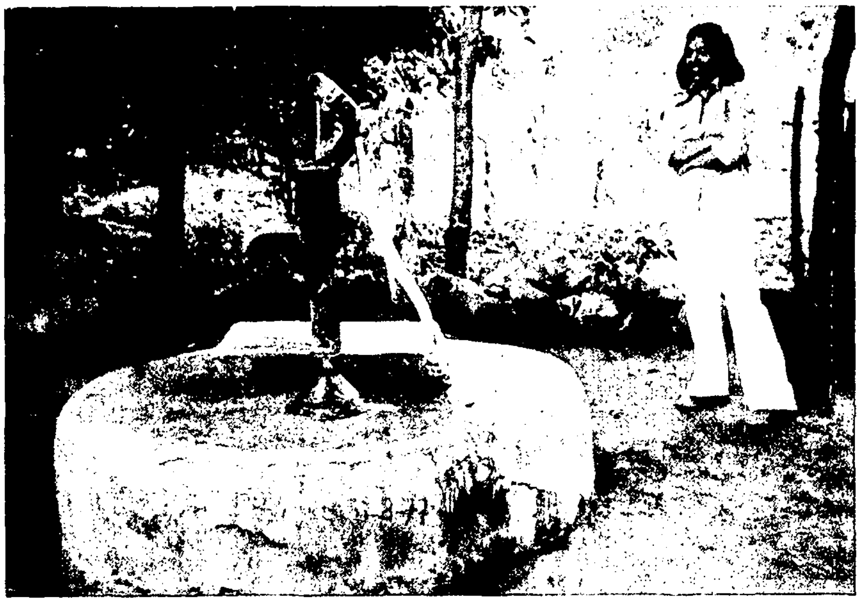


Nicaragua Site No. 22, located at Los Rincones (AID deep-well pump).

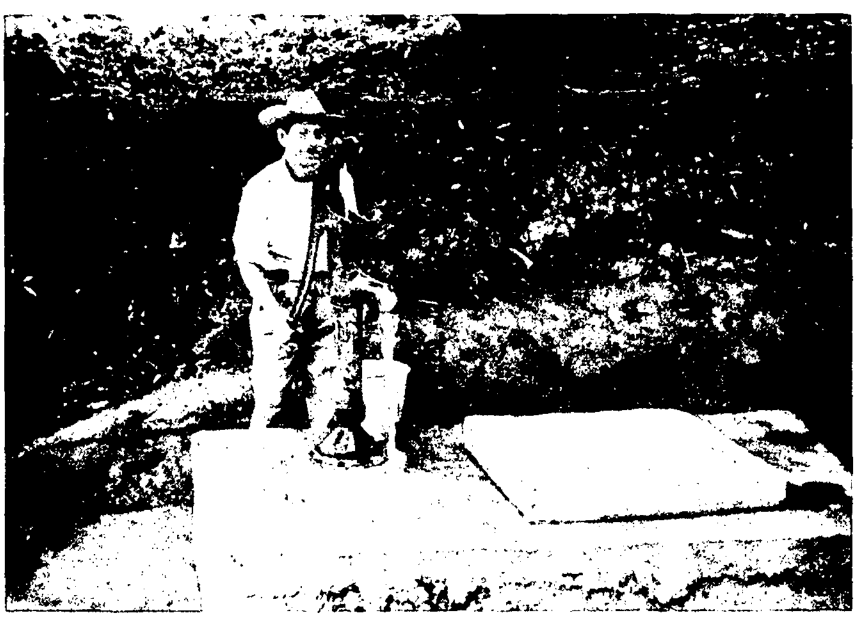
Nicaragua Site No. 23, located at Santa Rosa (AID deep-well pump).

Nicaragua Site No. 24, located at El Jocote (AID deep-well pump).

Nicaragua Site No. 25, located at Mechapa-La Concepcion (AID shallow-well pump).



Nicaragua Site No. 26, located at Licoroy (AID shallow-well pump).



Nicaragua Site No. 27, located at Tomabu (AID shallow-well pump).

Nicaragua Site No. 28, located at El Espinal (AID shallow-well pump).

Nicaragua Site No. 29, located at El Espinal (AID shallow-well pump).

Nicaragua Site No. 30, located at Sabana Grande (Marumby shallow-well pump).

Appendix 3

AID/BATTELLE PUMP WORKING DRAWINGS

The following changes have been incorporated into the original Battelle hand pump drawings by the Georgia Institute of Technology under contract No. AID/ta-C-1354.

- Drawing 2001

  Option B showing a pin-mounted pump cap has been eliminated. Option C has now become Option B.

  The modified deep-well pump cap has replaced the shallow-well cap along with the corresponding fulcrum handle which has been shortened to 8 1/4".

  The double cup assembly has replaced the single cup assembly.

  Find numbers 19, 20 and 21 have been added to show the location of the short and long bushings as well as the long pivot pin.

- Drawing 2002

  Option B showing a pin-mounted pump cap has been eliminated.

  A modified deep-well pump cap has replaced the original one.

  The fulcrum handle has been shortened to 8 1/4".

  Find numbers 25 and 26 have been added to show the location of the short and long bushings.

- Drawing 2003

  An asterisk along with the words "Use 1/2 Dia if 7/16 Dia is unavailable" has been added.

- Drawing 2004

  The diameter of the through hole has been increased from 41/64" to 29/32".

- Drawing 2005

  The distance between pin holes has been increased from 3 3/16 plus 1/16 minus 0 to 3 1/4 plus 1/16 minus 0.

  In the Material & Treatment box, the words "Harden to R_C-40" have been added.

- Drawing 2006 has been eliminated.

- Drawing 2007

  The draft angles of the front and rear of the pump body now angle outwards instead of inwards.

  The title has been changed from "Pump Body; Bolt on Cap Type" to "Pump Body".

- Drawing 2008

  The nipples for holding the cotter pins in one position have been eliminated.

  The diameter of the holes through the handle have been increased from 41/64" to 29/32".

- Drawing 2009 has been eliminated.

- Drawing 2011 has been eliminated.

- Drawing 2012 has been eliminated.

- Drawing 2013

  The distance between pin holes has been increased from 4 3/4 plus 1/16 minus 0 to 4 13/16 plus 1/16 minus 0.

  In the Material & Treatment box, the words "Harden to R_C-40" have been added.

- Drawing 2014

  The note has been changed to state the following:

  "Cylinder may be made of either of the following materials:

  - For deep-well pump; STD P.V.C. 1120 plastic pipe (Sch 40)
  - For deep- or shallow-well pumps; P.V.C. pipe to be used as a liner inside a 3" galvanized steel pipe."

- Drawing 2017

  An asterisk along with the words "This size is for a 3" ID cylinder and will vary with the ID of the PVC-lined cylinder" has been added.

- Drawing 2019

  The diameter of the leather cup has been reduced from 3" Dia to 2 15/16" Dia.

  The title has been changed to "Leather Cup".

- Drawing 2020 has been eliminated.

- Drawing 2023

  The 8 holes on the pump base are now equally spaced on a 9 1/2" Dia B.C. instead of a 9" Dia B.C.

- Drawing 2026

  The nipples for holding the cotter pins in one position have been eliminated.

  The diameter of the hole has been increased from 41/64" to 29/32".

- Drawing 2027

  The location where the fulcrum handle connects to the pump cap has been raised.

  The hole diameter of this connecting section has been increased from 41/64" to 29/32".

  The nipples for holding the cotter pins in one position have been eliminated.

  The draft angle of the front of the pump cap (top view) has been changed so as to angle outwards instead of inwards.

  The title has been changed from "Pump Cap; Deep Well Pump; Bolt on Type" to "Pump Cap".

- Drawing 2028 has been eliminated.

- Drawing 2029

  The nipples for holding the cotter pins in one position have been eliminated.

  The length of the fulcrum handle (center to center) has been reduced from 8 3/8" to 8 1/4".

  The drilled holes have been increased from 41/64" to 29/32".

  The title has been changed from "Handle Fulcrum; Deep Well Pump" to "Handle Fulcrum".

- Drawing 2030

  The title has been changed from "Three Inch Plunger Assembly; Double Cup" to "Plunger Assembly; Double Cup".

- Drawing 2031

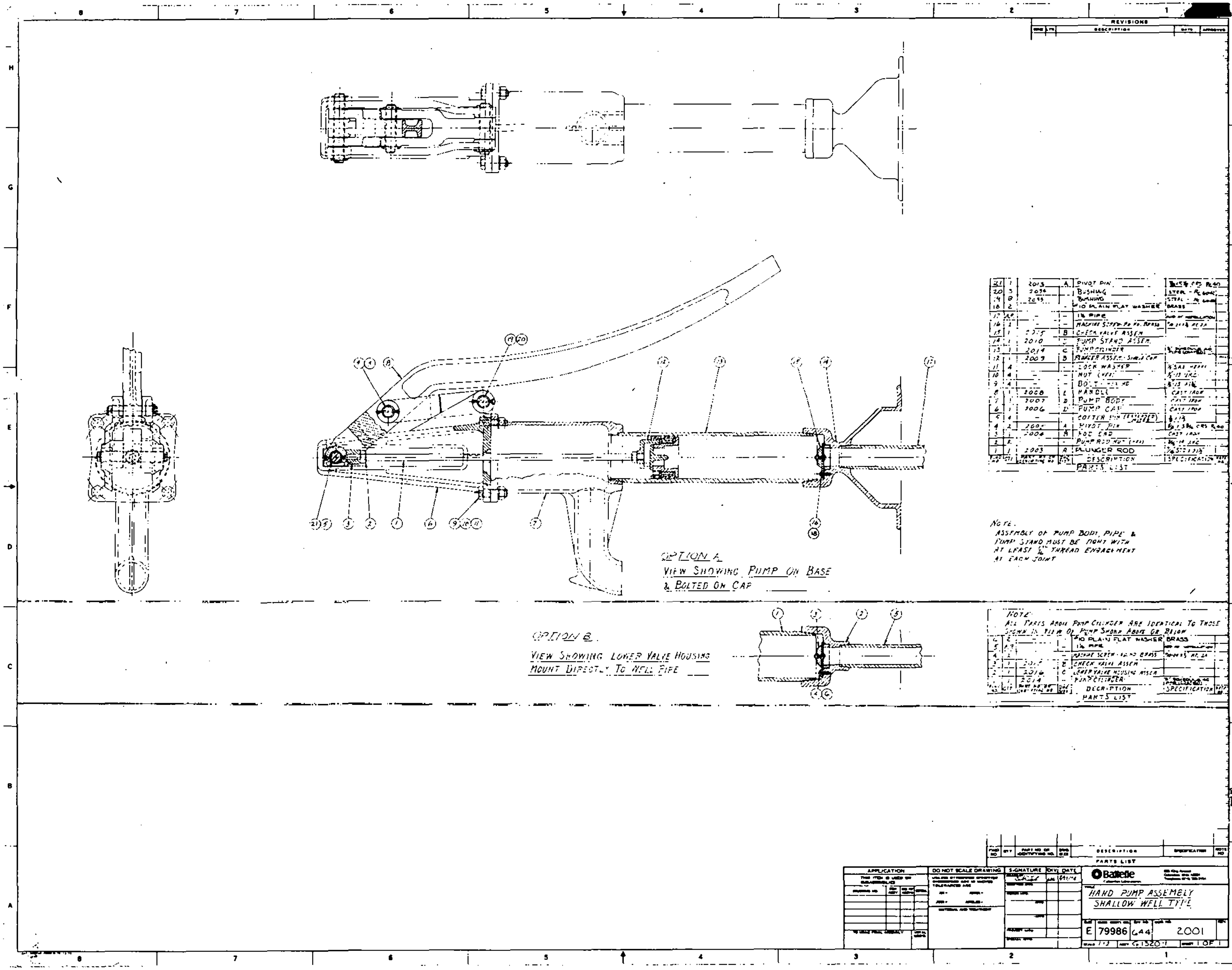
  An asterisk along with the words, "This size is for a 3" ID cylinder and will vary with the ID of the PVC pipe or liner" has been added.

- Drawing 2032

  An asterisk along with the words, "This size is for a 3" ID cylinder and will vary with the ID of the PVC pipe or liner" has been added.

- Drawing 2033 has been added.

- Drawing 2034 has been added.

