United States
Department of
Agriculture

Forest Service
Equipment
Development
Center

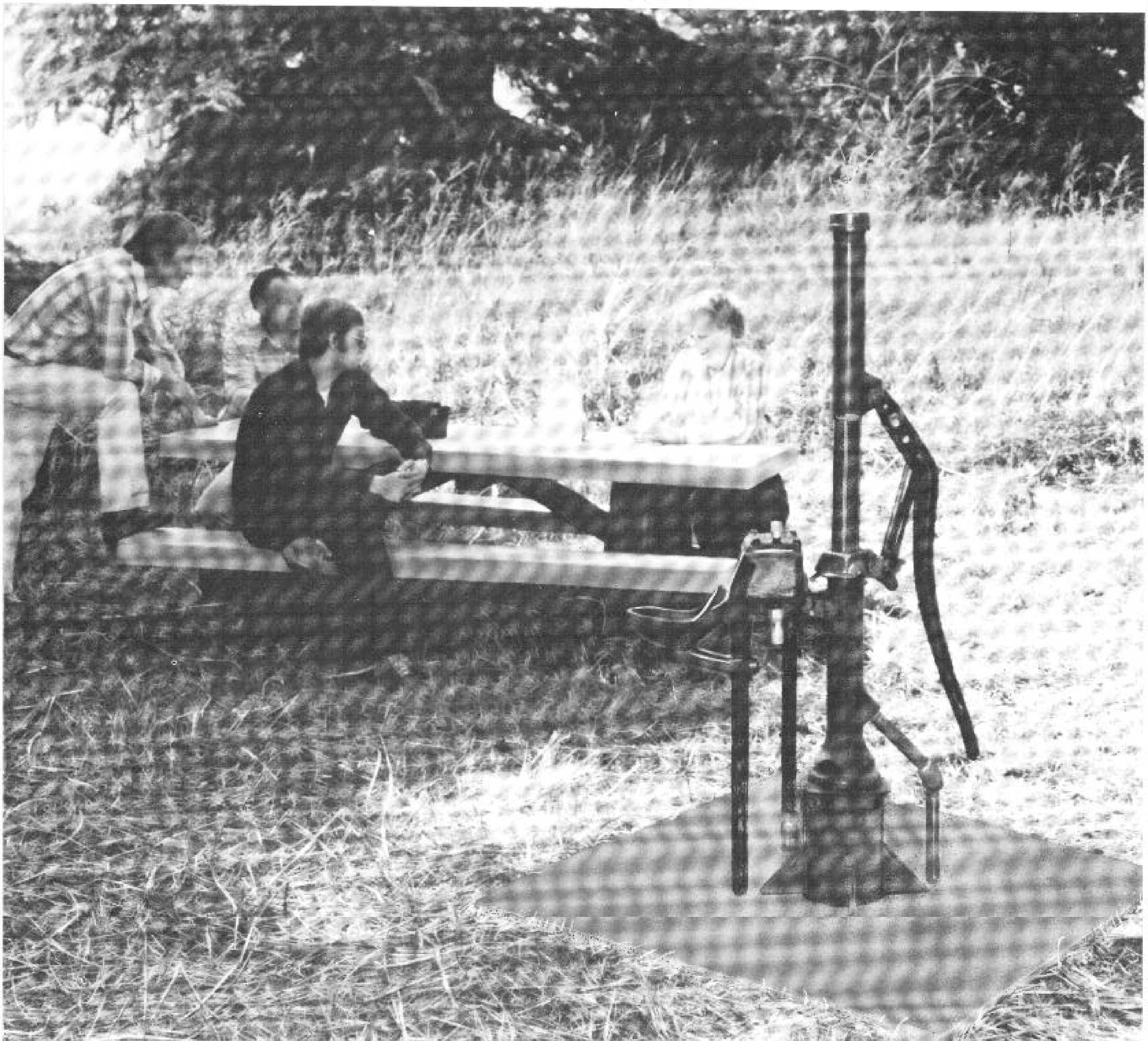
Project Record
8171 1201

2300—Recreation

San Dimas, CA

May 1981

Hand Pumps—Evaluation, Disinfection of Water, and Maintenance Procedures



Hand Pumps—Evaluation, Disinfection of Water, and Maintenance Procedures

by
Michael E. Smith—*Mechanical Engineer*

ED&T Project No. 7013
Hand Pump Design Review
and Treatment of Hand-Pumped
Water

Forest Service
Equipment
Development
Center

San Dimas, California

Project Record
8171 1201

May 1981

CONTENTS

ILLUSTRATIONS

TABLES

INTRODUCTION

The Problem

The Forest Service obtains drinking water from a variety of sources, ranging from wells and springs to surface water. Many of these sources are hand pumped and require disinfection to meet applicable health standards. The effectiveness of equipment that is available to pump and treat drinking water sources, and the validity of their design criteria, were not known. Also, hand pumps have been suspected of being unsanitary and/or incapable of protecting the sanitary quality of potable water sources.

Hand pump procurement criteria were needed to purchase affordable, durable, and trouble-free equipment that:

- Meets sanitary requirements and operates satisfactorily under field conditions
- Requires only occasional maintenance, which can be provided by personnel from a local agency unit
- Is easily operated and readily accepted by intended users.

