WATER OPERATION AND MAINTENANCE

BULLETIN NO. 80

JUNE 1972

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UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

The Water Operation and Maintenance Bulletin is published quarterly, for the benefit of those operating water-supply systems. Its principal purpose is to serve as a medium of exchanging operation and maintenance information. It is hoped that the reports herein concerning labor-saving devices and less costly equipment and procedures, will result in improved efficiency and reduced costs of the systems for those operators adapting these ideas to their needs.

To assure proper recognition of those individuals whose suggestions are published in the bulletins, the suggestion number as well as the person's name is given. All Bureau offices are reminded to notify their Suggestions Award Committee when a suggestion is adopted.

* * * * *

Division of Water Operation
and Maintenance
Engineering and Research Center
Denver, Colorado 80225

COVER PHOTOGRAPH:

Yellowtail Dam, Montana - The Dam forms a manmade lake 71 river miles long. Reservoir is in the Bighorn Canyon National Recreation Area. A Bureau-constructed dam, that provides power, flood control, recreation, and fish and wildlife propagation.

UNITED STATES DEPARTMENT OF THE INTERIOR
Rogers C. B. Morton
Secretary

BUREAU OF RECLAMATION
Ellis L. Armstrong
Commissioner

WATER OPERATION AND MAINTENANCE
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INTRODUCTION

"Cleaning Water Mains with Foam Plugs," the article beginning on page 1, is just what the title implies, and was considered by the Bureau of Water Services, Washington, D.C., to be a very worthwhile effort at a minimum of cost. It is not a cure-all and should not be considered a substitute for a regular O&M program.

A unique idea used by the Yuma County Water Users' Association to protect canal banks from being undermined by rodents can be found in the article on page 6.

If a maximum rewarding safety program is to be achieved, the two human factors, fatigue and noise, reviewed in the article on page 9, must be researched thoroughly.

The novel fencing device used by the Farwell Irrigation District, Farwell, Nebraska, for canal protection is the subject of an article to be found on page 11.

On page 13, a short article describes the telephone recording equipment used by the Rogue River Valley Irrigation District, to record incoming calls when the office is closed.

An easy to construct steel post driver used by the National Park Service is described in the article on page 14, and the article on page 15 describes the techniques to follow for stage construction of drains

Starting on page 16 you will find a very unique suggestion by a Bureau employee for a Oxy-Acetylene cutting table being used most successfully in the maintenance shop.

To reduce crop injury and improved weed control, temperature and moisture should be better understood and considered as pointed out in the article starting on page 20.

CLEANING WATER MAINS WITH FOAM PLUGS 1/

In the District of Columbia there are over 1,300 miles of water mains in sizes of 2-78 inches in diameter. Some mains date back to about 1850. Newer ones, those mains installed since 1942, are cement-mortar-lined. A continuing cleaning-and-lining program dates back to 1944.

About 300 miles of 4- and 6-inch mains were installed prior to 1900 and about the same length, in 6- and 8-inch mains, was installed between 1900 and 1942. All of these mains are unlined and badly tuberculated.

In July 1969, the Water Operations Division received 2,400 "muddy-water" complaint calls. The red, muddy appearance of the water responsible for the calls was caused by scouring loose calcium-carbonate and iron-oxide deposits from the hard-surfaced tubercules in the unlined mains.

The Division's immediate reaction was to initiate a massive main-flushing program. Working 24 hours a day it took about two weeks of continuous flushing to remove most of the discoloration from the water.

A number of ideas to alleviate the muddy-water condition were researched. One by one they were discarded in favor of a cleaning program that would use hydrants as launch and recovery portals for the cleaning medium. Principal concern was for a timely program that would accomplish the clean-up job and cause a minimum of consumer inconvenience. Economic- and public-relation factors such as costs to excavate and repair city streets, traffic, and pedestrian rerouting and safety influenced this decision to use the hydrants. Figure 1 on next page depicts a portion of the area in which work was performed.

Initial Failure

Initial tests did not produce sought-for results. The cleaning vehicle tested, called a pig, would not compress sufficiently to pass through the 4-inch opening in a hydrant boot and it would not negotiate the four-way valve. The problems with the pig hang-up could have been resolved by excavating and cutting the main--something which the Division did not want to do. While testing, the discovery was made that the pigs were too hard. They could not remove the soft sediment without also breaking through the tubercules and causing more problems.

1/ A paper presented by H. M. Stearn, PE, Chief, Water Operations Division, Bureau of Water Services, Department of Sanitary Engineering, Washington, D.C. - Reprinted from AWWA Journal, July 1971, by permission of the Association. Copyrighted 1971, by the American Water Works Association, Inc., 2 Park Avenue, New York, NY 10016.