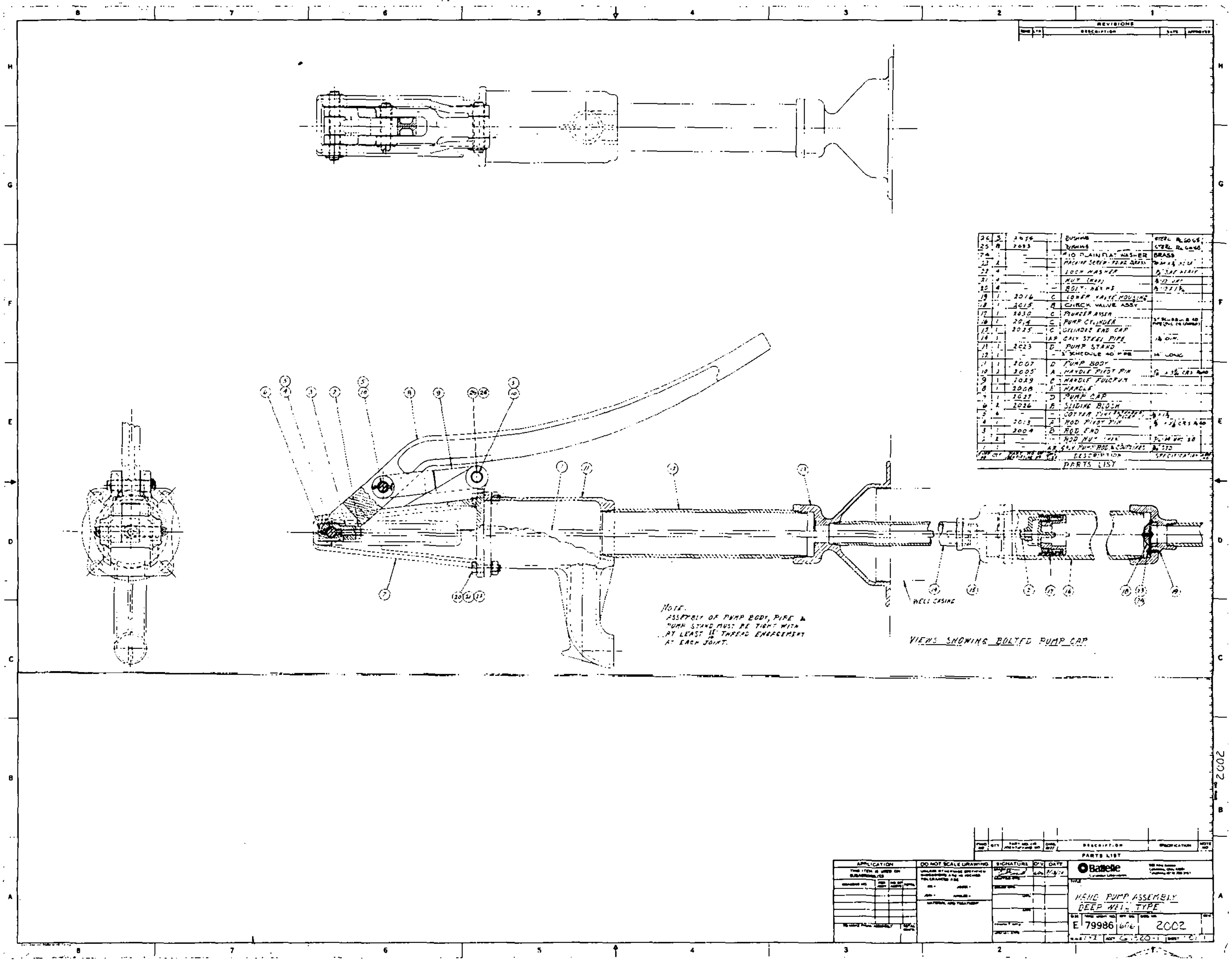


PARTS LIST

FIND NO	QTY	PART NO OR IDENTIFYING NO	DWG SIZE	DESCRIPTION	SPECIFICATION
21	1	2013	A	PIVOT PIN	3/8 x 5/8 CRS Rc40
20	3	2034		BUSHING	STEEL - Rc 60
19	8	2033		BUSHING	STEEL - Rc 60
18	2		-	#10 PLAIN FLAT WASHER	BRASS
17	AR	-	-	1¼ PIPE	
16	2	-	-	MACHINE SCREW BRASS	
15	1	2015	B	CHECK VALVE ASSEM	
14	1	2010		PUMP STAND ASSEM.	
13	1	2014	C	PUMP CYLINDER	
12	1	2009	B	PLUNGER ASSEM.	
11	4		-	LOCK WASHER	⅜ SAE
10	4	-	-	NUT (HEX)	⅜-16 UNC
9	4	-	-	BOLT - HEX HD	⅜-16 x 1¼
8	1	2008	E	HANDLE	CAST IRON
7	1	2007	D	PUMP BODY	CAST IRON
6	1	2006	D	PUMP CAP	CAST IRON
5	4	-		COTTER PIN	
4	2	2005	A	PIVOT PIN	
3	1	2004	B	ROD END	CAST IRON
2	2		-	PUMP ROD NUT (HEX)	5/16-18 UNC
1	1	2003	A	PLUNGER ROD	5/16 STD x 31½

PARTS LIST

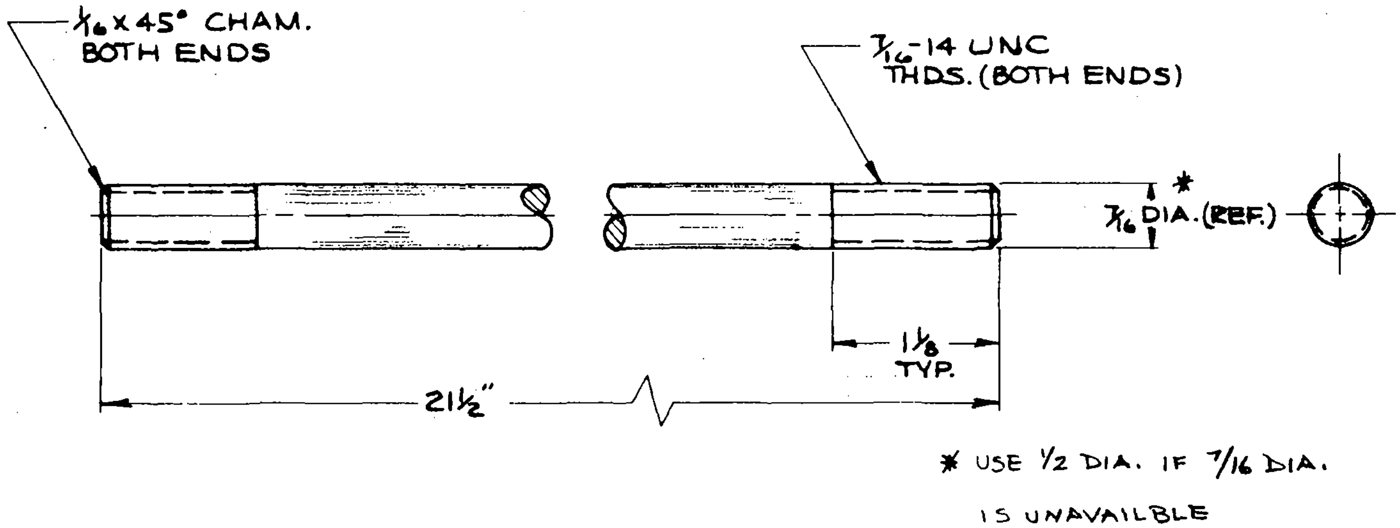
FIND NO	QTY	PART NO OR IDENTIFYING NO	DWG SIZE	DESCRIPTION	SPECIFICATION
6	2	-	-	#10 PLAIN FLAT WASHER	BRASS
5	AR		-	1¼ PIPE	
4	2		-	MACHINE SCREW BRASS	
3	1	2015	B	CHECK VALVE ASSEM	
2	1	2016	C	LOWER VALVE HOUSING ASSEM	
1	1	2014	-	PUMP CYLINDER	



FIND NO	QTY	PART NO. OR IDENTIFYING NO	DWG SIZE	DESCRIPTION	SPECIFICATION
26	5	2034		BUSHING	STEEL RL6065
25	8	2033		BUSHING	STEEL RL6068
24		–	–	#10 PLAIN FLAT WASHER	BRASS
23	2	–	–	MACHINE SCREW - FLAT HD BRASS	
22	4		–	LOCK WASHER	½ SAE HEAVY
21	4			NUT (HEX)	½-13 UNC
20	4	–	–	BOLT - HEX HD	
19	1	2016	C	LOWER VALVE HOUSING	
18	1	2015	B	CHECK VALVE ASSY	
17	1	2030	C	PLUNGER ASSEM	
16	1	2014	C	PUMP CYLINDER	
15	1	2025	C	CYLINDER END CAP	
14	1	–	AR	GALV STEEL PIPE	1¼ DIA.
13	1	2023	D	PUMP STAND	
12	1	–	–	3" SCHEDULE 40 PIPE	14" LONG
11	1	2007	D	PUMP BODY	
10	2	2005	A	HANDLE PIVOT PIN	
9	1	2029	C	HANDLE FULCRUM	
8	1	2008	E	HANDLE	
7	1	2027	D	PUMP CAP	
6	2	2026	B	SLIDING BLOCK	
5	6	–	–	COTTER PIN	
4	1	2013	A	ROD PIVOT PIN	
3	1	2004	B	ROD END	
2	2	–	–	ROD NUT (HEX)	
1	1	–	AR	GALV PUMP ROD & COUPLINGS	⅝" STD

PARTS LIST

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



APPLICATION			
THIS ITEM IS USED ON SUBASSEMBLIES			
DRAWING NO.	PER ASSY	NO. OF ASSYS	TOTAL
2001	1	1	1
TO MAKE FINAL ASSEMBLY			TOTAL REQ'D.

DO NOT SCALE DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE: ± 1/32
.XX = – .XXXX = –
.XXX = – ANGLES = ± 1/2°

MATERIAL & TREATMENT
7/16 DIA. GALV.
PUMP ROD

SIGNATURE	DIV.	DATE
DRAWN BY	699	1-7-75
DRAFTING APPD.		
DESIGN APPD.		
APPD.		
PROJECT APPD.		
SPECIAL APPD.		

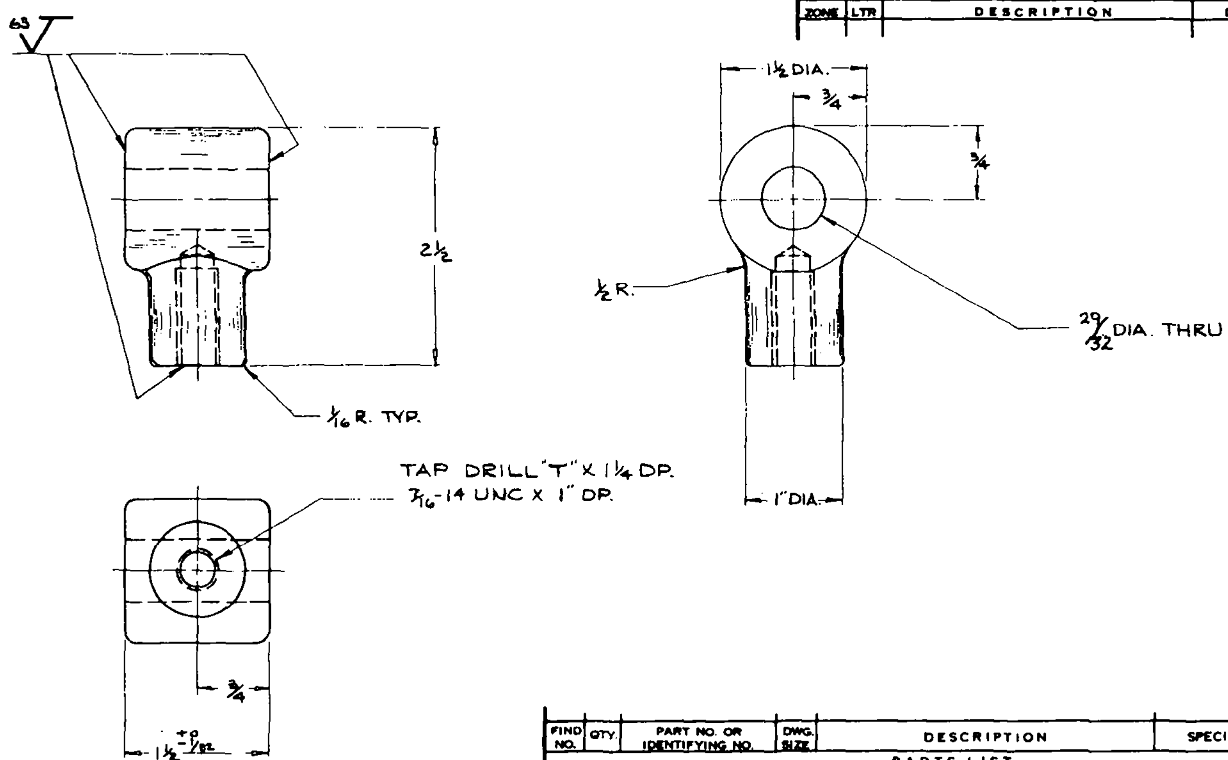
BATTELLE MEMORIAL INSTITUTE
COLUMBUS LABORATORIES
505 KING AVE., COLUMBUS, OHIO 43201

TITLE: PLUNGER ROD

SIZE	CODE IDENT. NO.	DIV. NO.	DWG. NO.	REV.
A	79986	644	2003	

SCALE 1" = 1" ACCT. G1320-1 SHEET 1 OF 1

CAT. 394163 FORM D-5 5-70



FIND NO.	QTY.	PART NO. OR IDENTIFYING NO.	DWG. SIZE	DESCRIPTION	SPECIFICATION	NOTE NO.

PARTS LIST

NOTES:

1. ALL DRAFT ANGLES TO BE 1½° TO 4°
2. ALL FILLETS & RADII TO BE ⅛" R. UNLESS OTHERWISE SPECIFIED

APPLICATION — THIS ITEM IS USED ON ASSEMBLIES

DRAWING NO.	PER ASSY	NO. OF ASSYS	TOTAL
2001	1	1	1
2002	1	1	1

TO MAKE FINAL ASSEMBLY — TOTAL REQ'D.

DO NOT SCALE DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE: ± 1/32

MATERIAL & TREATMENT: CAST IRON

SIGNATURE	DIV.	DATE
DRAWN BY	659	1-6-76
DRAFTING APPD.		
DESIGN APPD.		
APPD.		
PROJECT APPD.		
SPECIAL APPD.		

Battelle Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201
Telephone (614) 299-3151

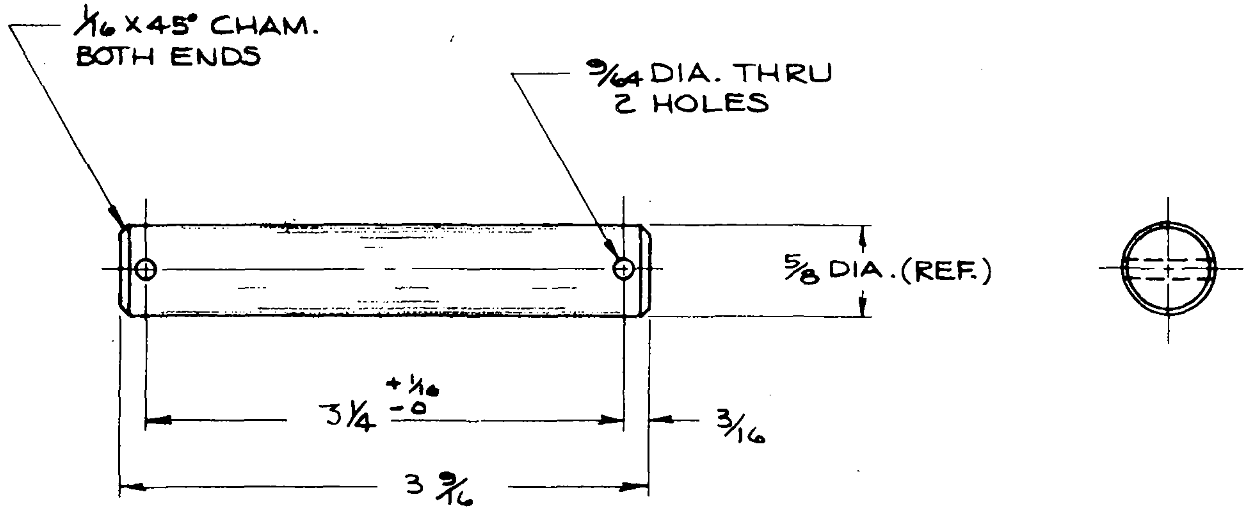
TITLE: ROD END

SIZE	CODE IDENT. NO.	DIV. NO.	DWG. NO.	REV.
B	79986	644	2004	

SCALE 1"=1" ACCT G1320-1 SHEET 1 OF 1

CAT. 604160 FORM D-7 10-75

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



APPLICATION			
THIS ITEM IS USED ON ASSEMBLIES			
DRAWING NO.	PER ASSY	NO. OF ASSYS	TOTAL
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2001 "A"	2	1	2
TO MAKE FINAL ASSEMBLY			TOTAL REQ'D.

DO NOT SCALE DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE: ± 1/32

.XX = — .XXXX = —

.XXX = — ANGLES = ± 1/2°

MATERIAL & TREATMENT

5/8 DIA. C.R.S. ROUND

HARDEN TO Rc 40

SIGNATURE	DIV.	DATE
DRAWN BY [illegible]	659	1-7-74
DRAFTING APPD.		
DESIGN APPD.		
APPD.		
PROJECT APPD.		
SPECIAL APPD.		