Hand Pumps

A typical hand pump (fig. 1) consists of the pump stand assembly (left-hand side of sectional view) plus the below-ground plunger assembly (right-hand side), which consists of a pump cylinder and drop pipe. The pump rod runs the length of the entire hand pump. The pump stand assembly transmits motive power to the pump rod, discharges pumped water through a spout, and provides sanitary protection of the water source. The pump cylinder is the actual pumping element, the drop pipe carries water from the plunger assembly to the spout, while the pump rod transmits forces between the pump stand handle and the plunger assembly. [1]

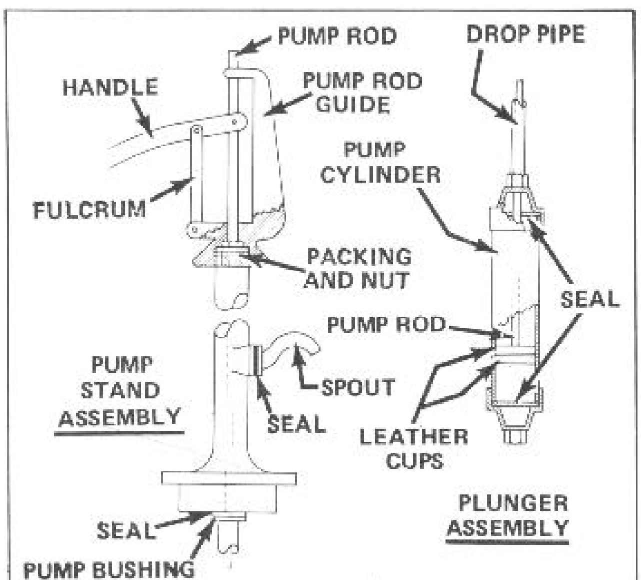


Figure 1. Typical hand pump (sectional view).

HAND PUMP MARKET SEARCH AND USE SURVEY

To develop the procurement criteria, the San Dimas Equipment Development Center (SDEDC) conducted (a) a market search for all hand pumps being offered and (b) a survey of which ones were being used by Forest Service units. The search resulted in a list of seven hand pump manufacturers (table 1); the survey revealed that three brands prevail in Forest Service use: Monitors (Baker Mfg. Co.), Red Jackets, and Dempsters.

Table 1. Manufacturers of hand pumps in the United States

Baker Manufacturing Co. Evansville, WI 53336 608/882-5100	Columbia Pump Co. Columbia, OH 44408 216/482-3383
Central Machine Co. Quapaw, OK 74363 918/675-5110	Dempster Industries Beatrice, NE 68310 402/223-4026
Clayton Mark Evanston, IL 60204 312/438-2303	Heller-Allen Co. Napoleon, OH 43545 419/592-1856
Red Jacket Fluid System Products Davenport, IA 52805 *(No longer produces hand pumps)*	

[1] A United Nations publication contains everything you ever wanted to know about hand pumps, plus a whole lot more: "A state of the art report. Topics discussed include rationale for use of hand pumps; history of hand pumps; description of various types of hand pumps; principles of operation; nomenclature; hydraulic, structural, and energy analysis; and the design of each component of reciprocating hand pumps . . . Also administration of hand pump programs with emphasis on installation and maintenance practices; recent hand pump research . . ." McJunkin, F.E., 1977, Hand pumps for use in drinking water supplies in developing countries. Tech. Pap. 10, Intl. Ref. Cntr. for Community Water Supply, P. O. Box 140, 2260 AC Leidschendam, The Netherlands.

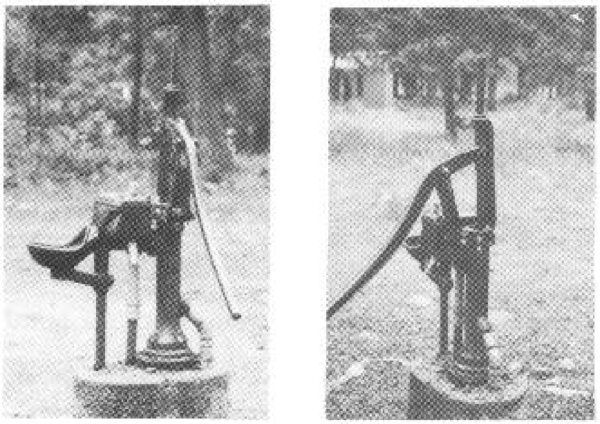


Figure 2. Monitor DF-HT hand pump in field use.

SDEDC personnel contacted the seven manufacturers (table 1) about their hand pump design features, optional attachments (e.g., drinking faucets), and ability to hookup to disinfection equipment. Since the Baker Mfg. Co. line of Monitor hand pumps had proved to be the most widely used on National Forests and also appeared to best suit Forest Service requirements, two Monitor DF-HT hand pumps (fig. 2) were purchased for testing at SDEDC to evaluate their durability.

HAND PUMP DURABILITY

Test Program

The two DF-HT pumps were placed in test stands at SDEDC (figs. 3 and 4). Instruments (figs. 4 and 5) monitored:

- Water pressure and vacuum at specific points on the pumps
- Input energy (strokes/min)
- Barometric pressure
- Air temperature
- Inlet and outlet water temperatures
- Water specific gravity
- Data from weigh tank—to calculate pump output flow in gallons per minute (gpm).