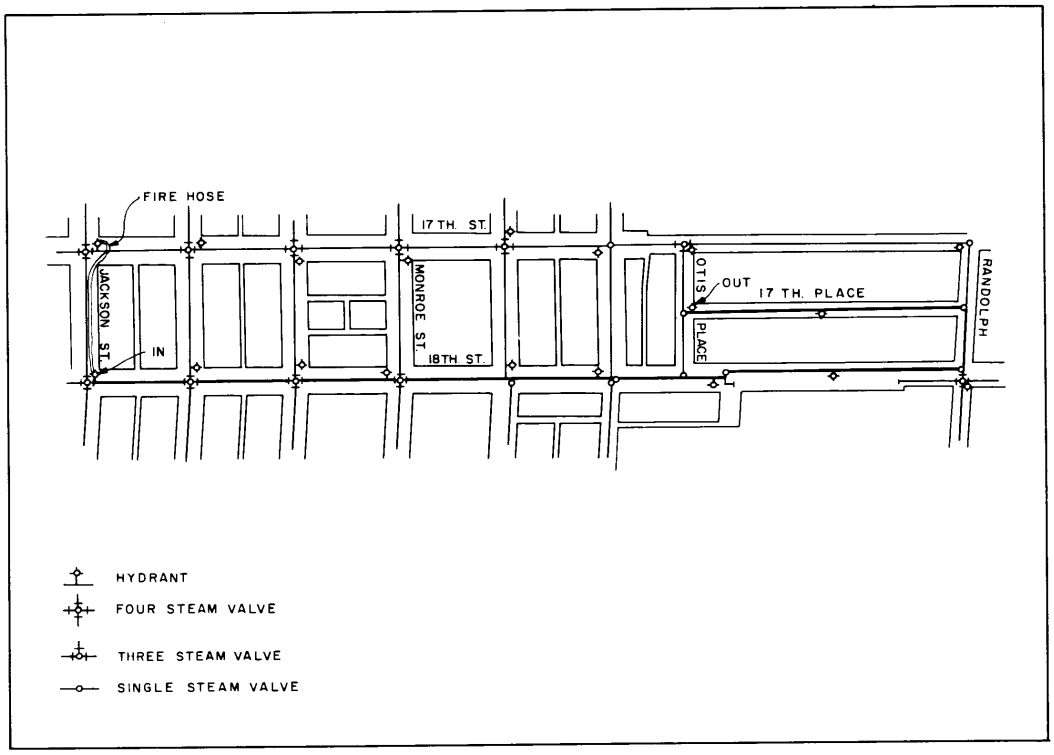

Figure 1. Typical Area Map for Swabbing Operation

However, Clive A. Jenkins (see references at end of article) had detailed a hydrant entry and recovery system for soft-foam water-main swabbing. In another article, F. G. Denton (see references at end of article) reported Winnipeg, Manatoba, experience with soft polyurethane-foam swabbing to eliminate its dirty water problems. Since the Washington Water Operations Division wanted to remove the sediment responsible for the water discoloration from the hard-surfaced tubercules without disturbing them, it now concentrated on testing the soft swabs.

As with the pigs, there were problems to overcome in lauching and recovering the swabs. First, in the District of Columbia, hydrants have a 2-inch valve stop that projects about 2 inches from the bottom of the hydrant boot. Second, use is made of multistem valves in most 8-inch and smaller valves. A number of swab sizes and densities were tested before it was found that one would remove the sediment from the tubercules (without disturbing them) and negotiate a 90-degree turn through the multistem valves as well. The polyurethane-foam swab finally selected weighs 1.4 lb/cu ft and is used ordinarily in furniture manufacture.

During the swab testing period the Division also developed a hydrant launch system to get the swab into a main. Since the swab compresses readily and effects through the recovery hydrant easily, there is no need for a recovery chute or deflector on the recovery hydrant. While testing and developing operating procedures, 78,000 feet of 8-inch mains were cleaned and to date not a single complaint has been received