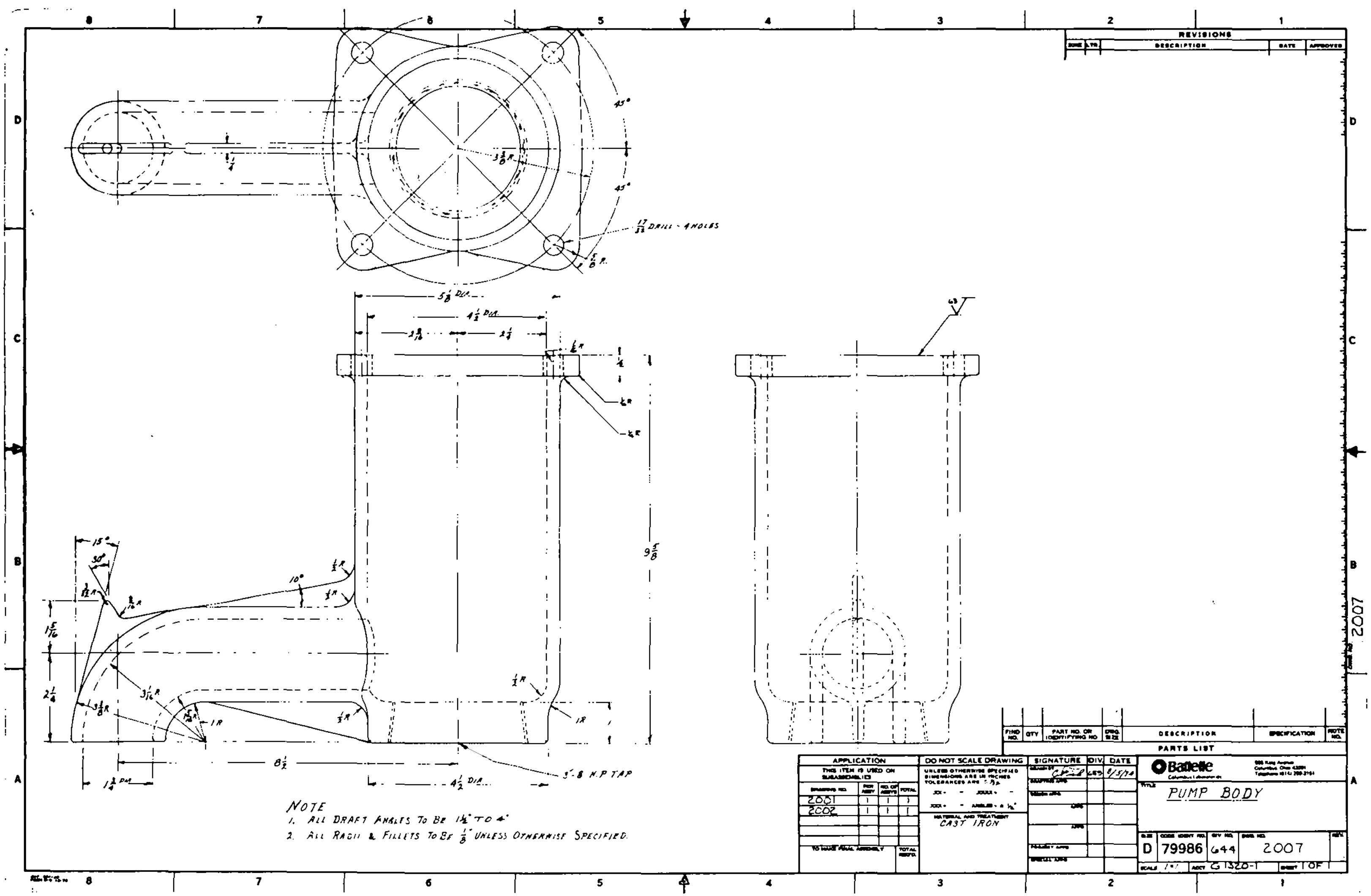
BATTELLE MEMORIAL INSTITUTE
COLUMBUS LABORATORIES
505 KING AVE., COLUMBUS, OHIO 43201

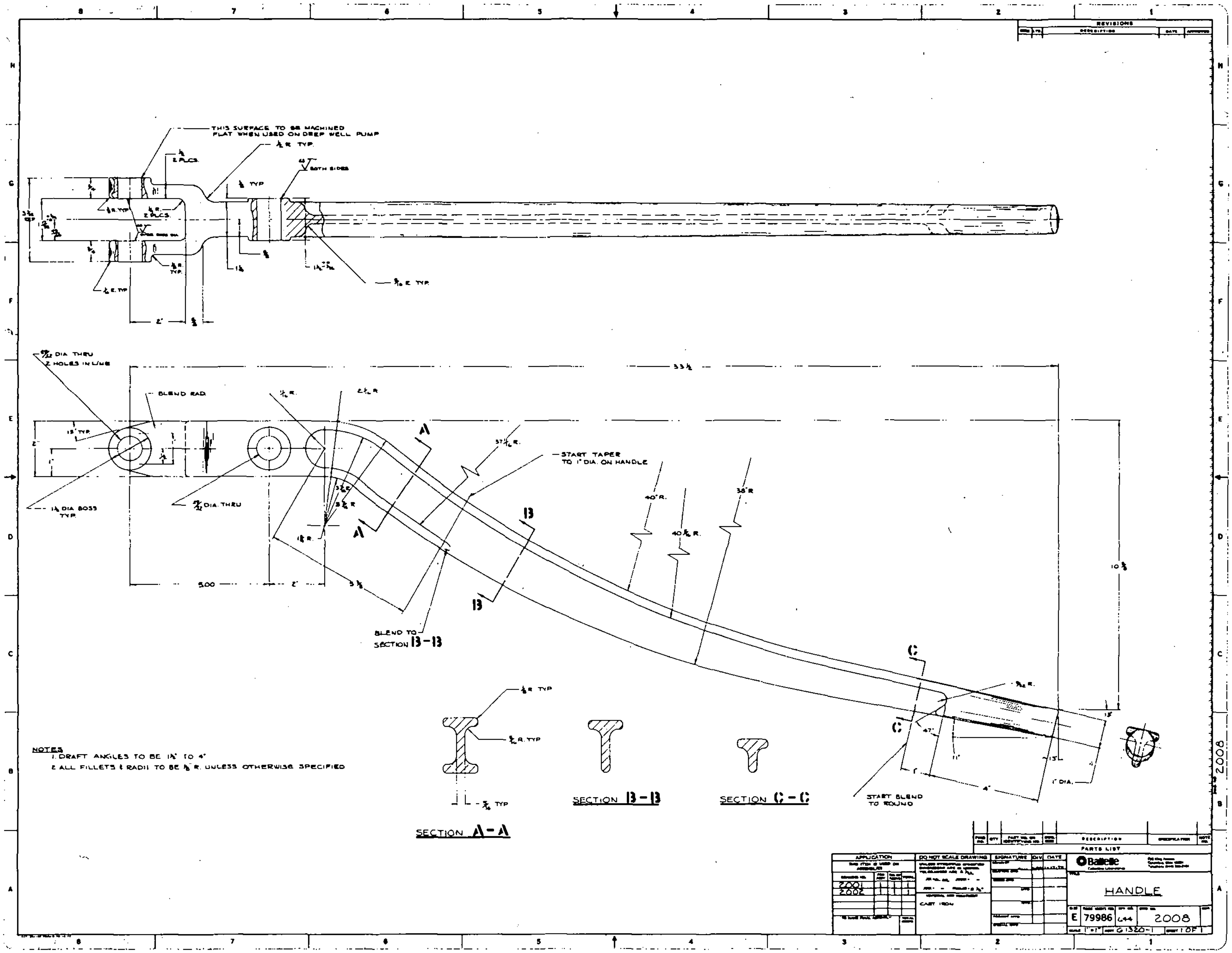
TITLE: HANDLE PIVOT PIN

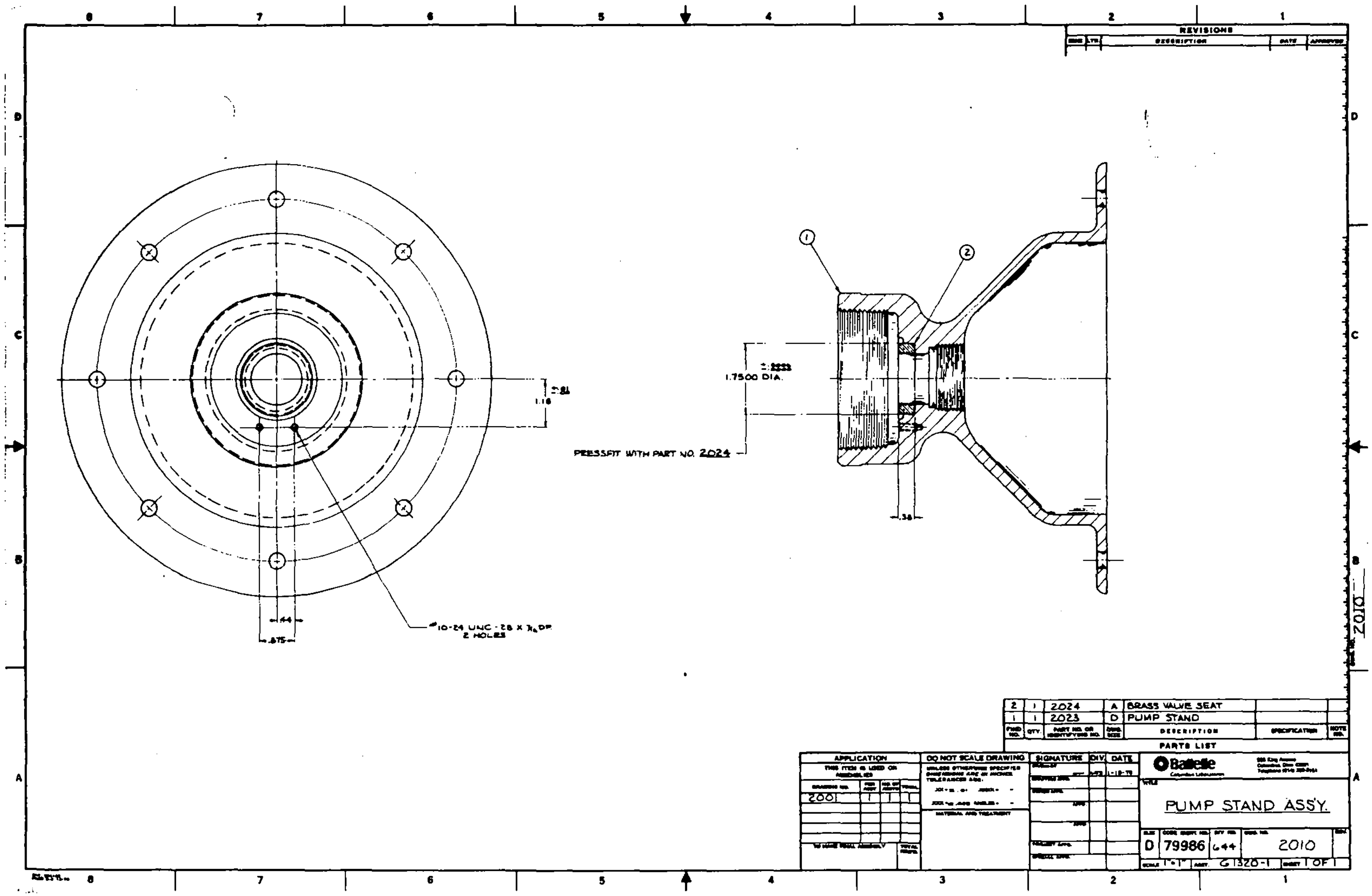
SIZE	CODE IDENT. NO.	DIV. NO.	DWG. NO.	REV.
A	79986	644	2005	

SCALE 1" = 1" ACCT. G1320-1 SHEET 1 OF 1

CAT. 294163 FORM D-5 5-70

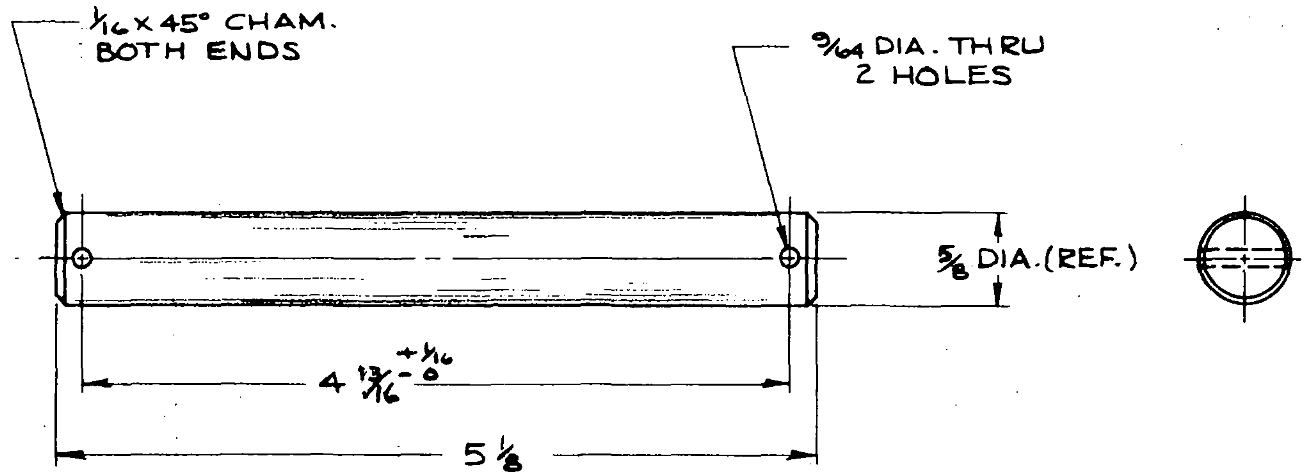

REVISIONS
DESCRIPTION
DATE
APPROVED
45°
$3\frac{3}{8}$ R.
$\frac{17}{32}$ DRILL - 4 HOLES
$\frac{5}{8}$ R.
$5\frac{5}{8}$ DIA.
$4\frac{1}{2}$ DIA.
$9\frac{5}{8}$
15°
30°
10°
$8\frac{1}{2}$
$4\frac{1}{2}$ DIA.
$\frac{3}{8}$ - 8 N.P. TAP
NOTE
1. ALL DRAFT ANGLES TO BE $1\frac{1}{2}$° TO 4°
2. ALL RADII & FILLETS TO BE $\frac{1}{8}$" UNLESS OTHERWISE SPECIFIED.
FIND NO.
QTY
PART NO. OR IDENTIFYING NO
DWG. SIZE
DESCRIPTION
SPECIFICATION
NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
2001
2002
TO MAKE FINAL ASSEMBLY
TOTAL REQ'D.
DO NOT SCALE DRAWING
MATERIAL AND TREATMENT
CAST IRON
SIGNATURE
DIV
DATE
8/5/74
Battelle
PUMP BODY
D
79986
644
2007
1 OF 1
2007