The survey of Forest Service hand pump use had indicated that the agency's wells range from 10- to 200-ft (3- to 61-m) deep. Thus, the test stands were setup so that one of the pumps simulated use in a 10-ft (3-m)

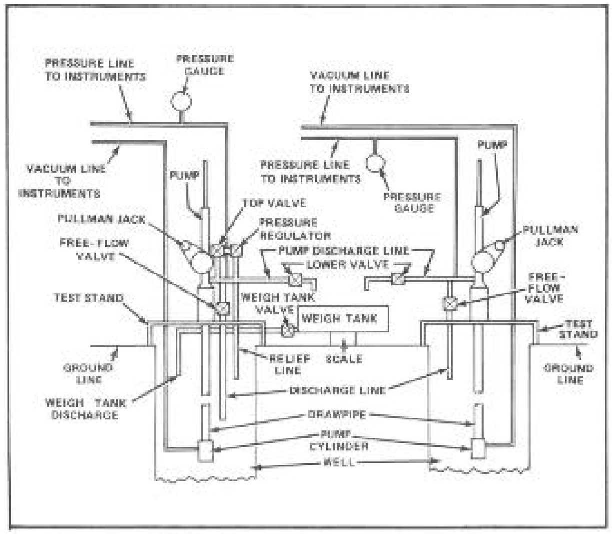


Figure 3. Hand pump test stands.

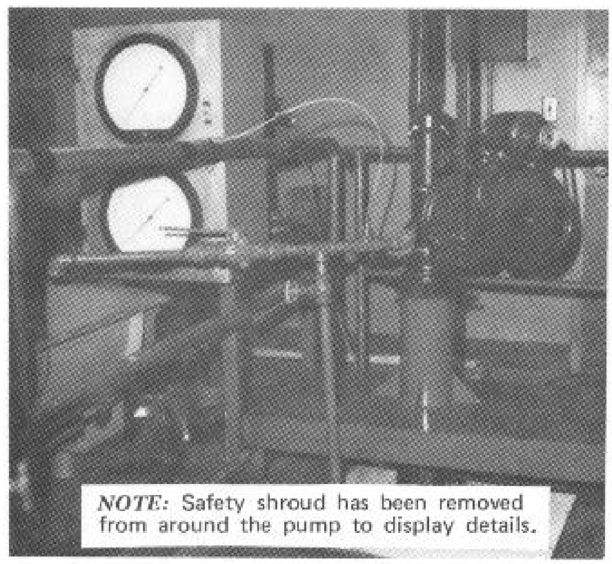


Figure 4. Hand pump in test stand.

deep well ("light-duty" application); the other in a 200-ft (61-m) deep well ("most adverse" application). These depths were simulated by restricting the output flow of water to cause a back pressure and create a head approximately equivalent to that in a 10-ft (3-m) and a 200-ft (61-m) deep well.

The test program was designed to determine the wear resistance of the mechanical parts of the pumps—including the pump cylinders and rods, the leather plunger cups, the packing and the packing nuts, and surfaces where friction occurs. Each pump was run for 1,000 hours at rates of 43, 58, 88, and 115 strokes per minute. This represents

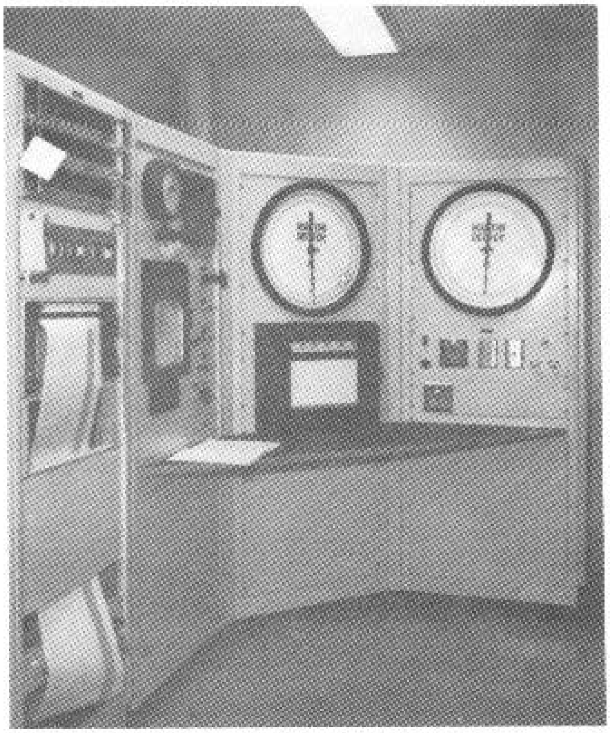


Figure 5. Test instrumentation.

approximately 3 to 5 years of field use for a hand pump. After every 125 hours the pumps were disassembled and parts were measured and checked for wear. Collected data were analyzed and later used to develop hand pump maintenance guidelines (see appendix I).

Test Results and Observations

Three parts from both Monitor DF-HT pumps had to be replaced regularly throughout the 1,000-hour test: The valve stem packing, the packing nut, and the upper piston guide. The packing—1/8-in (1/3-cm) diameter rope impregnated with graphite—serves as a seal around the pump rod. It had to be replaced approximately every 200 hours. Additionally, if the packing was not tightened down—using the brass packing nut—every 10 to 15 hours, water leakage occurred. Through trial and error, a torque of 82 in-lb (9.3 J) was found to be the force needed to prevent leaks. Any less force, the pump continued to leak; any greater, the packing separated and/or blewout (fig. 6).