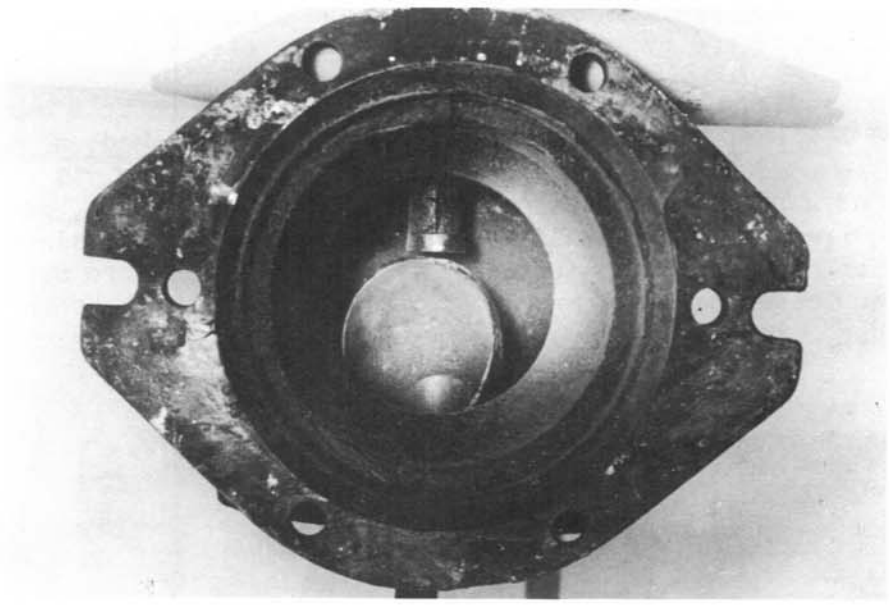

Figure 2. Hydrant Boot with Swab Entry Chute in Place. Photo P222-D-71334

Figure 3. Hook-up for Propelling Swab Using Another Hydrant as Pressure Source. Photo P222-D-71333

from the areas served by them. See Figure 2 and 3 on the preceding page for entry chute and hydrant hook-up, respectively.

Optimum swabbing distance was found to be about 4,000 feet at a maximum speed of 2.5 fps. After that distance and at that speed, a swab is worn to the internal diameter of the main and, hence, is ineffective for any further cleaning action. At slower speeds, fewer swabs are required to clean the same length of main; however, since labor costs far exceed the swab costs it is more economical to use more swabs and less labor. Figure 4 below shows the used swabs in sequence of use, are progressively cleaner.

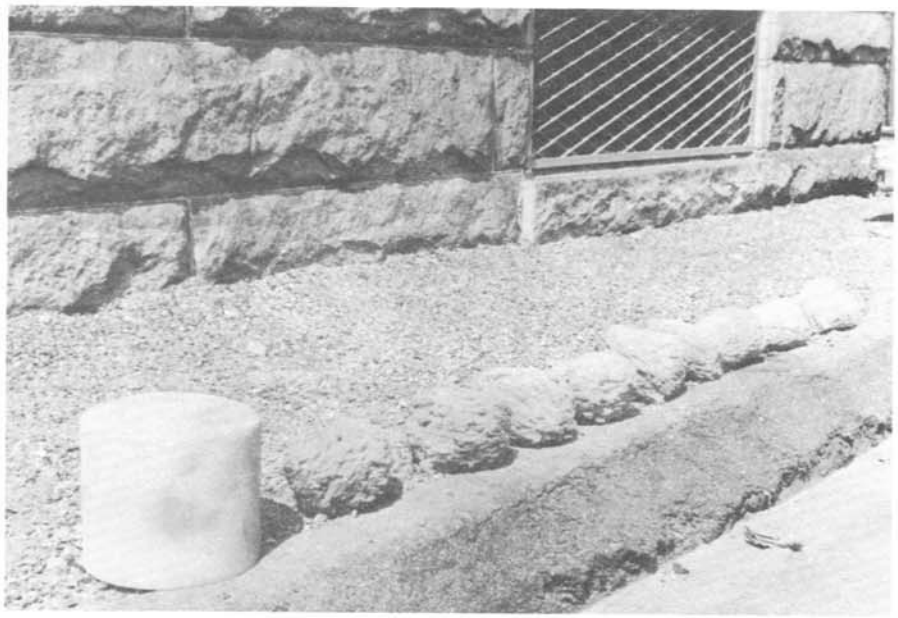

Figure 4. Unused and used swabs. Photo P222-D-71332

Procedures are quite simple - but detailed so that almost any contingency is covered. As a preliminary step, the Division studies a plan of the area to be swabbed, selects entry and recovery hydrants, scales the length of the swab run, and notes the numbers and types of valves. A field investigation is made to determine who and what will be affected and whether or not temporary water-supply lines must be provided. All valves on the main are tested to ensure they can be isolated.

Notification

At least two days before the swabbing operation, special notices are distributed to all addresses that will be affected by the main shutdown. Another step prior to the actual operation starts the day before, when all valves that can be left closed overnight are closed.

On the scheduled swabbing date, the internal mechanisms are removed from the entry and recovery hydrants and the drains are plugged. The hydrants' caps are removed and a specially designed chute is inserted into the entry hydrant. A 2-1/2-inch supply hose with a valve and pressure gauge is attached to a special cover affixed to the entry hydrant, a swab is inserted, and the hydrant cap is replaced.

At the time indicated on the special notices distributed to the affected addresses, the last valve isolating the system is closed, the supply-hose valve is opened, and the swab is propelled into the main. As previously mentioned, the swab's travel time is estimated at 2.5 fps. After leaving the entry hydrant, as indicated on the pressure gauge, if the swab does not exit at the estimated time plus 10 minutes, the flow in the main is reversed and the swab is recovered at the entry hydrant.

After the first swab has made its run and been recovered, swabs are entered into the system at 5-minute intervals until the water behind the swab clears up in less than one minute. The number of swabs used varies from 15-20. When the last swab has been recovered, the main is flushed to clean out particles of the swabs. The particle flushing usually takes about 1 hour, after which the hydrant mechanisms are replaced and the main is returned to service.