THIS SURFACE TO BE MACHINED FLAT WHEN USED ON DEEP WELL PUMP
BOTH SIDES
DIA. THRU 2 HOLES IN LINE
BLEND RAD.
1¼ DIA BOSS TYP.
DIA. THRU
33½
START TAPER TO 1" DIA. ON HANDLE
40" R.
38" R.
BLEND TO SECTION B-B
10⅞
START BLEND TO ROUND
1" DIA.
NOTES
1. DRAFT ANGLES TO BE 1½° TO 4°
2. ALL FILLETS & RADII TO BE ⅛ R. UNLESS OTHERWISE SPECIFIED
SECTION A-A
SECTION B-B
SECTION C-C
REVISIONS
PARTS LIST
DESCRIPTION
APPLICATION
2001
2002
DO NOT SCALE DRAWING
CAST IRON
SIGNATURE
DATE
Battelle
HANDLE
E
79986
2008
G1320-1
1 OF 1



REVISIONS
1.7500 DIA.
PRESSFIT WITH PART NO. 2024
.38
1.16
.81
.44
.875
10-24 UNC-2B X 3/4 DP 2 HOLES
2 | 1 | 2024 | A | BRASS VALVE SEAT
1 | 1 | 2023 | D | PUMP STAND
FIND NO. | QTY. | PART NO. OR IDENTIFYING NO. | DWG. SIZE | DESCRIPTION | SPECIFICATION | NOTE NO.
PARTS LIST
APPLICATION
2001
DO NOT SCALE DRAWING
MATERIAL AND TREATMENT
SIGNATURE
DIV.
DATE
Battelle
PUMP STAND ASSY.
D
79986
644
2010
G1320-1
1 OF 1
2010

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



APPLICATION			
THIS ITEM IS USED ON SUBASSEMBLIES			
DRAWING NO.	PER ASSY	NO. OF ASSYS	TOTAL
2001 "A"	1	1	1
2002	1	1	1
TO MAKE FINAL ASSEMBLY			TOTAL REQ'D

DO NOT SCALE DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE: ± 1/32
.XX = .XXXX = —
.XXX = — ANGLES = ± 1/2°

MATERIAL & TREATMENT
5/8 C.R.S. ROUND
HARDEN TO Rc 40

SIGNATURE	DIV.	DATE
DRAWN BY 644659		1-7-75
DRAFTING APPD.		
DESIGN APPD.		
APPD.		
PROJECT APPD.		
SPECIAL APPD.		

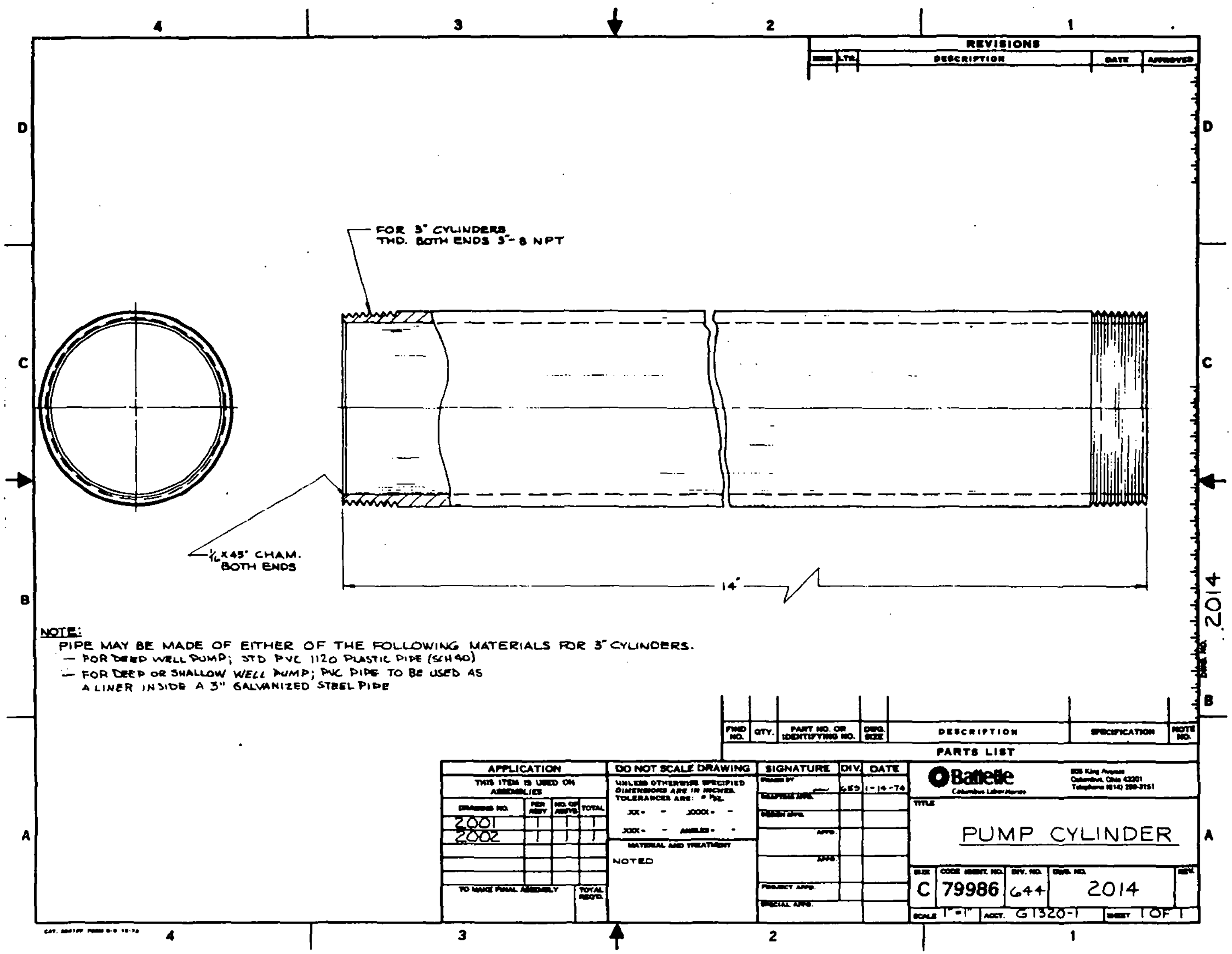
BATTELLE MEMORIAL INSTITUTE
COLUMBUS LABORATORIES
505 KING AVE., COLUMBUS, OHIO 43201

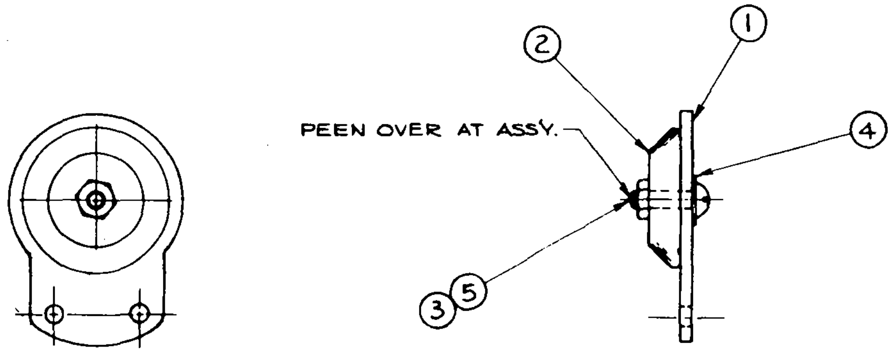
TITLE: ROD PIVOT PIN

SIZE	CODE IDENT. NO.	DIV. NO.	DWG. NO.	REV.
A	79986	644	2013	

SCALE 1" = 1" ACCT. G 1320-1 SHEET 1 OF 1

CAT. 294163 FORM D-6 5-70-


REVISIONS
DESCRIPTION
DATE
APPROVED
FOR 3" CYLINDERS
THD. BOTH ENDS 3"- 8 NPT
1/16 X45° CHAM.
BOTH ENDS
14"
NOTE:
PIPE MAY BE MADE OF EITHER OF THE FOLLOWING MATERIALS FOR 3" CYLINDERS.
— FOR DEEP WELL PUMP; STD PVC 1120 PLASTIC PIPE (SCH 40)
— FOR DEEP OR SHALLOW WELL PUMP; PVC PIPE TO BE USED AS A LINER INSIDE A 3" GALVANIZED STEEL PIPE
FIND NO.
QTY.
PART NO. OR IDENTIFYING NO.
DWG. SIZE
DESCRIPTION
SPECIFICATION
NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON ASSEMBLIES
DRAWING NO.
2001
2002
TOTAL
DO NOT SCALE DRAWING
MATERIAL AND TREATMENT
NOTED
SIGNATURE
DIV.
DATE
1-14-74
Battelle
Columbus Laboratories
TITLE
PUMP CYLINDER
SIZE
C
79986
644
2014
SCALE 1"=1"
ACCT. G1320-1
SHEET 1 OF 1
DWG. NO. 2014



REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

PARTS LIST

FIND NO.	QTY.	PART NO. OR IDENTIFYING NO.	DWG. SIZE	DESCRIPTION	SPECIFICATION	NOTE NO.
5	1	–	–	#10 NC-2B HEX NUT	BRASS	
4	1	–	–	#10 PLAIN FLAT WASHER	BRASS	
3	1	–	–	#10-24 NC-2A X ¾ LONG RD. HD SCR.	BRASS	
2	1	2022	A	CHECK VALVE WEIGHT		
1	1	2021	B	VALVE FLAPPER		

APPLICATION

THIS ITEM IS USED ON ASSEMBLIES

DRAWING NO.	PER ASSY	NO. OF ASSYS	TOTAL
2001	1	1	1
2002	1	1	1

TO MAKE FINAL ASSEMBLY — TOTAL REQ'D.

DO NOT SCALE DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:

.XX ± .XXXX ±
.XXX± ANGLES±

MATERIAL & TREATMENT

SIGNATURE	DIV.	DATE
DRAWN BY	659	1-9-78
DRAFTING APPD		
DESIGN APPD.		
APPD		
PROJECT APPD		
SPECIAL APPD		

Battelle
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201
Telephone (614) 299-3151

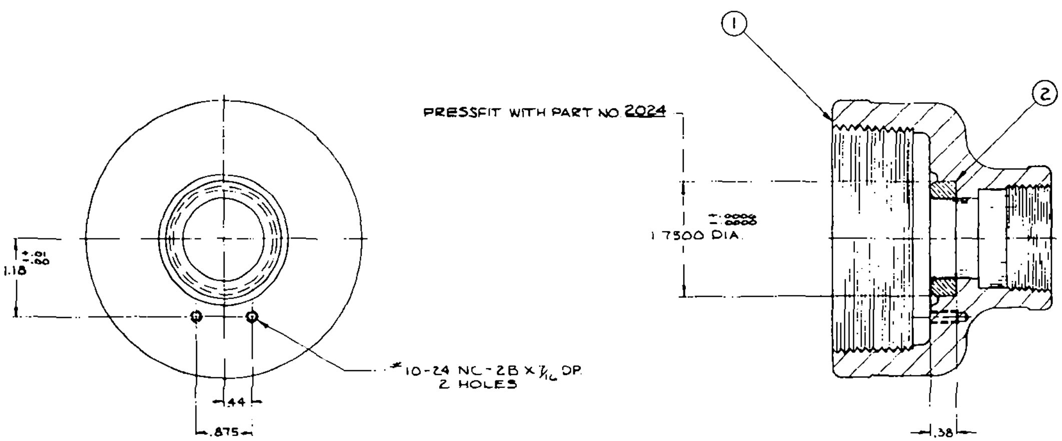
TITLE: CHECK VALVE ASSY.

SIZE	CODE IDENT. NO.	DIV. NO.	DWG. NO.	REV.
B	79986	644	2015	

SCALE 1" = 1" ACCT. SHEET 1 OF 1

CAT. 904166 FORM B-7 12-75

-130-



FIND NO.	QTY.	PART NO. OR IDENTIFYING NO.	DWG. SIZE	DESCRIPTION	SPECIFICATION	NOTE NO.
2	1	2024	A	BRASS VALVE SEAT		
1	1	2025	C	CYLINDER END CAP		

PARTS LIST

APPLICATION			
THIS ITEM IS USED ON SUBASSEMBLIES			
DRAWING NO.	PER ASSY	NO. OF ASSYS	TOTAL
2001	1	1	1
2002	1	1	1
TO MAKE FINAL ASSEMBLY			TOTAL REQ'D.

DO NOT SCALE DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE:

.XX = ± .01 .XXXX = –

.XXX = ± .005 ANGLES = –

MATERIAL AND TREATMENT

SIGNATURE	DIV.	DATE
DRAWN BY	655	1-14-75
DRAFTING APPD.		
DESIGN APPD.		
APPD.		
APPD.		
PROJECT APPD.		
SPECIAL APPD.		

Battelle
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201
Telephone (614) 299-3151

TITLE

LOWER VALVE HOUSING ASSY.

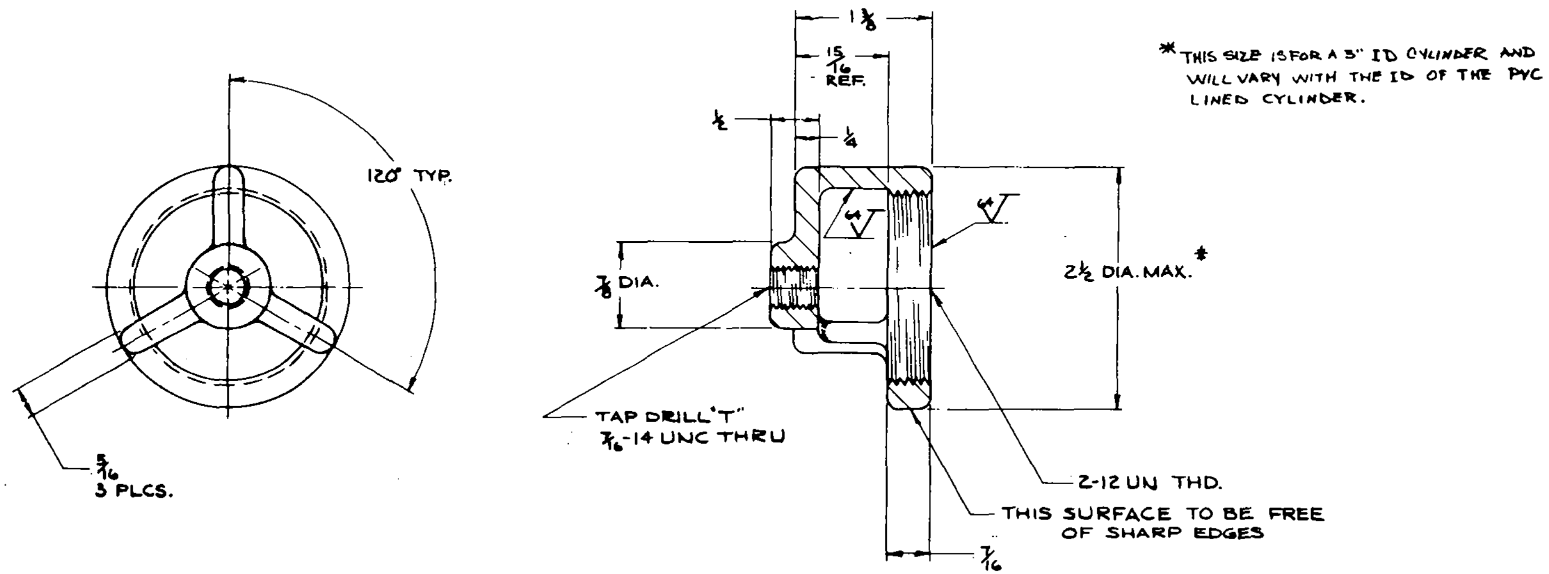
SIZE	CODE IDENT. NO.	DIV. NO.	DWG. NO.	REV.
C	79986	644	2016	

SCALE 1" = 1" ACCT. G1320-1 SHEET 1 OF 1

DWG. NO. 2016

REVISIONS

ZONE	LTR.	DESCRIPTION	DATE	APPROVED



NOTES:

1. ALL DRAFT ANGLES TO BE 1½° TO 4°
2. ALL FILLETS & RADII TO BE ⅛" R. UNLESS OTHERWISE SPECIFIED

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

PARTS LIST

FIND NO.	QTY.	PART NO. OR IDENTIFYING NO.	DWG. SIZE	DESCRIPTION	SPECIFICATION	NOTE NO.