Furthermore, in the course of the 1,000-hour test, the packing nuts and upper piston guides of the two pumps were replaced three times (i.e., their lifespan ≅ 300 hours). When the guide wore out, the pump rod would move out

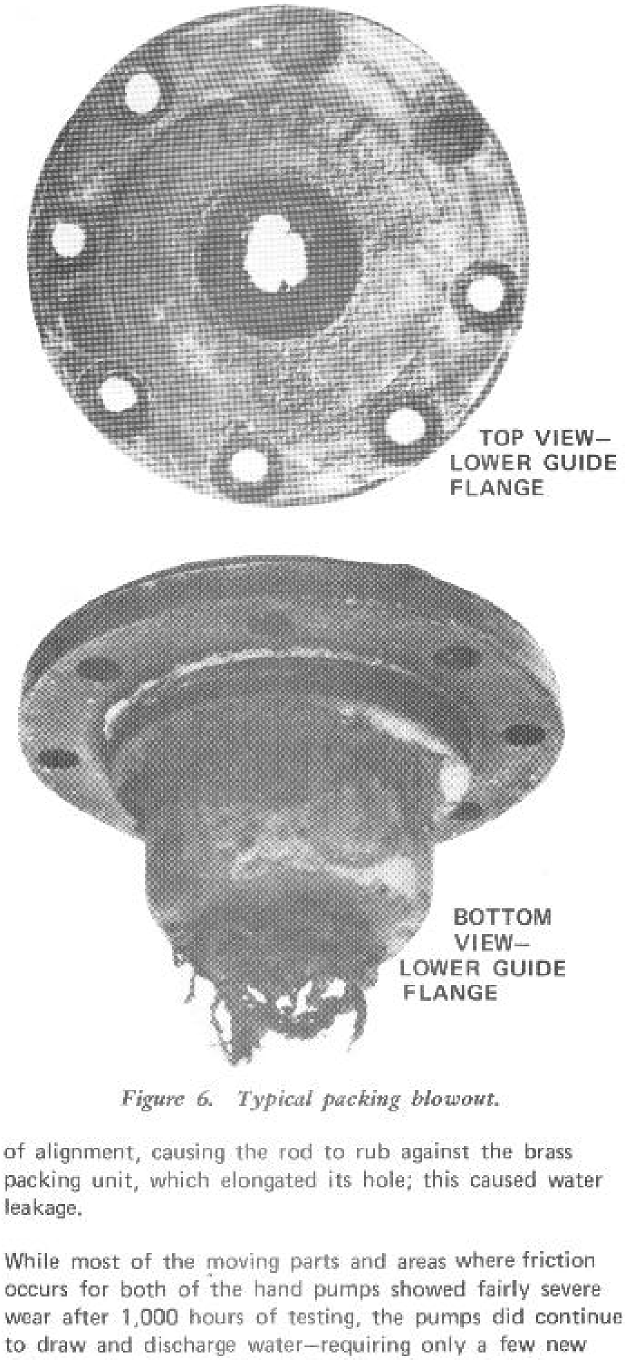


Figure 6. Typical packing blowout.

of alignment, causing the rod to rub against the brass packing unit, which elongated its hole; this caused water leakage.

While most of the moving parts and areas where friction occurs for both of the hand pumps showed fairly severe wear after 1,000 hours of testing, the pumps did continue to draw and discharge water—requiring only a few new parts as already detailed. For instance, the leather double-cup plunger (fig. 7) was worn and the brass pump cylinder (fig. 8) was grooved, yet the discharge rate from the pumps hardly dropped at all at any of the pump stroke rates used during the test program.

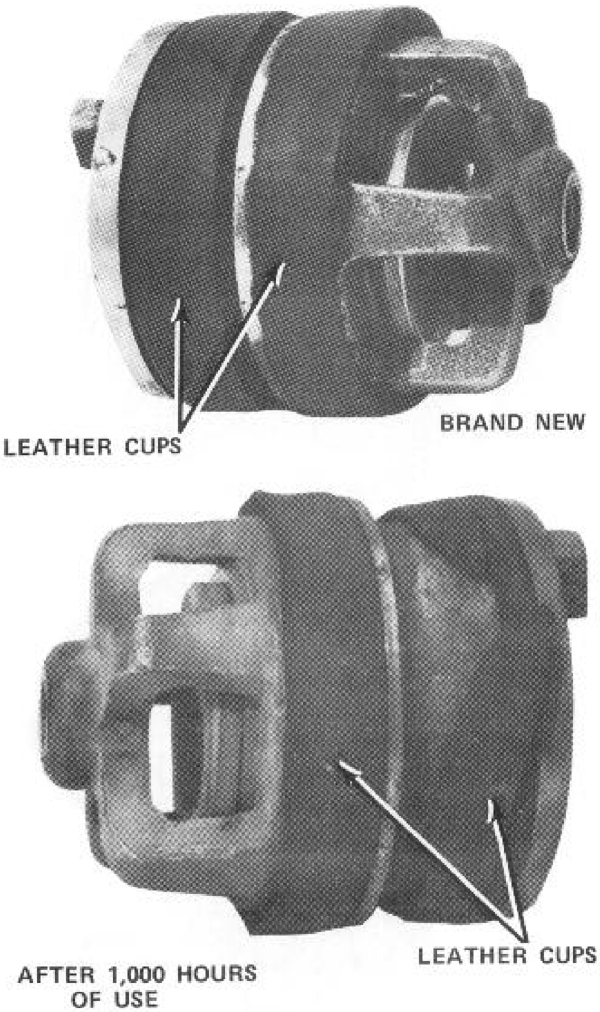


Figure 7. Double-cup plunger.