Foam swabbing is not replacing the cleaning-and-lining program, nor is it taking the place of other maintenance programs. However, it has been found to be extremely useful in this instance where particulate matter is easily removed from hard surfaces. The Division found it worth the effort and the moderate cost to clean up the water at the consumer's tap.

As for cost, labor ($102.40/1,000 ft) is by far the most expensive part. The polyurethane foam costs only $1.40/1,000 ft of main swabbed. The Division is certain that the money spent on the program is well spent and buys more in public relations than the amount expended might indicate.

The Division's swabbing operations started in May and continued until mid-October.

References

1. Jenkins, Clive A., "Foam Swabs for Water Main Cleaning." Journal AWWA, 60:8:899 (1968).

2. Denton, F. G., "Foam Swabbing of Water Lines." Public Works. 100:118 (1969).

* * * * *

GOPHER WALL 1/

When prime irrigation land is subdivided--who becomes liable for damages to homes and property caused by major canal breaks? This is an age old question and one that has been settled in and out of court many times. It is generally agreed that when an irrigation district diligently maintains its canals and has an active rodent control program, it probably would not be held liable for a damaging canal break.

The interpretation of adequate maintenance and adequate rodent control is the question. This was the problem when the Yuma Valley started being subdivided for urban living that prompted the Water Users' Association, Yuma, Arizona, to start a program of protecting critical and historical canal break areas with gopher walls.

Several hundred feet of an unique gopher barrier along canals have now been installed on the Valley Division of the Yuma Project by the association. These gopher barriers were built mostly along reaches of canal that are higher than nearby urbanized areas, and they have proven very successful in preventing gophers, muskrats and other rodents from crisscrossing the bank.

A thin concrete wall 2 inches wide and 5 feet deep are poured in the center of a canal bank forming a barrier. It is preferable in an unlined canal to trench and pour the wall when the canal is unwatered, otherwise the trench may slump shut in waterlogged pockets or soft spots and will prevent further casting until the bank is dry.

Figure 5 on next page shows a trenching machine excavating for the wall near a subdivided area. The trencher is the type used by utility companies for burying telephone and power lines. After completion, the wall will be covered so as not to interfere with grading the maintenance road.

The wall should not be poured too close to the waters edge because it is possible for the inside of the bank to cave off into the canal. In order that miximum depth can be attained, it is advisable to roll or grade the bank so that the top elevation of the gopher wall is at least three inches above the highest high-water mark elevation.

1/ Article written especially for this publication by Mr. T. L. Long, Manager, Yuma County Water Users' Association, Yuma, Arizona.

Figure 5 Photo P35-D-71337

Figure 6 below, shows the slip wall form mounted on a farm tractor hydraulic lift with a transit mix discharging concrete into the hopper. Concrete should be a thin slurry to allow even flow through the narrow slip form.

Figure 6 Photo P35-D-71338

Figure 7 below shows an employee hand tamping the slurry to insure good compaction of the concrete.

Figure 7 Photo P35-D-71339

Work and materials have been furnished under contract, however, the Association at this time, is considering purchasing the gopher wall equipment for future installations. If additional information is desired regarding this gopher barrier, please write to the Yuma County Water Users' Association, P. O. Box 708, Yuma, Arizona 85364.

* * * * *

Research and Development in biological control of agricultural pests pre-dates chemical control research by at least 100 years, and the records show that more than 8 times as much money has been spent on research in biological control as on research in chemical control during the past 5 years.

THE EFFECT OF NOISE AND FATIGUE ON HUMAN SAFETY 1/

Fatigue

Few of us have failed to observe or experience declining work efficiency and accidents with fatigue as a contributory factor. Fatigue is relatively intangible--there is no adequate way of measuring the phenomenon. Biochemical, physiological, psychological and social factors are so involved that fatigue is often unrelated to the amount of energy expended. Skill and attention demands beyond capacity, monotony, external emotional stresses, responsibility, and disease are but a few of the many factors involved. The only consistent characteristics are a decrease in output of work and a conscious sense of tiredness.

There are, however, practical limitations of worker endurance that have been observed. During World War 1 the British found production output significantly decreased if work hours exceeded 60 per week and that maximum hourly output was achieved at 8 hours per day, 6 days a week. Other studies have demonstrated sick absenteeism increased when a 50 hour workweek was exceeded. Accident rates increase as well if similar workweeks are imposed.

Sleeplessness or insufficient sleep must not be confused with fatigue, but may coexist to create a combined and more serious effect. Controlled studies have demonstrated memory lapses, irritability, inattention, hallucinations or illusions, and loss of equilibrium if sleeplessness is prolonged over 30 hours. Subtle changes accompanying an overwhelming desire to sleep may occur earlier in some individuals that adversely affect mental and physical performance, especially when mixed with other factors such as the aforementioned fatigue, following an all night drinking spree or hangover. I doubt that any data on field accidents attributed to sleeplessness is proportionate to real occurrence.