APPLICATION — THIS ITEM IS USED ON SUBASSEMBLIES

DRAWING NO.	PER ASSY	NO. OF ASSYS	TOTAL
2030	1	1	1

TO MAKE FINAL ASSEMBLY — TOTAL REQD.

DO NOT SCALE DRAWING — UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE: ± 1/32; .XX = –; .XXXX = –; .XXX = –; ANGLES = ± ½°

MATERIAL & TREATMENT: CAST IRON

SIGNATURE	DIV.	DATE
DRAWN BY	659	1-5-78
DRAFTING APPD.		
DESIGN APPD.		
APPD.		
PROJECT APPD.		
SPECIAL APPD.		

Battelle Columbus Laboratories, 505 King Avenue, Columbus, Ohio 43201, Telephone (614) 299-3151

TITLE: PLUNGER CAGE

SIZE	CODE IDENT. NO.	DIV. NO.	DWG. NO.	REV.
B	79986	644	2017	

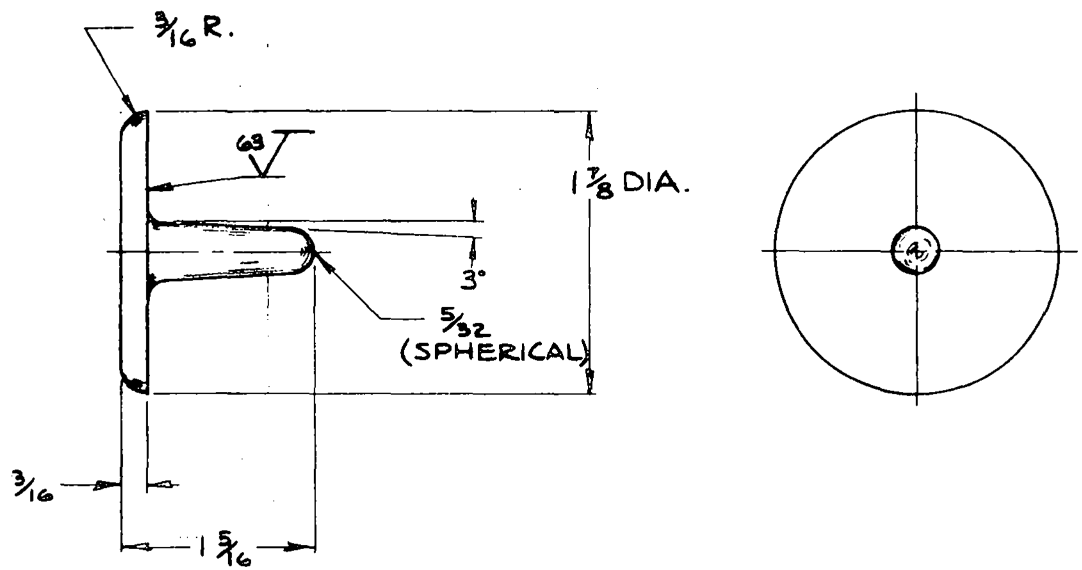
SCALE 1" = 1" ACCT. G1320-1 SHEET 1 OF 1

CAT. 804165 FORM B-7 12-73

NOTES:

1. ALL DRAFT ANGLES TO BE 1½ TO 4°
2. ALL FILLETS & RADII TO BE ⅛" R. UNLESS OTHERWISE SPECIFIED

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



APPLICATION			
THIS ITEM IS USED ON SUBASSEMBLIES			
DRAWING NO.	PER ASSY	NO. OF ASSY'S	TOTAL
2030	1	1	1
TO MAKE FINAL ASSEMBLY			TOTAL REQ'D.

DO NOT SCALE DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE: ± 1/32

.XX = – .XXXX = –

.XXX = – ANGLES = ± ½°

MATERIAL & TREATMENT: CAST IRON

SIGNATURE	DIV.	DATE
DRAWN BY	659	1-7-75
DRAFTING APPD.		
DESIGN APPD.		
APPD.		
PROJECT APPD.		
SPECIAL APPD.		

BATTELLE MEMORIAL INSTITUTE
COLUMBUS LABORATORIES
505 KING AVE., COLUMBUS, OHIO 43201

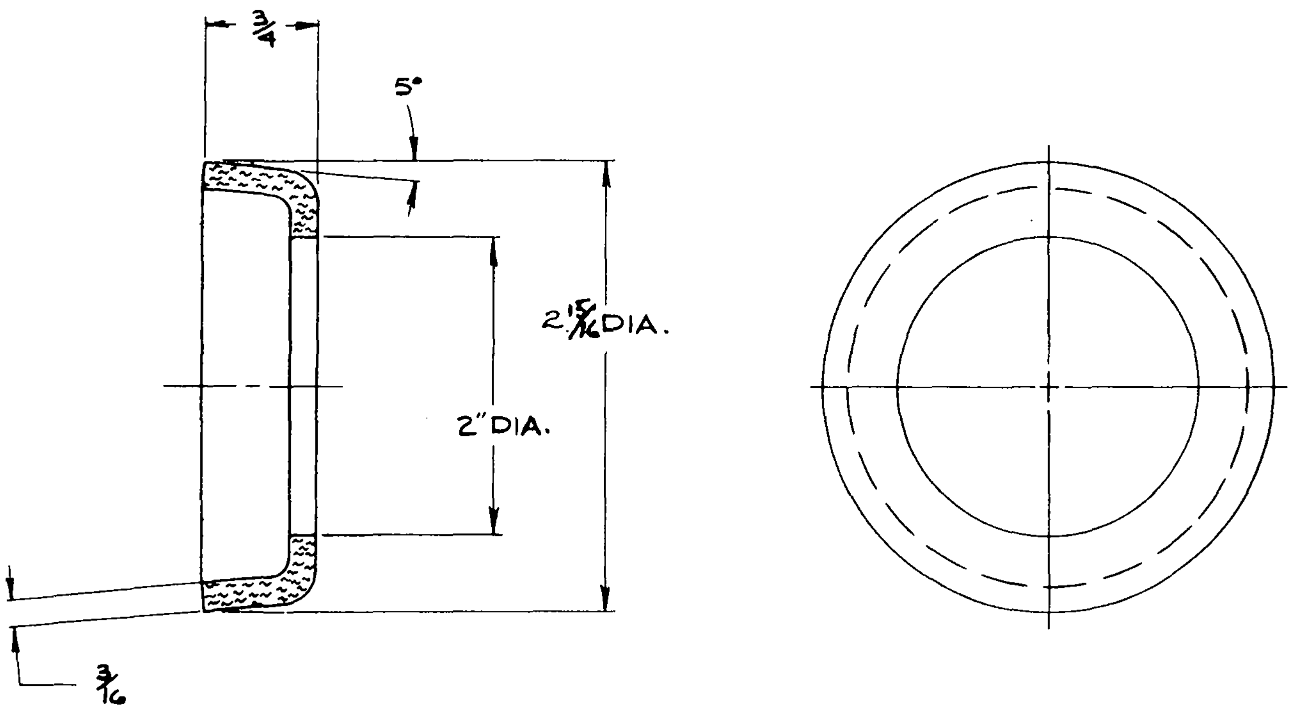
TITLE: PLUNGER POPPET

SIZE	CODE IDENT. NO.	DIV. NO.	DWG. NO.	REV.
A	79986	644	2018	

SCALE 1" = 1" ACCT. G1320-1 SHEET 1 OF 1

CAT. 294163 FORM D-5 5-70

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



APPLICATION			
THIS ITEM IS USED ON SUBASSEMBLIES			
DRAWING NO.	PER ASSY	NO. OF ASSYS	TOTAL
2030	1	1	1
TO MAKE FINAL ASSEMBLY			TOTAL REQ'D.

DO NOT SCALE DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE: ± 1/32
.XX = – .XXXX = –
.XXX = – ANGLES = ± 1°

MATERIAL & TREATMENT: LEATHER

SIGNATURE	DIV.	DATE
DRAWN BY	659	1-7-75
DRAFTING APPD.		
DESIGN APPD.		
APPD.		
PROJECT APPD.		
SPECIAL APPD.		

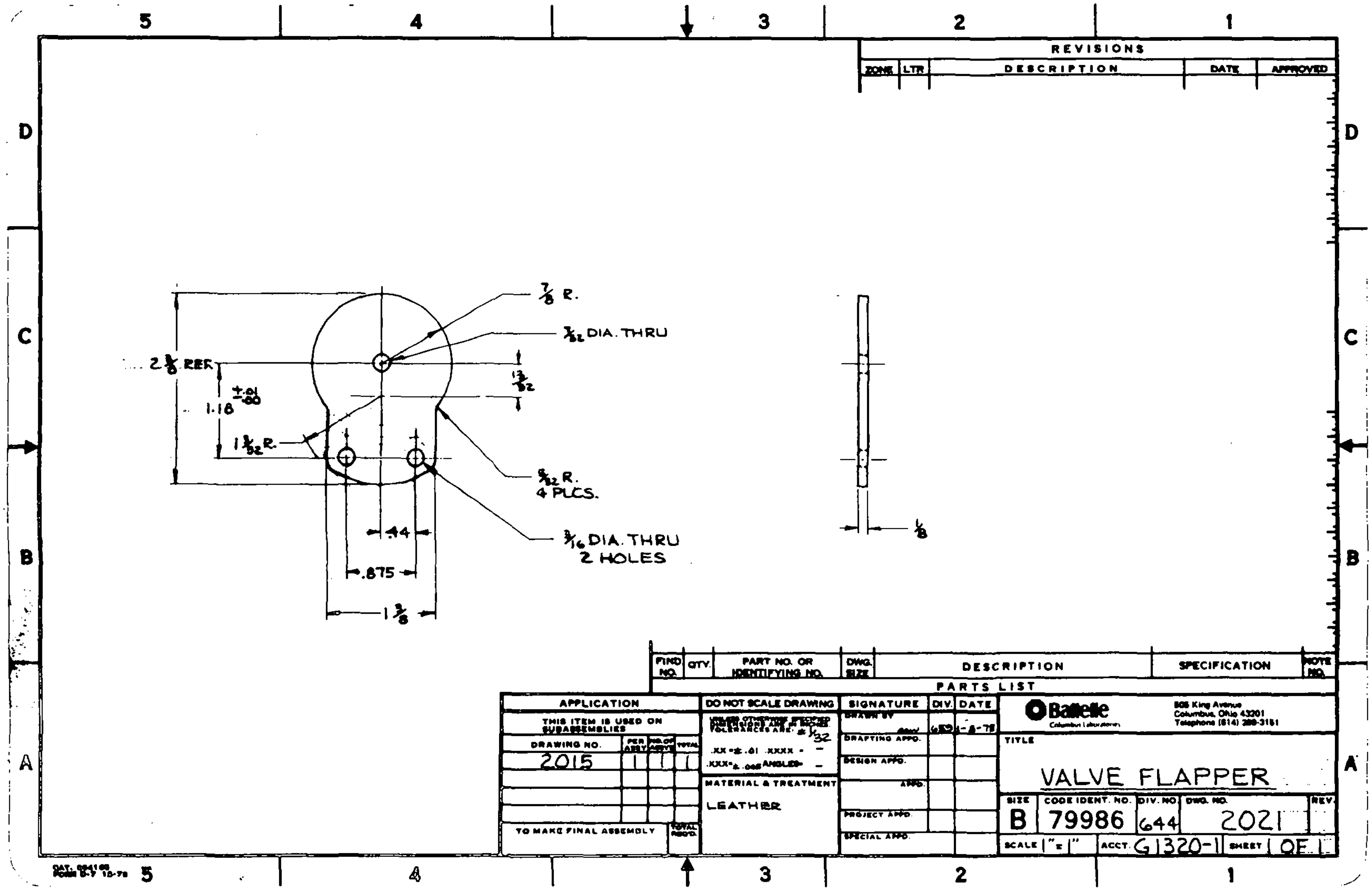
BATTELLE MEMORIAL INSTITUTE
COLUMBUS LABORATORIES
505 KING AVE., COLUMBUS, OHIO 43201

TITLE: LEATHER CUP

SIZE	CODE IDENT. NO.	DIV. NO.	DWG. NO.	REV.
A	79986	644	2019	

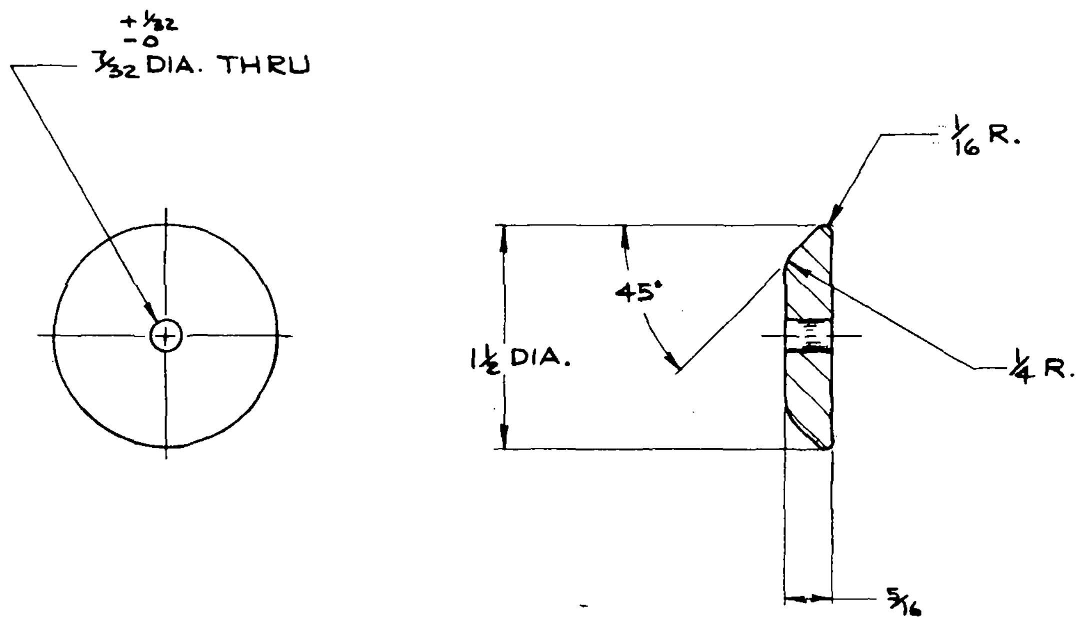
SCALE 1" = 1" ACCT. G1320-1 SHEET 1 OF 1