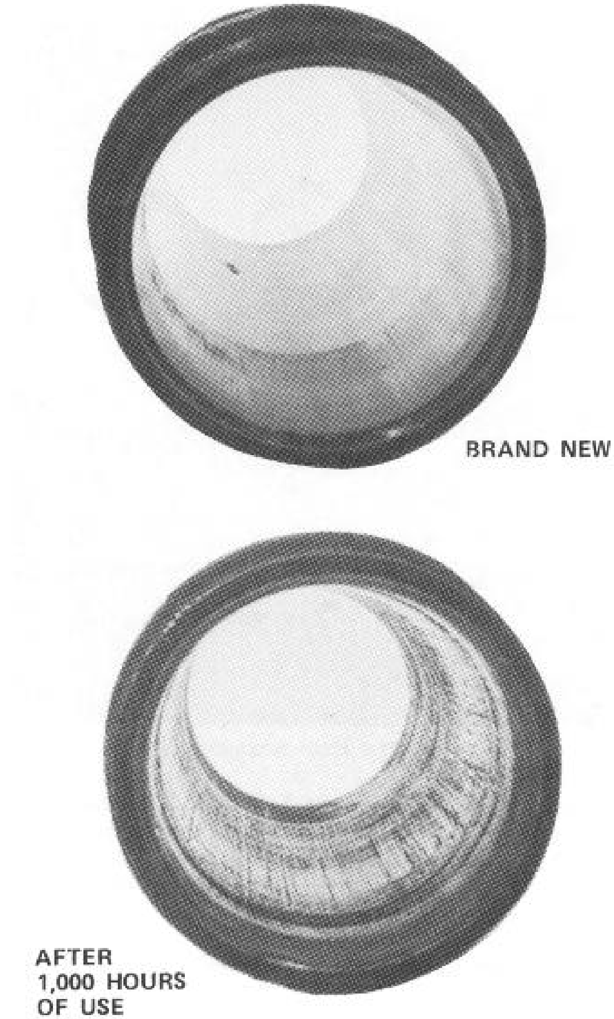


Figure 8. Brass pump cylinder.

HAND PUMP SANITATION

Test Program

At each of the 125-hour disassembly intervals during the 1,000-hour durability tests, the sanitary effectiveness of both of the pumps was tested to determine whether they could protect the water source from contamination. Each pump was mounted on a special test stand over a water tank (fig. 9). After a pump was in place, a short length of pipe was placed about the pump rod and the pipe edge that rested on the lower guide flange of the pump (fig. 6) was sealed with silicon. This pipe was used as a reservoir for a bacteria "tracer"—a water-base sample containing a laboratory-certified count of *Serratia marcescens* bacteria.

These bacteria are commonly found in water supplies, so the water in the tank probably already had a small quantity of the bacteria present. Thus, before placing a pump on the special test stand, tank water samples were sent for laboratory analysis to establish the initial *Serratia marcescens* bacteria count. Then (after the pump was in place), the tracer (with its known bacteria count) was placed into the reservoir around the pump (fig. 10) and the pump was operated for 1 hour. Water from the test stand tank was pumped out a discharge pipe leading back to the tank.

At the end of the hour, water samples were again taken from the tank (fig. 11) so the water source contamination could be quantified. A swab was also used to gather a very small amount of water from the pump rod (fig. 12) so that the concentration of the tracer that had accumu-

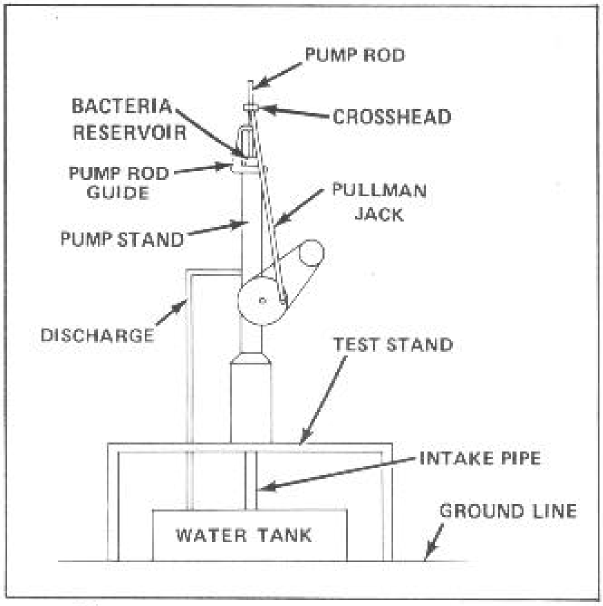


Figure 9. Sanitation evaluation test stand.

lated on the pump could be determined. The test program would show whether bacteria could penetrate the graphite-impregnated rope valve stem packing or could seep through (a) the seal between the base of the pump stand assembly and the well casing, (b) the seal around the pump rod, or (c) the packing washer between the lower guide flange and the pump base.

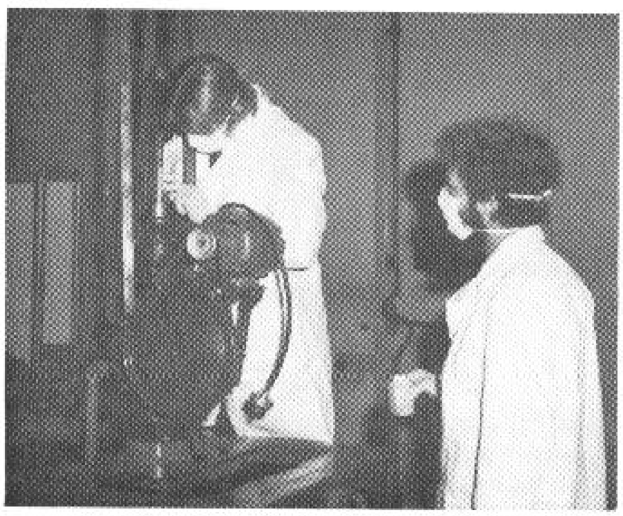


Figure 10. Bacteria tracer is placed into reservoir.