Noise

Although everyone is aware of the annoyance of noise, the influence of noise upon work efficiency and accidents is a subject rarely discussed. Noise is generally tolerated as a necessary element of environmental discomfort. However, noise is known to cause mental irritability and "nervous strain;" reduce efficiency and accuracy;

1/ Abstracted from a talk presented by Capt. C. A. Burkhart, MC, USN, Staff, COMSUBLANT, Norfolk, Va., at the Navy East Coast Regional Safety Conference.

and have a distracting effect upon mental tasks and the capacity for alertness, especially when the noise is loud and intermittent in nature. With all the tin knocking, chipping and hammering in the Navy, it would be amazing if a significant contribution to accidents is not being effected. In a telephone exchange wrong numbers were observed to decrease 42 percent when the background noise was reduced from 50 to 35 decibels. The effect of background noise at this low level suggests a certain contribution to human error where environmental noise ranging over decibels is commonplace. Human error, more often than not, is cause for accidents.

General

Fatigue and Noise bear no apparent resemblance, however, they have a common characteristic--they are both sources of human stress causing man to perform in such a manner as to produce less and increase his accident liability. There are other factors that could be discussed at length--internal stresses of disease and worry, or external stresses such as temperature extremes and poor illumination. The important thing to remember is that man is subject to many stresses that minimize or distract him from a healthy fear of danger or cause him to work less efficiently. Yet, except for alcohol (and, more recently, drugs) these human factors are rarely reported as associates to accidents, even though the magnitude of this influence is impressive. A recent study revealed 59 percent of accidents were due to personal failure alone; only 7 percent could be attributed to causes not under the control of the worker.

Take a look at the vectors of stress affecting man and his ability to perform efficiently and safely. Often these factors coexist. When this happens, the effect on the man's liability is more likely to be multiplied rather than additive. Here the term "accident proneness" may be correctly applied. As long as these stresses are applied, singly or in multiples, the interaction sets up the potentials of repeated accidents. Hence, an "accident repeater" is more likely to be found and the truth is that these factors make up all more accident prone at varying times and to varying extents. This is not shifting all the blame to the individual, rather it is an appreciation that accidents to a large extent are the result of man being unable to cope with some stresses and danger simultaneously. If we are to reduce this susceptibility to accidents, we must be aware of and begin to evaluate these factors more carefully. From deeper evaluation I am confident we will find the stimulus and guidance for a different approach to accident prevention.

* * * * *

Leadership appears to be a function of at least three complex variables--the individual, the group of followers, the conditions.

CANAL FENCING

The unique fencing device described in this article was designed and built by employees of the Farwell Irrigation District, Farwell, Nebraska, and is in use at fence line crossings on canals and laterals.

This device consists of a pipe connected to a fence post with a cable attached to raise and lower a section of fence above the water surface. Figure 8 below shows how the fence post is supported to the cattle guard and it also shows the pipe attachment that raises and lowers the fence. When the water surface in the water prism raises, the operator turns the pipe, this in turn twists the cable around the pipe pulling the fence up to the high-water line.

Figure 8 Photo P707-D-71336

Figure 9 on the next page shows the fence panel on the canal side slope between the cattleguard and the high-water line. The fence is designed so that the weeds which float on top of the water surface are not caught in the fence. The photograph however shows some weeds attached to bottom wire of the fence which were probably blown in after the water was turned off.

A sketch at bottom of page 12 shows a somewhat modified version of the canal fence. It shows the detail of the winch and cable attachment

Figure 9 Photo P707-D-71335

on the fixed and movable posts, and it also shows a full cross section at the fence line with the fence in the high and low water condition. Additional information regarding this idea may be obtained by writing to the Farwell Irrigation District, Farwell, Nebraska 68838.