CAT. 294163 FORM D-5 8-70



7/8 R.
7/32 DIA. THRU
2 3/8 REF.
13/32
1.18 +.01 -.00
1 3/32 R.
5/32 R.
4 PLCS.
3/16 DIA. THRU
2 HOLES
.44
.875
1 3/8
1/8
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
FIND NO.
QTY.
PART NO. OR IDENTIFYING NO.
DWG. SIZE
DESCRIPTION
SPECIFICATION
NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
DRAWING NO.
PER ASSY
NO. OF ASSYS
TOTAL
2015
1
1
1
TO MAKE FINAL ASSEMBLY
TOTAL REQ'D.
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE: ± 1/32
.XX = ± .01
.XXXX = –
.XXX = ± .005
ANGLES = –
MATERIAL & TREATMENT
LEATHER
SIGNATURE
DIV.
DATE
DRAWN BY
644
1-8-79
DRAFTING APPD.
DESIGN APPD.
APPD.
PROJECT APPD.
SPECIAL APPD.
Battelle
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201
Telephone (614) 299-3151
TITLE
VALVE FLAPPER
SIZE
B
CODE IDENT. NO.
79986
DIV. NO.
644
DWG. NO.
2021
REV.
SCALE
1" = 1"
ACCT.
G1320-1
SHEET
1 OF 1

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



APPLICATION

THIS ITEM IS USED ON SUBASSEMBLIES

DRAWING NO.	PER ASSY	NO. OF ASSY'S	TOTAL
2015	1	1	1

TO MAKE FINAL ASSEMBLY — TOTAL REQ'D.

DO NOT SCALE DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE: 1/32
.XX = – .XXXX = –
.XXX = – ANGLES = ± ½°

MATERIAL & TREATMENT

CAST IRON

SIGNATURE	DIV.	DATE
DRAWN BY	659	1-8-75
DRAFTING APPD.		
DESIGN APPD.		
APPD.		
PROJECT APPD.		
SPECIAL APPD.		

BATTELLE MEMORIAL INSTITUTE
COLUMBUS LABORATORIES
505 KING AVE., COLUMBUS, OHIO 43201

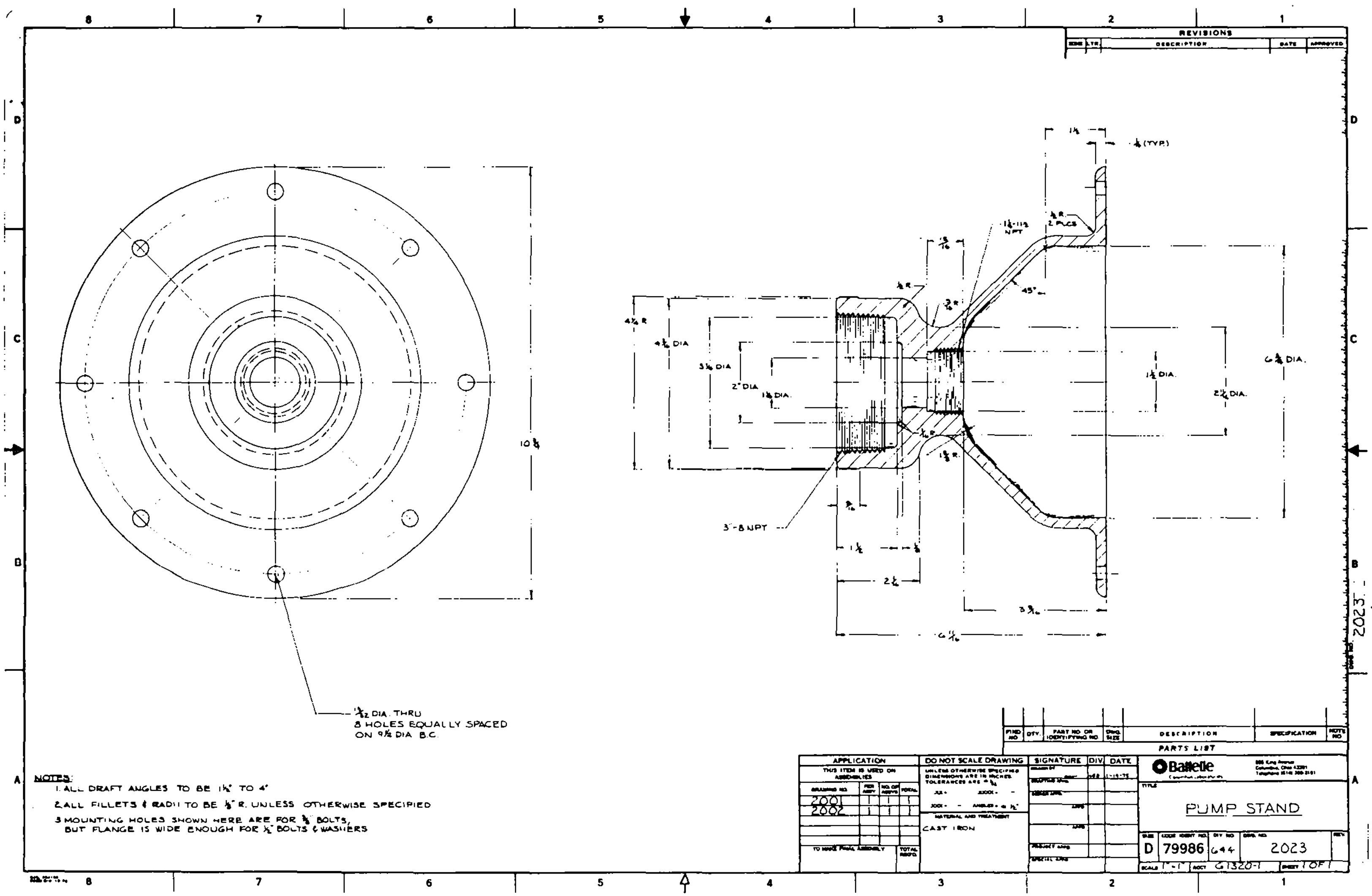
TITLE

CHECK VALVE WEIGHT

SIZE	CODE IDENT. NO.	DIV. NO.	DWG. NO.	REV.
A	79986	644	2022	

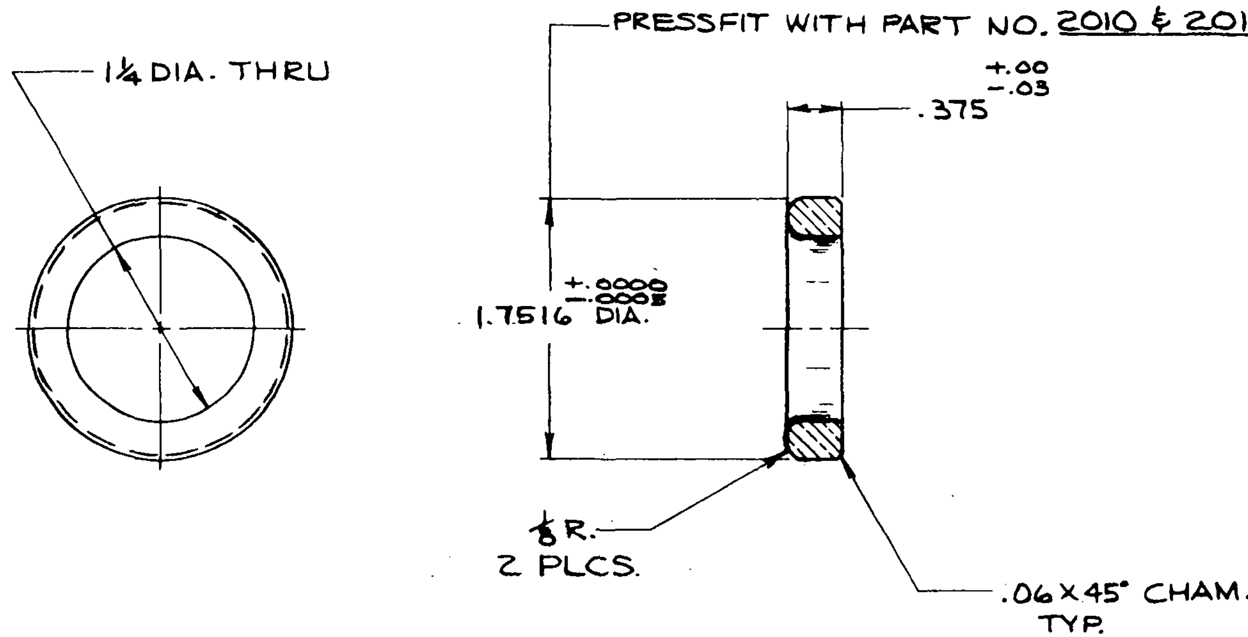
SCALE 1" = 1" ACCT G1320-1 SHEET 1 OF 1

CAT. 204161 FORM D-5 5-70



13/32 DIA. THRU
8 HOLES EQUALLY SPACED
ON 9½ DIA B.C.
10½
3"-8 NPT
1¼-11½ NPT
45°
6⅜ DIA.
2½ DIA.
1½ DIA.
NOTES:
1. ALL DRAFT ANGLES TO BE 1½° TO 4°
2. ALL FILLETS & RADII TO BE 1/8" R. UNLESS OTHERWISE SPECIFIED
3. MOUNTING HOLES SHOWN HERE ARE FOR 3/8" BOLTS,
BUT FLANGE IS WIDE ENOUGH FOR 1/2" BOLTS & WASHERS
REVISIONS
FIND NO | QTY. | PART NO OR IDENTIFYING NO | DWG. SIZE | DESCRIPTION | SPECIFICATION | NOTE NO
PARTS LIST
APPLICATION
THIS ITEM IS USED ON ASSEMBLIES
DRAWING NO. | PER ASSY | NO. OF ASSYS | TOTAL
2001 | 1 | 1 | 1
2002 | 1 | 1 | 1
TO MAKE FINAL ASSEMBLY | TOTAL REQ'D
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE ± 1/32
MATERIAL AND TREATMENT
CAST IRON
SIGNATURE | DIV. | DATE
Battelle
TITLE
PUMP STAND
SIZE D | CODE IDENT NO. 79986 | DIV NO 644 | DWG. NO. 2023
SCALE 1" = 1" | ACCT G1320-1 | SHEET 1 OF 1
2023

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



APPLICATION			
THIS ITEM IS USED ON SUBASSEMBLIES			
DRAWING NO.	PER ASSY	NO. OF ASSYS	TOTAL
2010	1	1	1
2016	1	1	1
TO MAKE FINAL ASSEMBLY			TOTAL REQ'D.

DO NOT SCALE DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE: ± 1/32

.XX = ±.01 .XXXX = –

.XXX = – ANGLES = ± ½°

MATERIAL & TREATMENT

BRASS

SIGNATURE	DIV.	DATE
DRAWN BY [signature]	659	1-7-75
DRAFTING APPD.		
DESIGN APPD.		
APPD.		
PROJECT APPD.		
SPECIAL APPD.		

BATTELLE MEMORIAL INSTITUTE
COLUMBUS LABORATORIES
505 KING AVE., COLUMBUS, OHIO 43201

TITLE

BRASS VALVE SEAT

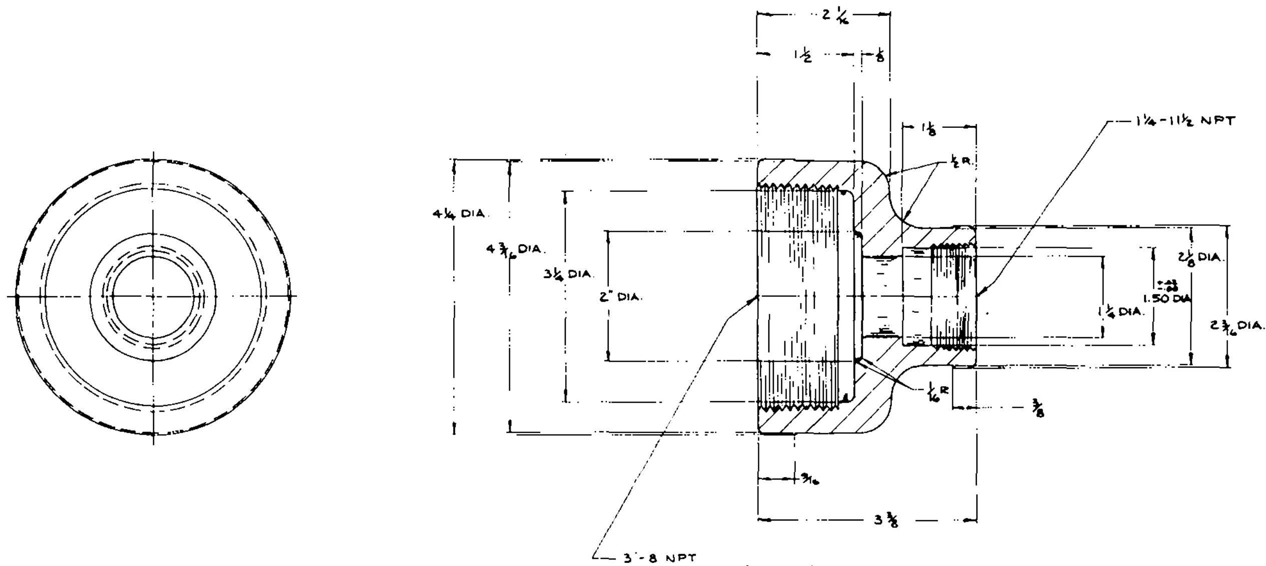
SIZE	CODE IDENT. NO.	DIV. NO.	DWG. NO.	REV.
A	79986	644	2024	

SCALE 1" = 1" ACCT. G 1320-1 SHEET 1 OF 1

CAT. 294163 FORM D-8 5-70

REVISIONS

ZONE	LTR.	DESCRIPTION	DATE	APPROVED



2025

NOTES:

1. ALL DRAFT ANGLES TO BE 1 1/2° TO 4°
2. ALL FILLETS & RADII TO BE 1/8" R. UNLESS OTHERWISE SPECIFIED

FIND NO.	QTY.	PART NO. OR IDENTIFYING NO.	DWG. SIZE	DESCRIPTION	SPECIFICATION	NOTE NO.