Figure 11. Water sample is collected from water tank.

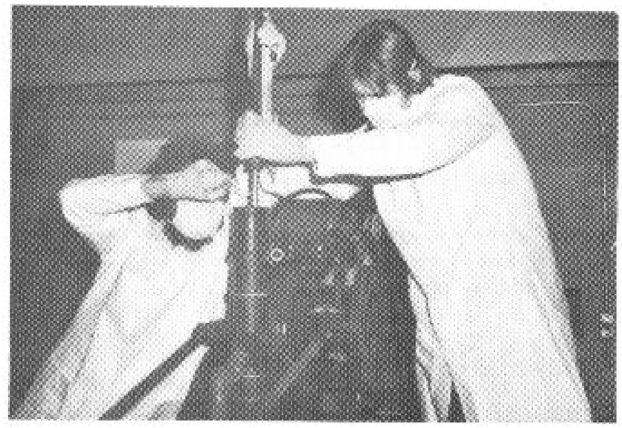


Figure 12. Swab is used to collect tiny water sample from pump.

The procedure was repeated for a worn pump rod, a worn valve stem packing and nut, and a loose packing and nut. Thus, from the laboratory-obtained bacteria concentrations at the beginning and end of the 1-hour tests, the contamination allowed by a pump could be determined.

Test Results and Observations

The data collected during the sanitation tests are presented in table 2. Bacteria did penetrate the pump seals and washer. Even when the valve stem packing was tightened to near blowout, it could not prevent the bacteria in the tracer from seeping through. Further, while a worn pump rod showed little effect on the pump's performance (since the graphite-rope packing would conform to the shape of the rod and did not leak when the packing was properly tightened), the results of the analyses indicate that neither a loose nor a tight packing prevented bacteria from entering the water source.

Table 2. Results of bacteria analyses of water samples

Elapsed pumping time (hr)	No. of bacteria per ml initially in water tank	No. of bacteria per ml in tracer water sample	No. of bacteria per ml after 1 hr, in water tank	No. of bacteria per ml in swab sample, on pump
125	8	47×10^6	30×10^3	52×10^3
250	2	68×10^9	60×10^3	98×10^5
375	1	180×10^8	50×10^3	110×10^1
500	8	280×10^8	75×10^4	110×10^4
625	1	280×10^7	69×10^3	180×10^3
750	<1	38×10^9	240×10^3	260×10^3
875	9	130×10^8	96×10^3	51×10^3
1,000	4	127×10^8	73×10^4	78×10^3

HAND-PUMPED WATER SOURCE DISINFECTION

Since the sanitation test program showed that a hand pump could allow a water source to become contaminated, a method of disinfecting hand-pumped water was sought. A market search was conducted for hand pump disinfection equipment that would:

- Meet U.S. Environmental Protection Agency (EPA) potable water specifications
- Operate with just a little, or no, pressure flow
- Be economical to purchase, install, and operate
- Require little maintenance.

Presently, available devices use either hypochlorination or iodination to disinfect water systems—both had been studied by SDEDC personnel. [2]

Test Program

Although the hypochlorinator met most of our requirements, an iodine dispenser (fig. 13) was selected for the test program because it met more of the requirements. It previously had been used in conjunction with hand pumps that were supplied with adaptor blocks for an iodine dispenser. It costs less than other systems, and has been successful in killing agents (including coliform bacteria) that cause such diseases as typhoid, cholera, and bacillary dysentery, plus diarrhea symptoms.

Figure 13. Typical iodine dispenser.

Iodine, in theory, can be used as a virucide, bactericide, and cysticide. When an iodine dispenser is connected to a hand pump for disinfection purposes, the iodine is introduced into the water at a specified concentration and this water, with the iodine residual, is then plumbed to an underground

[2] Pickett, T.L., and D.L. Sirois, 1970, Aerofeed hypochlorinator (series WF) evaluation, ED&T 7400-4· Cook, B., 1976, Iodine dispenser for water supply disinfection, ED&T 7400-1; USDA For. Serv. Eqpt. Dev. Ctr., San Dimas, Calif.

holding tank where the iodine performs the disinfection. The hand pump then dispenses water from the holding tank. Detailed information on iodine as a disinfectant is contained in numerous reports (see appendix II).

Another special test stand was designed and assembled (figs. 14 and 15) to conduct this particular test program. It consisted of a particle filter, flow meter, un-iodinated water sample valve, and the iodine dispenser with ancillary equipment—all connected to the discharge side of a hand pump. The iodine dispenser was adjusted to provide a 0.5 to 1.0 ppm iodine residual with the pump operated at 30 to 35 strokes per minute.

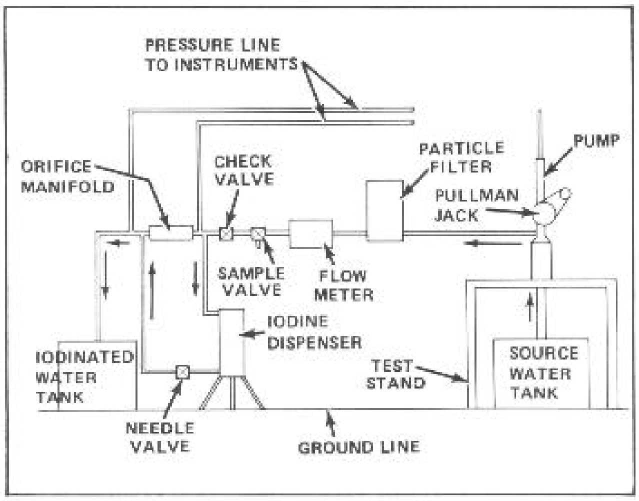


Figure 14. Iodine dispenser disinfection test stand.