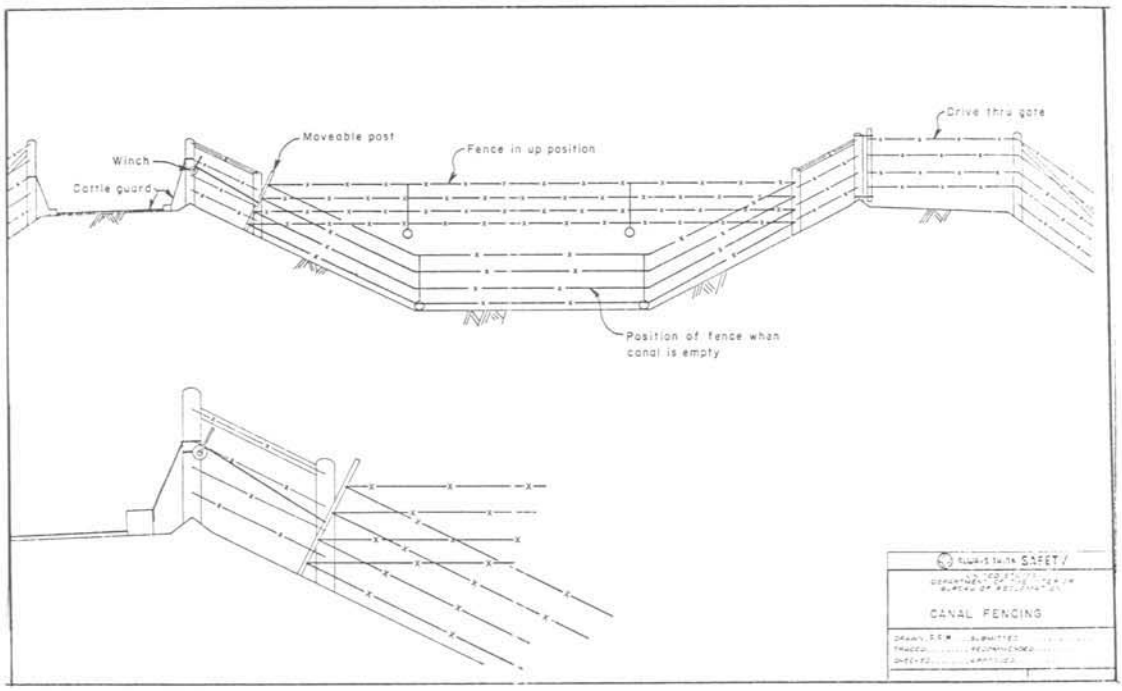

Figure 10

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TELEPHONE RECORDING MACHINE

A relatively new recording instrument is now being used by the Rogue River Valley Irrigation District, Medford, Oregon. This device was just recently brought to our attention, and its possibilities might be of interest to others who operate water supply systems. The District reports that it has proven to be a very worthwhile investment.

When the office is left unattended such as on Saturdays, Sundays, holidays, and evenings, the recording machine is turned on to answer and record all incoming calls. The device informs the caller that the office is closed, but to please leave a message for the office staff to handle upon their return.

One other very fine feature of this machine is a special remote recorder device which being smaller than a pack of cigarettes can be carried in a pocket or a purse. Use of this device requires only the dialing of your own number from any convenient telephone, placing the remote key up to the mouthpiece of the telephone, pressing a button and listening. The device will precisely repeat each and every message it recorded. This particular device enables the ditchriders to check with the machine on weekends, evenings and also in the mornings before reporting to the office and the ditchrider is instantly alerted to any problems that he can take care of immediately or as soon as required.

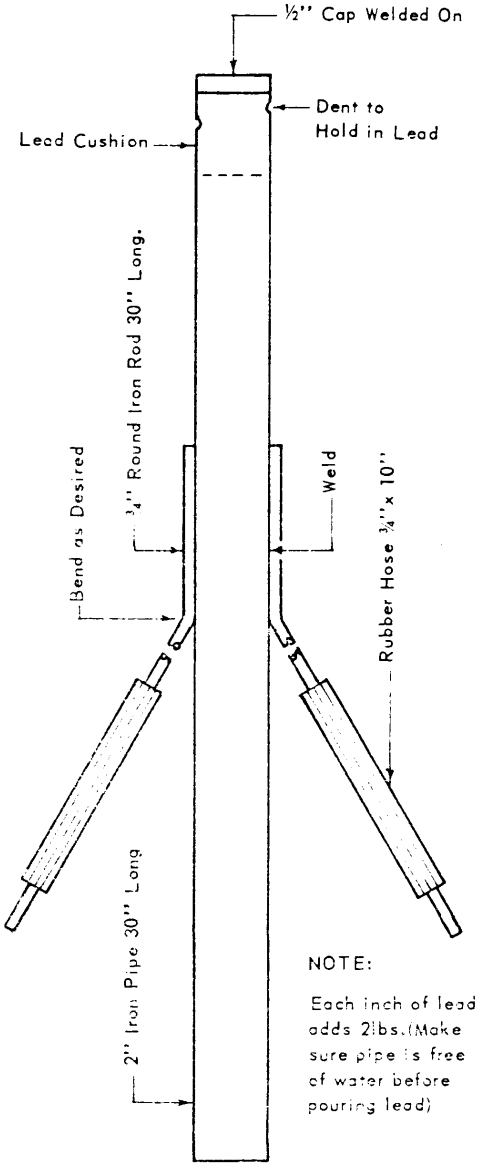
If further information is desired regarding this equipment, please write to the Rogue River Irrigation District, 3139 Merriman Road, Medford, Oregon 97501.

* * * * *

Water is important in so many ways. It's a principal necessity of life, and man depends in so many ways on the vital element--water. Water is for fun, too. In the early springtime there's the fun of playing in puddles of water after a shower--and sailing toy boats in the street gutter. And we never forget the first dip in the old swimming hole in the early spring. Water has a way of providing fun in so many ways, especially for the "small fry." When vacation time comes, many families usually head for a beach, lake or mountain stream for enjoyable fun by the water. Even though water is so vital in many ways, we'd have to say that not the least of these is--water is for fun, too!