PARTS LIST

APPLICATION

THIS ITEM IS USED ON SUBASSEMBLIES

DRAWING NO.	PER ASSY	NO. OF ASSYS	TOTAL
2016	1	1	1
2002	1	1	1
2001"B"	1	1	1

TO MAKE FINAL ASSEMBLY — TOTAL REQ'D.

DO NOT SCALE DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE: ± 1/32

.XX ± — .XXXX ± —

.XXX ± — ANGLES ± 1/2°

MATERIAL AND TREATMENT

CAST IRON

SIGNATURE	DIV.	DATE
DRAWN BY	469	1-10-75
DRAFTING APPD.		
DESIGN APPD.		
APPD.		
APPD.		
PROJECT APPD.		
SPECIAL APPD.		

Battelle Columbus Laboratories

505 King Avenue, Columbus, Ohio 43201, Telephone (614) 299-3151

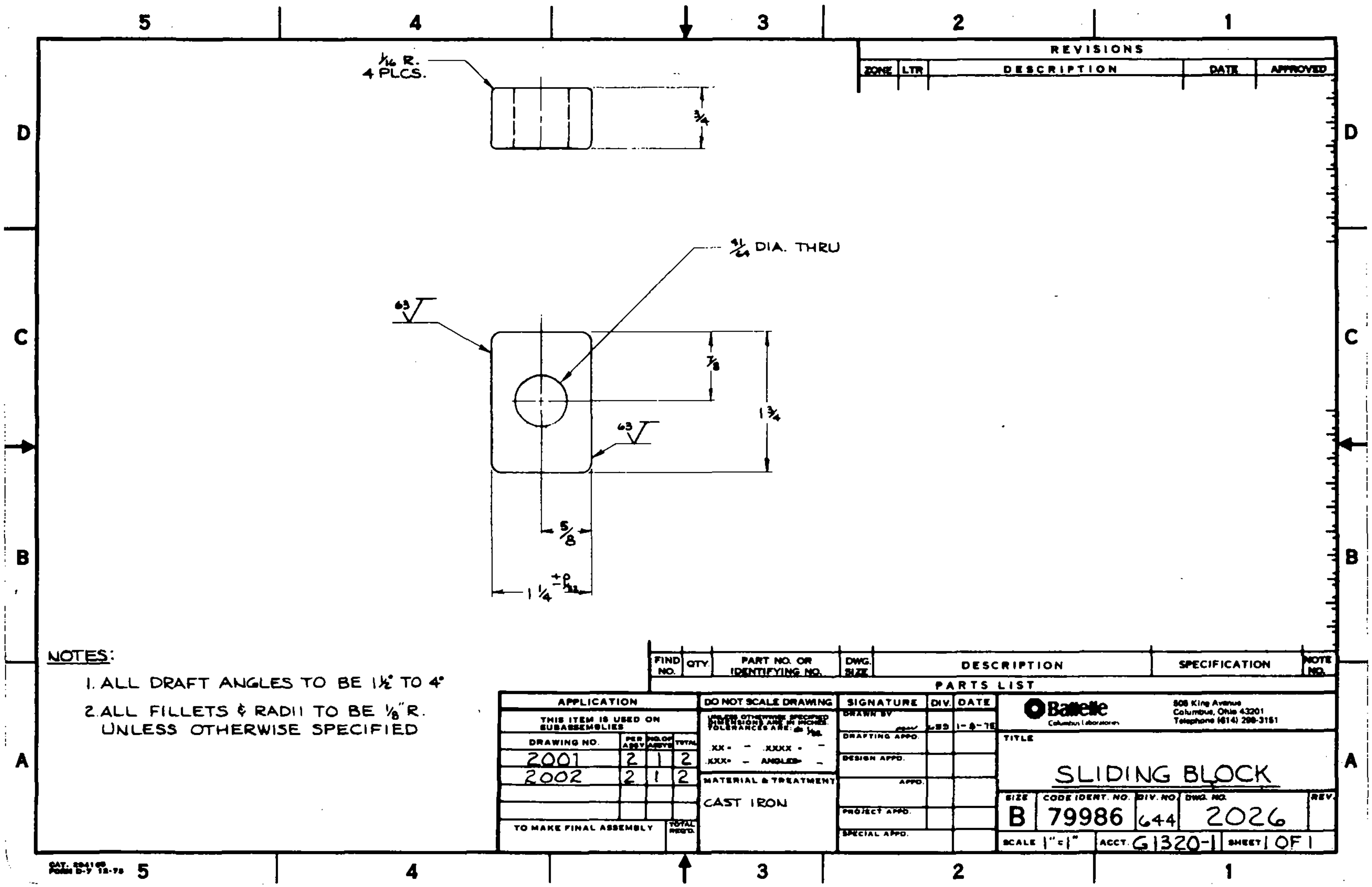
TITLE

CYLINDER END CAP

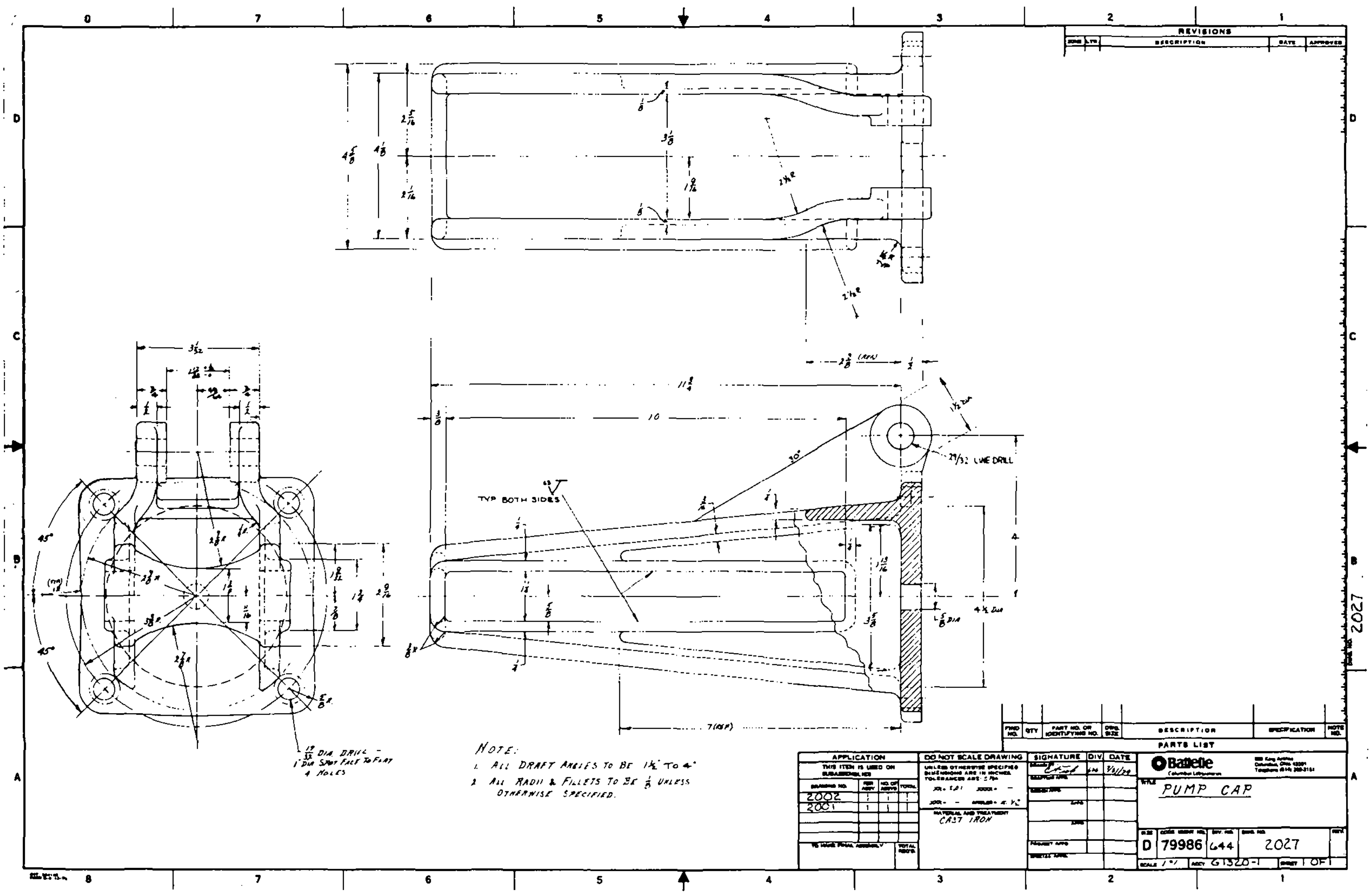
SIZE	CODE IDENT. NO.	DIV. NO.	DWG. NO.	REV.
C	79986	644	2025	

SCALE 1"=1" ACCT. G1320-1 SHEET 1 OF 1

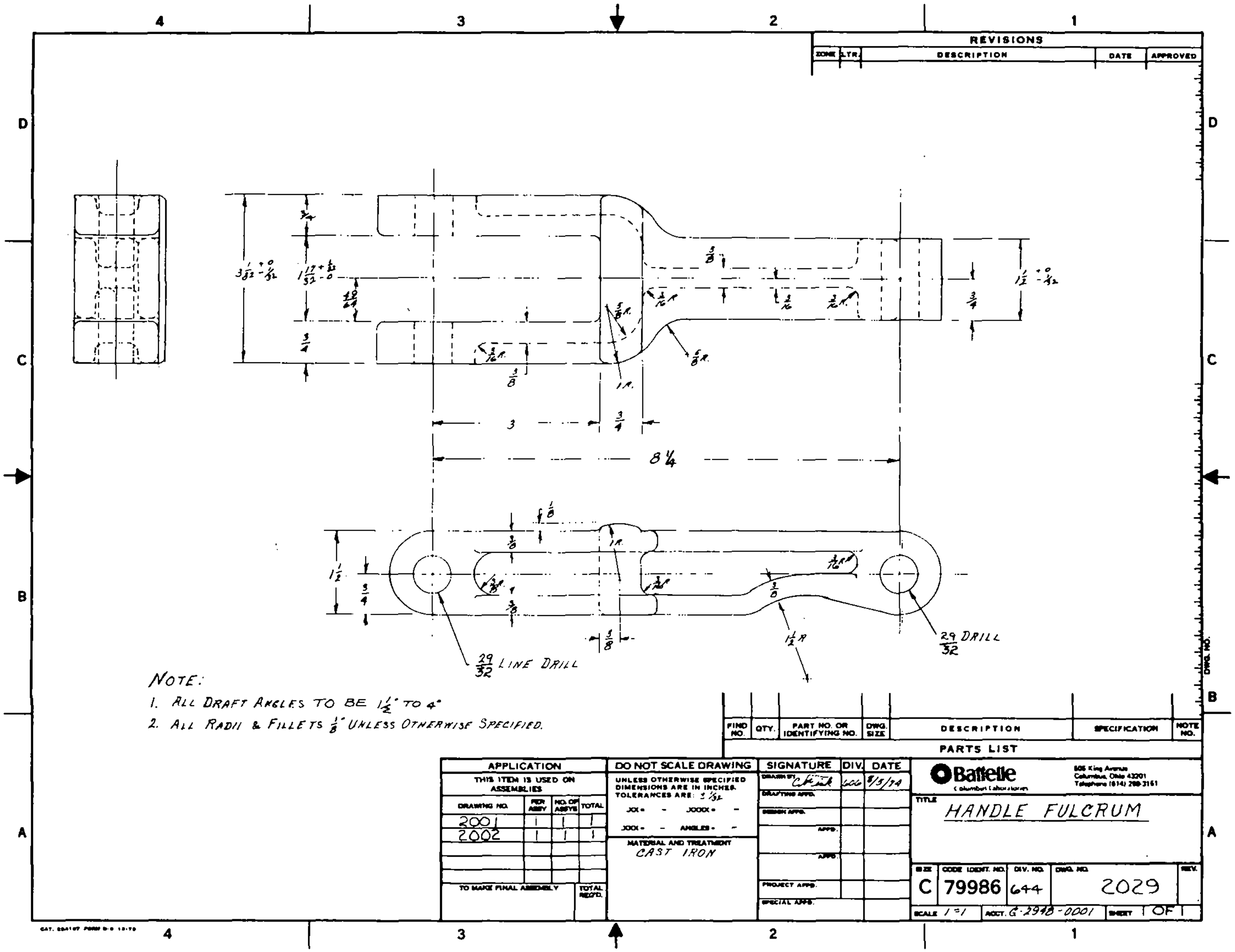
CAT. 904107 FORM 9-6-10-75



1/16 R.
4 PLCS.
3/4
41/64 DIA. THRU
63
7/8
1 3/4
5/8
1 1/4 ±.010
NOTES:
1. ALL DRAFT ANGLES TO BE 1½° TO 4°
2. ALL FILLETS & RADII TO BE 1/8" R. UNLESS OTHERWISE SPECIFIED
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
FIND NO.
QTY
PART NO. OR IDENTIFYING NO.
DWG. SIZE
DESCRIPTION
SPECIFICATION
NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
DRAWING NO.
2001
2002
TO MAKE FINAL ASSEMBLY
DO NOT SCALE DRAWING
MATERIAL & TREATMENT
CAST IRON
SIGNATURE
DIV.
DATE
DRAWN BY
DRAFTING APPD.
DESIGN APPD.
PROJECT APPD.
SPECIAL APPD.
Battelle
505 King Avenue
Columbus, Ohio 43201
TITLE
SLIDING BLOCK
SIZE
B
CODE IDENT. NO.
79986
DIV. NO.
644
DWG. NO.
2026
REV.
SCALE 1"=1"
ACCT. G1320-1
SHEET 1 OF 1



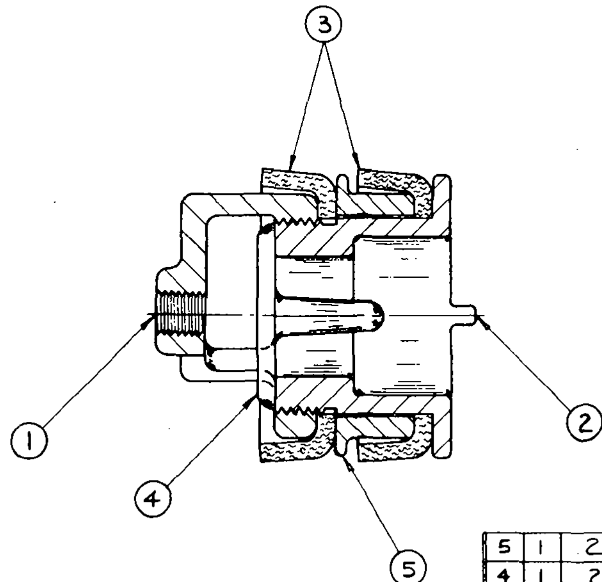
TYP BOTH SIDES
29/32 LINE DRILL
19/32 DIA DRILL - 1" DIA SPOT FACE TO FLAT 4 HOLES
NOTE:
1. ALL DRAFT ANGLES TO BE 1½° TO 4°
2. ALL RADII & FILLETS TO BE 1/8 UNLESS OTHERWISE SPECIFIED.
REVISIONS
PARTS LIST
APPLICATION
2002
2001
DO NOT SCALE DRAWING
MATERIAL AND TREATMENT
CAST IRON
SIGNATURE
DIV
DATE
Battelle
Columbus Laboratories
PUMP CAP
D
79986
644
2027
SCALE 1"/1
G1320-1
SHEET 1 OF 1



REVISIONS
ZONE LTR. DESCRIPTION DATE APPROVED
8 1/4
29/32 LINE DRILL
29/32 DRILL
NOTE:
1. ALL DRAFT ANGLES TO BE 1 1/2° TO 4°
2. ALL RADII & FILLETS 1/8" UNLESS OTHERWISE SPECIFIED.
FIND NO. QTY. PART NO. OR IDENTIFYING NO. DWG. SIZE DESCRIPTION SPECIFICATION NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON ASSEMBLIES
DRAWING NO. PER ASSY NO. OF ASSYS TOTAL
2001 1 1 1
2002 1 1 1
TO MAKE FINAL ASSEMBLY TOTAL REQ'D.
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE: ± 1/32
MATERIAL AND TREATMENT
CAST IRON
SIGNATURE DIV. DATE
DRAWN BY 606 8/5/74
DRAFTING APPD.
DESIGN APPD.
APPD.
APPD.
PROJECT APPD.
SPECIAL APPD.
Battelle
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201
Telephone (614) 299-3151
TITLE
HANDLE FULCRUM
SIZE C
CODE IDENT. NO. 79986
DIV. NO. 644
DWG. NO. 2029
REV.
SCALE 1=1
ACCT. G-2948-0001
SHEET 1 OF 1

ZONE	LTR	DESCRIPTION	DATE	APPROVED

REVISIONS



5	1	2032	A	PLUNGER SPACER		
4	1	2018	A	PLUNGER POPPET		
3	2	2019	A	THREE INCH CUP		
2	1	2031	B	PLUNGER FOLLOWER		
1	1	2017	B	PLUNGER CAGE		
FIND NO.	QTY.	PART NO. OR IDENTIFYING NO.	DWG. SIZE	DESCRIPTION	SPECIFICATION	NOTE NO.