A bacteria, *Escherichia* coliform American Type Culture Collection (ATCC) No. 26, which is commonly found in human feces, was used as a tracer to test the effectiveness of the iodine dispenser. The bacteria was introduced into the water source tank; evidence of the tracer was looked for in the iodinated water holding tank. If the ATCC No. 26 had been killed by the 0.5 to 1.0 ppm iodine concentration (per EPA guidelines), then safe drinking water from hand-pumped wells would be assured.

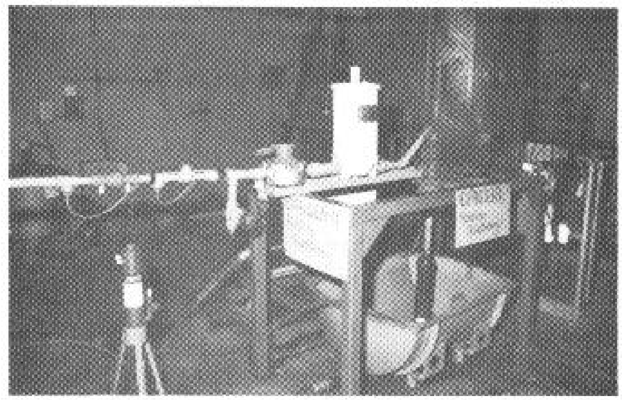


Figure 15. Hand-pumped water source disinfection test in progress.

Test Results and Observations

The data collected during the disinfection tests are presented in table 3. In all five test runs, the iodine

Table 3. Results of iodine disinfection tests

Temperature of pumped water °F	°C	No. of bacteria added per ml to source water tank	No. of bacteria per ml in un-iodinated filtered sample	Concentration (mg/1) of dispensed iodine residual (same as ppm)	No. of bacteria per ml in iodinated water tank after: 5 min.	20 min.
63	17.2	230 x 10^3	110 x 10	0.65	<1	<1
65	18.3	110 x 10^3	640 x 10	1.0	21	<1
63	17.2	70 x 10^3	39 x 10	0.65	21	<1
63	17.2	31 x 10^3	70 x 10	0.6	400	<1
63	17.2	110 x 10^2	8 x 10	0.65	<1	<1

completely killed the ATCC No. 26 tracer bacteria after 20 minutes of contact. Both the EPA and the manufacturers of iodine dispensers recommend a residual iodine concentration of 0.5 to 1.0 ppm and a 20-minute contact time. The following two firms produce iodine dispensers:

Hydrodine Corp.	*Iodinamics Corp.*
7140 N.W. 2nd Court	P. O. Box 26428
Miami, FL 33150	El Paso, TX 79926

HAND PUMP EQUIPMENT FIELD TESTS

Test Program

This test program consisted of SDEDC personnel monitoring hand pumps that were operating at nine different field sites in the western portion of the United States. Five of these pumps had no disinfection equipment, two had iodination disinfection equipment, and two had hypochlorination. Monthly bacteria analyses were made on source water samples at the hand pump sites to determine the extent of contamination present. Then a comparison of source water contamination could be made for sites having/not having disinfection equipment.

Test Results and Observations

Over 90 bacteria analyses were conducted on source water samples from the 9 sites. When disinfection devices are properly maintained, those sites with disinfection equipment did not have contaminated water coming from the spout, while those without such equipment generally did.

In addition, we inspected available previous records pertaining to the nine sites. The four pump sites having disinfection equipment consistently showed no contamination, while the five sites without such devices did. Moreover, at two of the sites having disinfection equipment, previous records indicate that for the many years prior to the installation of disinfection devices, the source water was contaminated. After the disinfection equipment had been installed, the record indicates initial significant contamination reduction. Then, as time passed and the equipment has properly adjusted and regular maintenance was provided, the water became contamination free at the spout.

CONCLUSIONS AND RECOMMENDATIONS

Based on the durability test program, the key to successful hand pump service is to follow a program of regular maintenance (see appendix I). Also, the results from this project indicate that the likelihood of contamination of a hand-pumped water source is very high, and the installation of disinfection equipment would assure obtaining safe, potable water from a hand pump. However, at those sites where hand-pumped water sources are consistently absent of contamination when tested, then the local manager should decide whether or not disinfection equipment is necessary.

While performing the various tasks in conjunction with this project, SDEDC personnel came to the realization that the Forest Service should probably conduct training programs related to hand pumps. Instruction should emphasize hand pump/disinfection equipment installations and their operation and maintenance—including ***on-the-job training*** at hand pump site(s). A collection of worn and broken parts should be available for demonstration purposes for the trainee class.

HAND PUMP MAINTENANCE GUIDELINES

These guidelines for scheduling maintenance and for troubleshooting problems that arise are based on data collected in the course of the test programs reported on in this *Project Record*, plus suggestions from manufacturers of hand pumps and disinfection equipment. Based on local experience and any available manufacturers' instructions for your pump or disinfection device, the following suggested maintenance schedule ***for frequently used hand pumps*** (fig. 16) should be amended or supplemented, as needed, by each field unit:

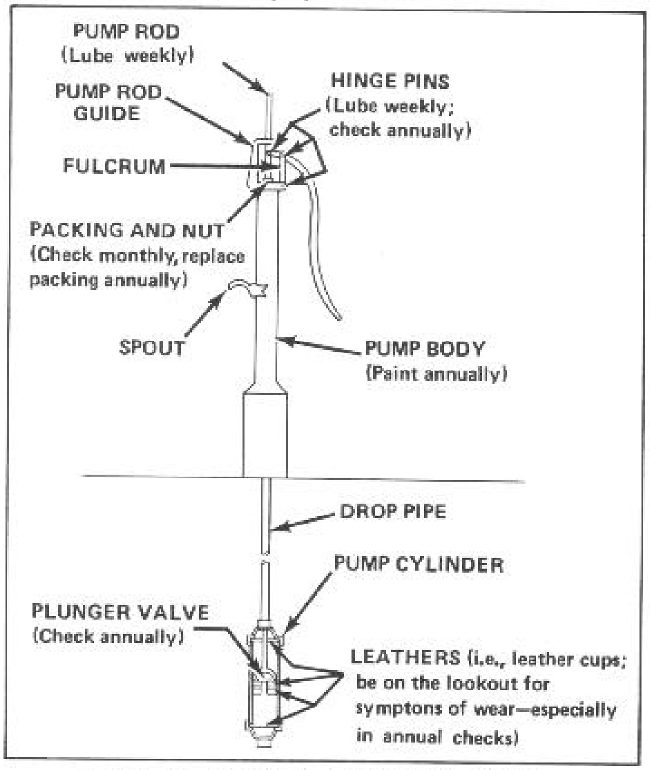


Figure 16. Maintenance hand pump parts.

Suggested Hand Pump/Disinfection Equipment Maintenance Schedule

DAILY–

CLEAN hand pump, pump base, and concrete slab.

WEEKLY–

CHECK disinfection equipment for proper operation and residual dispensing; follow recommended maintenance procedures for the device.

CHECK hand pump, pump base, and concrete slab; lubricate all hinge pins, bearings, and sliding parts; remove any accumulated rust.

REPORT for corrective action (repair or replacement) any problems discovered during above checks, or as reported by pump users–such as leaks, malfunctions of parts, a fall-off in drawn water flow, or cracked concrete.

MONTHLY–

TIGHTEN, as necessary, all nuts, bolts, and pins–paying special attention to the packing nut.

ANNUALLY–

PAINT all exposed parts.

CHECK AND REPLACE, as necessary, all leaking or worn-out parts, including hinges, nuts, bolts, pins; the plunger valve(s); handle; pump rod connectors and lengths; upper piston guide; packing and packing nut; and leather plunger cups. Check of the last item usually requires pulling the pump stand and plunger assemblies out of the well.

Troubleshooting Common Hand Pump Troubles

TROUBLE	*LIKELY CAUSE*	*REMEDY*
Pump functions, but delivers only a small amount of water	Plunger leather cups badly worn	Replace leather cups
	Plunger valve(s) leaking	Repair or replace valve(s)
	Well not yielding enough water	Decrease demand or establish a new source
	Cracked pump cylinder	Replace cylinder
	Cracked drop pipe or coupling	Replace damaged section or coupling
Pump functions (operates freely without resistance), but no water is delivered	Plunger leather cups may be worn out	Replace leather cups
	Pump rod may be broken	Broken rods must be replaced, requiring pulling the hand pump out of the well
	Hole in drop pipe	Replace pipe
	Pump cylinder may be cracked	Replace cylinder
	Leaks from pump cylinder	Tighten cylinder caps
	Drop pipe may be plugged with scale, bacteria, or trash	Remove drop pipe and clear or replace
	No water, well is dry or water level has dropped below pump cylinder	Reduce pump rate, lower pump cylinder, or develop a new source of water
Pump leaks around the top	Packing loose or worn out	Tighten packing nut
	Packing nut has become elongated	Replace packing nut and packing
Pump is noisy	Bearings or other moving parts of the pump are loose	Tighten or replace as necessary
	Pump rod may be slapping against the drop pipe	Install guides for rod or straighten crooked plunger rod
	Pump is loose on mountings	Tighten pump mounting screws
	Plunger may be too high in pump cylinder causing a throbbing on the upward stroke	Lower the pump rod and relocate the pin holes
Pump handle springs up after down stroke	Drop pipe plugged above pump cylinder	Remove pump and clean out drop pipes; if mud is evident, it may be necessary to drill the well deeper or relocate the pump site
	Plunger valve falls to open	Repair or replace valve
Pump requires many strokes to start	The cylinder leather cup may be worn beyond use	Replace leather cups

REPORTS ON USE OF IODINE AS WATER SUPPLY DISINFECTANT

Black, A.P., R.N. Kinman, W.C. Thomas, Jr., and others.
1965. Use of iodine for disinfection. J. Am. Water Works Assoc. 57(11):1401-1421.

Black, A.P., W.C. Thomas, Jr., R.N. Kinman, and others.
1968. Iodine for disinfection of water. J. Am. Water Works Assoc. 60(1):69-70.

Frink, D.W., and R.D. Fonnon, Jr.
1970. The continued development and field evaluation of the AID hand-operated water pump. Office of the War on Hunger, Health Services Division, Agency for International Development.

Greshenfeld, Louis.
1955. Iodine as a virucidal agent. J. Am. Pharm. Assoc. Sci. Ed. 44(3):177-182.

Morgan, Donald P., and Raymond J. Karpen.
1953. Test of chronic toxicity of iodine as related to purification of water. U.S. Armed Forces Med. J. 4:725-728.

Zoeteman, B.C.J.
1972. The suitability of iodine compounds as disinfectants for small water supplies. Tech. Paper 2. World Health Org., Hague, The Netherlands.

FOREST SERVICE
U S
DEPARTMENT OF AGRICULTURE