STEEL POST DRIVER

(Reprinted by permission of GRIST, November/December 1971 issue, a publication by the National Conference on State Parks, Washington, D.C.)



The simple driver shown in the sketch can be built in about a half hour from scrap material. Jack G. Stour, maintenance foreman, Colonial National Historical Park, Yorktown, Virginia, cites a number of advantages. The driver is easily handled by one man which makes it possible for him to stand on the ground while driving. Also, it is safer and less tiresome. By allowing the driver to spend more time driving, installation time can be cut by 30 per cent.

The driver is constructed of 2-inch pipe and 3/4-inch round iron rod (see sketch for other dimensions). The length of pipe can vary according to length of post to be driven. The length shown works fine for a post from six to eight and a half feet.

If additional weight is desired, lead may be added. One inch of lead will add approximately two pounds of weight. It will also help cushion any shock. Make sure the pipe is thoroughly dry, make a small dent on each side of the pipe near the end (to hold lead in place); then pour in the lead. Weld a 1/2-inch cap to the top of the pipe and the iron rod (bent to the right angle) to the sides.

* * * * *

STAGE CONSTRUCTION FOR DRAINS 1/

Excavating to design grade in deep open drains, using only one pass by normal excavation equipment is practically impossible in saturated fine sand, silt, silt loam, and very fine sandy loam soils. Well points can usually be used successfully to dewater the drain section and complete construction in one pass, but costs are quite high.

The answer to this problem may be stage construction, where that portion of the drain section which will remain relatively stable is rough-excavated and the banks allowed to drain and stabilize before the next stage of excavation is started. If construction can be scheduled during the nonirrigation season, ground-water drawdown will be more rapid and the time and number of stages required will be minimum. However, in areas of short nonirrigation periods, where the water table is constantly being recharged, stage construction might extend over a 1- to 3-year period before the finished design section can be attained.

Stage construction presents scheduling problems for the contractor and is seldom used under the contract form of drain construction because it is difficult to determine beforehand how many stages will be required and the time between stages. However, for drain construction or maintenance by irrigation districts, this method can be fitted into the regular maintenance program, and there need be no idle machine time waiting for the banks to stabilize. After one or two passes to determine time required between stages, the regular maintenance work can be planned so there will be little or no additional moving costs.

Stage construction costs for open drains varies with the irrigation schedule, who performs the work, type of material, depth of drain, side slopes, and skill of the dragline operator, but range between 20 and 50 percent over what the drain would have cost if it could have been completed in one stage.

1/ Written especially for this publication by Mr. R. J. Winger, Jr., Civil Engineer, Division of Water Operation and Maintenance, Drainage and Groundwater Branch, Engineering and Research Center, DFC., Denver, Colorado, dated February 29, 1972.

OXY-ACETYLENE CUTTING TABLE
(Suggestion R3Y-71S-11)

The suggestion presented in this article was submitted by Mr. John J. Gifford of the Yuma Projects Office, Yuma, Arizona. His idea for an Oxy-Acetylene cutting table was designed and fabricated at a minimum of cost, from materials on hand in the Project shop.

In his suggestion Mr. Gifford states that in cutting steel for fabricating various steel items, it has been the practice in the welding shop to lift plate steel, strap iron or angle iron onto the welding bench or the back of the welding truck. In this manner a straight edge or circle cutter must then be used in a somewhat hazardous position to cut the material to the desired shape and in this cutting process, the worker must be very careful of hot slag and or heavy pieces of steel falling from the bench. This process Mr. Gifford reports is slow, hazardous, and inefficient. The following two photographs show how the bench looks when completed. Figure 11 below, shows a front view of the cutting table and Figure 12 on the next page shows a good side view of the bench. (Note how the hot slag is directed away from the worker.)