PARTS LIST

NOTE:

1. DOUBLE CUP PLUNGER TO BE USED WHEN WATER LEVEL IS MORE THAN 50 FT. BELOW SURFACE

APPLICATION

THIS ITEM IS USED ON ASSEMBLIES

DRAWING NO.	PER ASSY	NO. OF ASSYS	TOTAL
2001	1	1	1
2002	1	1	1

TO MAKE FINAL ASSEMBLY — TOTAL REQ'D.

DO NOT SCALE DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:

.XX ± .XXXX ±
.XXX± ANGLES±

MATERIAL & TREATMENT

SIGNATURE	DIV.	DATE
DRAWN BY	659	1-10-76
DRAFTING APPD.		
DESIGN APPD.		
APPD		
PROJECT APPD		
SPECIAL APPD.		

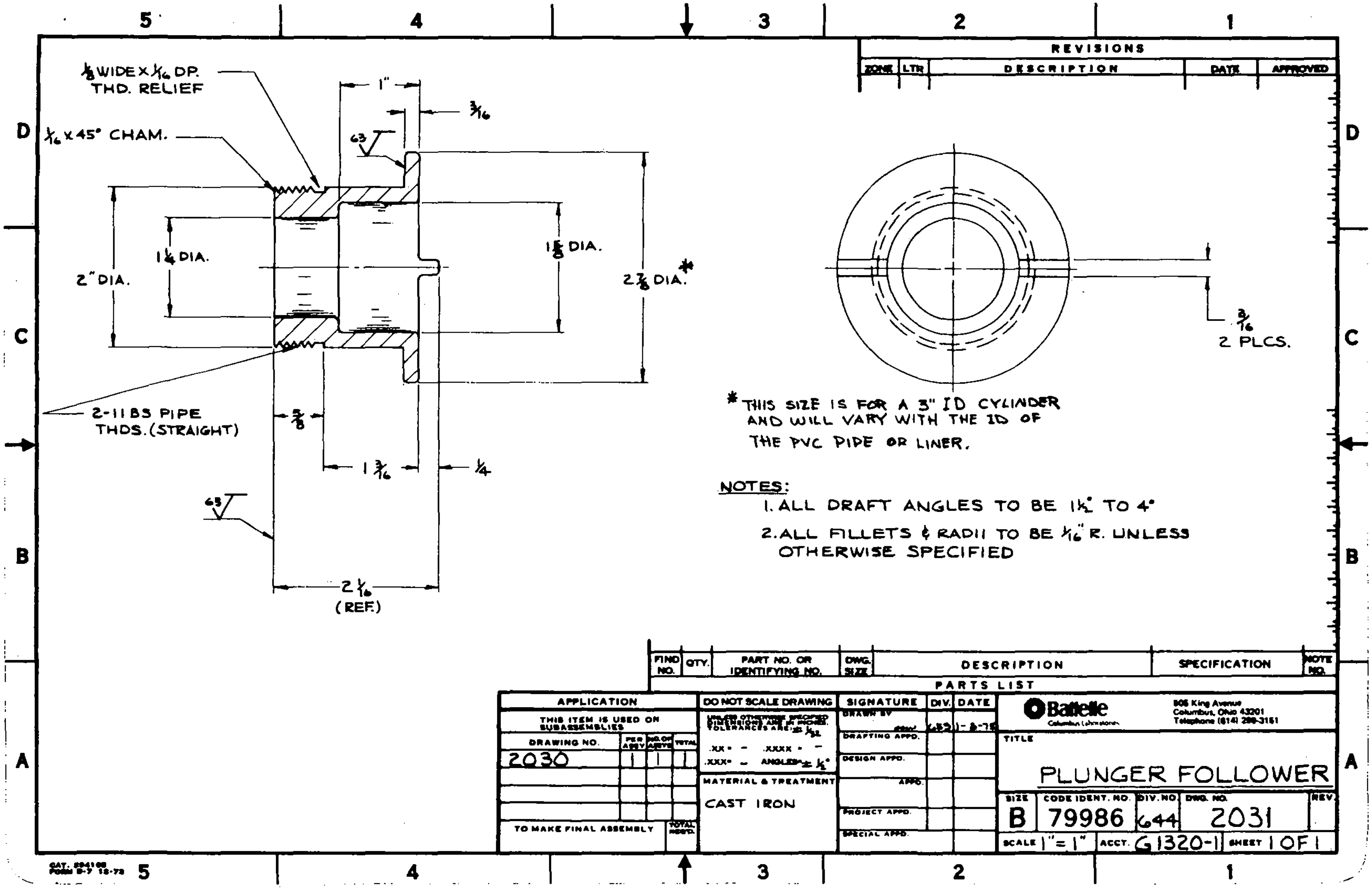
Battelle Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201
Telephone (614) 299-3151

TITLE
PLUNGER ASSEMBLY, DOUBLE CUP

SIZE	CODE IDENT. NO.	DIV. NO.	DWG. NO.	REV.
B	79986	644	2030	

SCALE 1" = 1" ACCT. SHEET 1 OF 1

CAT. 294106
FORM D-7 10-75



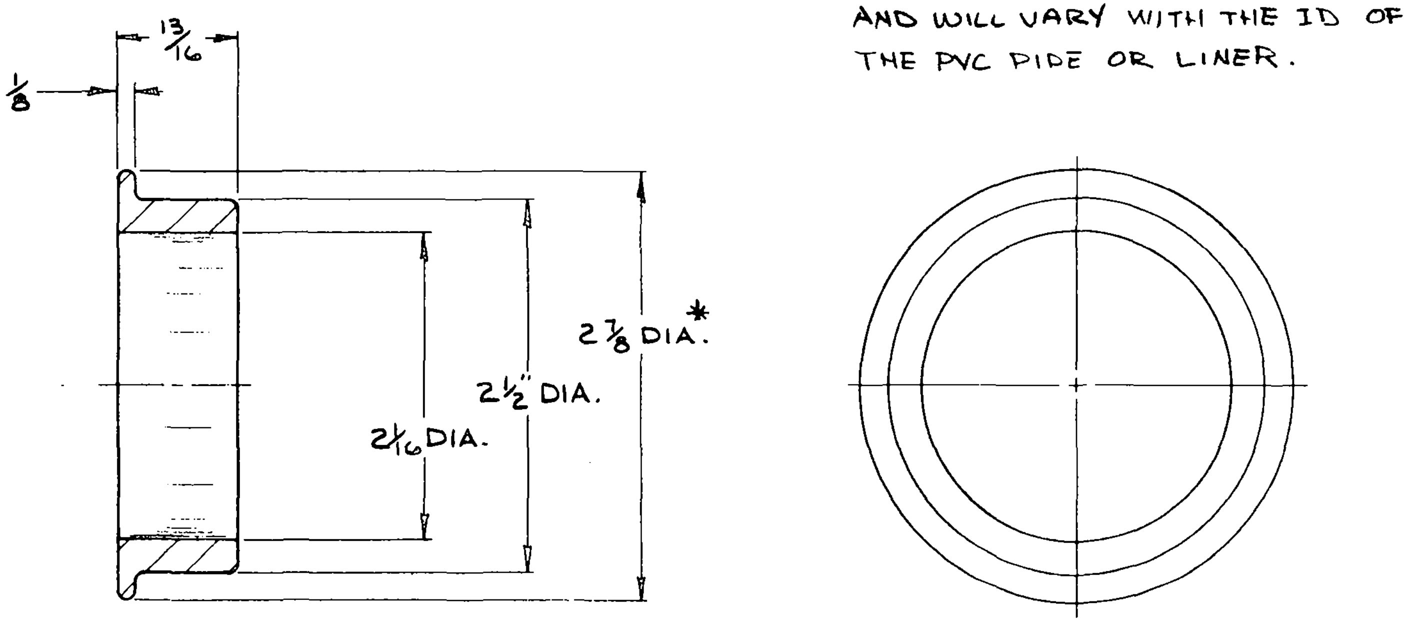
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
1/8 WIDE X 1/16 DP. THD. RELIEF
1/16 X 45° CHAM.
1"
3/16
63
2" DIA.
1 1/4 DIA.
1 5/8 DIA.
2 7/8 DIA.*
2-11 BS PIPE THDS. (STRAIGHT)
5/8
1 3/16
1/4
63
2 1/16 (REF.)
3/16 2 PLCS.
* THIS SIZE IS FOR A 3" ID CYLINDER AND WILL VARY WITH THE ID OF THE PVC PIPE OR LINER.
NOTES:
1. ALL DRAFT ANGLES TO BE 1 1/2° TO 4°
2. ALL FILLETS & RADII TO BE 1/16" R. UNLESS OTHERWISE SPECIFIED
FIND NO.
QTY.
PART NO. OR IDENTIFYING NO.
DWG. SIZE
DESCRIPTION
SPECIFICATION
NOTE NO.
PARTS LIST
APPLICATION
THIS ITEM IS USED ON SUBASSEMBLIES
DRAWING NO.
2030
TO MAKE FINAL ASSEMBLY
DO NOT SCALE DRAWING
MATERIAL & TREATMENT
CAST IRON
SIGNATURE
DIV.
DATE
DRAWN BY
DRAFTING APPD.
DESIGN APPD.
PROJECT APPD.
SPECIAL APPD.
Battelle
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201
TITLE
PLUNGER FOLLOWER
SIZE
B
CODE IDENT. NO.
79986
DIV. NO.
644
DWG. NO.
2031
SCALE 1" = 1"
ACCT. G1320-1
SHEET 1 OF 1

NOTES:

1. ALL DRAFT ANGLES TO BE 1½° TO 4°
2. ALL FILLETS & RADII TO BE ⅛" R. UNLESS OTHERWISE SPECIFIED

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

* THIS SIZE IS FOR A 3" ID CYLINDER AND WILL VARY WITH THE ID OF THE PVC PIPE OR LINER.



APPLICATION			
THIS ITEM IS USED ON SUBASSEMBLIES			
DRAWING NO.	PER ASSY	NO. OF ASSY'S	TOTAL
2030	1	1	1
TO MAKE FINAL ASSEMBLY			TOTAL REQ'D.

DO NOT SCALE DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE: ± 1/32

.XX = – .XXXX = –
.XXX = – ANGLES = –

MATERIAL & TREATMENT: CAST IRON

SIGNATURE	DIV.	DATE
DRAWN BY [signature]	659	1-7-78
DRAFTING APPD.		
DESIGN APPD.		
APPD.		
PROJECT APPD.		
SPECIAL APPD.		

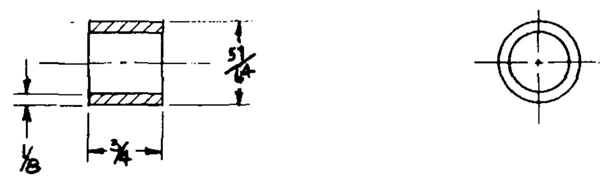
BATTELLE MEMORIAL INSTITUTE
COLUMBUS LABORATORIES
505 KING AVE., COLUMBUS, OHIO 43201

TITLE: PLUNGER SPACER

SIZE	CODE IDENT. NO.	DIV. NO.	DWG. NO.	REV.
A	79986	644	2032	

SCALE 1"=1" ACCT G1320-1 SHEET 1 OF 1

CAT. 294163 FORM D-5 5-70



HARDEN TO R_c 60-65

APPLICATION —

DRAWING NO.	PER ASSY.	NO. OF ASSYS.	TOTAL
2008	2	1	2
2026	1	2	2
2027	2	1	2
2029	2	1	2

OFFICE OF INTERNATIONAL PROGRAMS
ENGINEERING EXPERIMENT STATION
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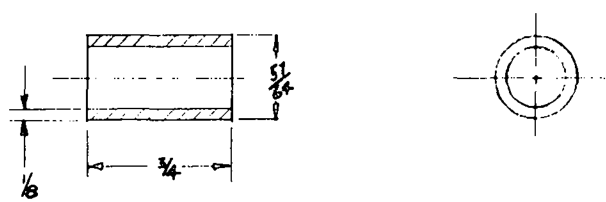
ATLANTA, GEORGIA 30332

TITLE: SHORT BUSHING — STEEL

DRAWN BY	APPROVED BY	REVISION NO. 1	REVISION NO. 2
G.K. WEBB	H.C. [illegible]	BY	BY
DATE 1/17/79	DATE 1/17/79	DATE	DATE

SCALE	PROJECT NO.	SHEET
1" = 1"		2033



HARDEN TO R_c 60-65

APPLICATION-

DRAWING NO.	PER ASSY.	NO. OF ASSYS.	TOTAL
2004	1	1	1
2008	1	1	1
2029	1	1	1

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ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

TITLE LONG BUSHING - STEEL

DRAWN BY G.K.WEBB DATE 1/17/79	APPROVED BY H. C. Moh DATE 1/17/79	REVISION NO. 1 BY DATE	REVISION NO. 2 BY DATE
SCALE 1" = 1"	PROJECT NO.		SHEET 2034