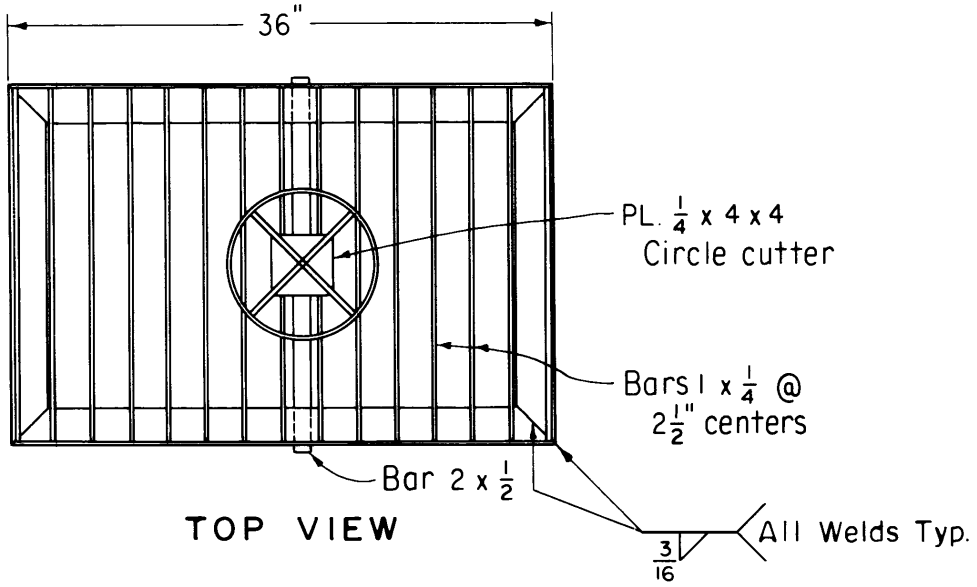
Figure 11 Photo P35-D-71340

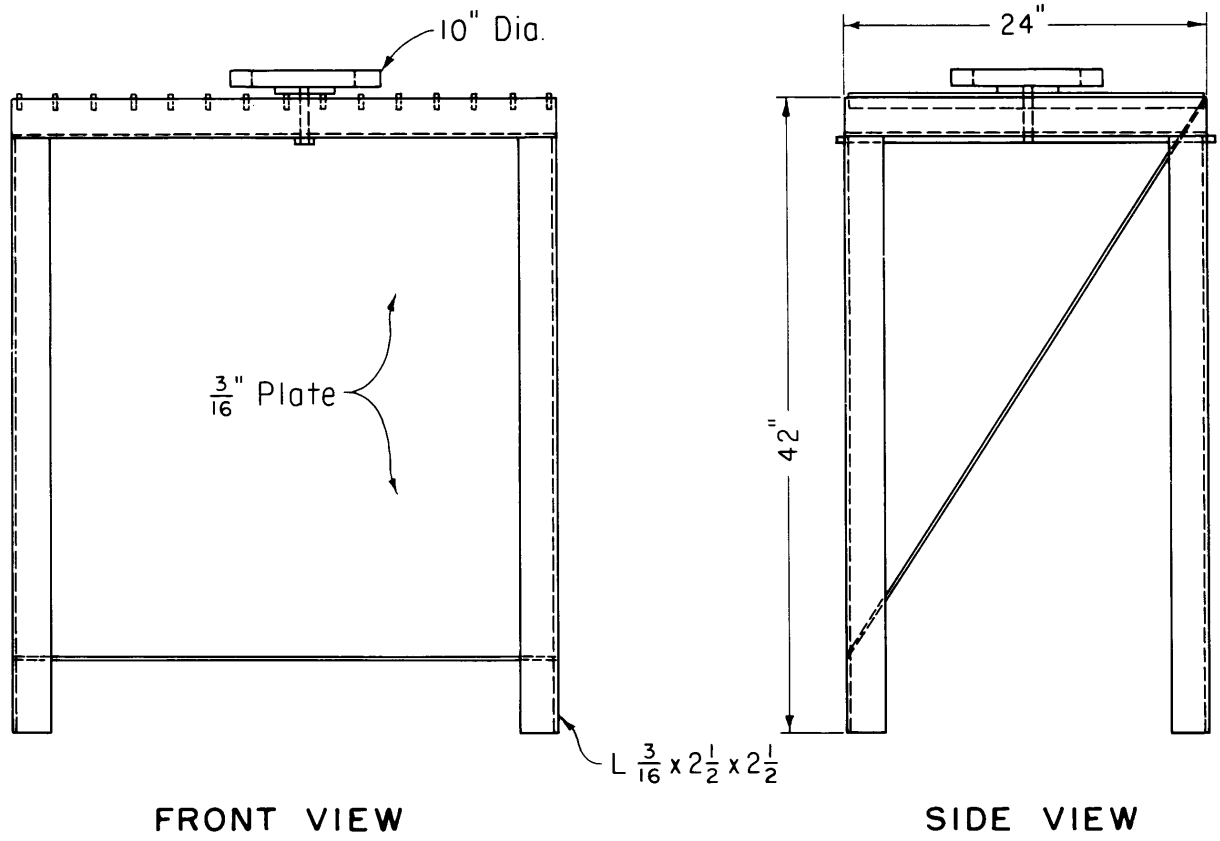
Figure 12 Photo P35-D-71341

The overall dimensions of the cutting table are as follows: 42 inches high, 36 inches long and 24 inches wide. Top of table should be made from 1/4" x 1" strap iron on 2-1/2-inch centers. See sketch on page 18 (Figure 13). The spark shield should be made from light-weight steel 36" x 48", and the frame should be made from 3/16" x 2" x 2" angle iron. A circle cutter and a straightedge makes the bench complete. Figure 14 on page 19, shows an overall sketch of the Oxy-Acetylene cutting table.

Less time in cutting and fitting, increased production, less waste, and a much reduced chance of injury from hot sparks and falling steel, are just a few of the benefits that they reported were realized from the suggestion.

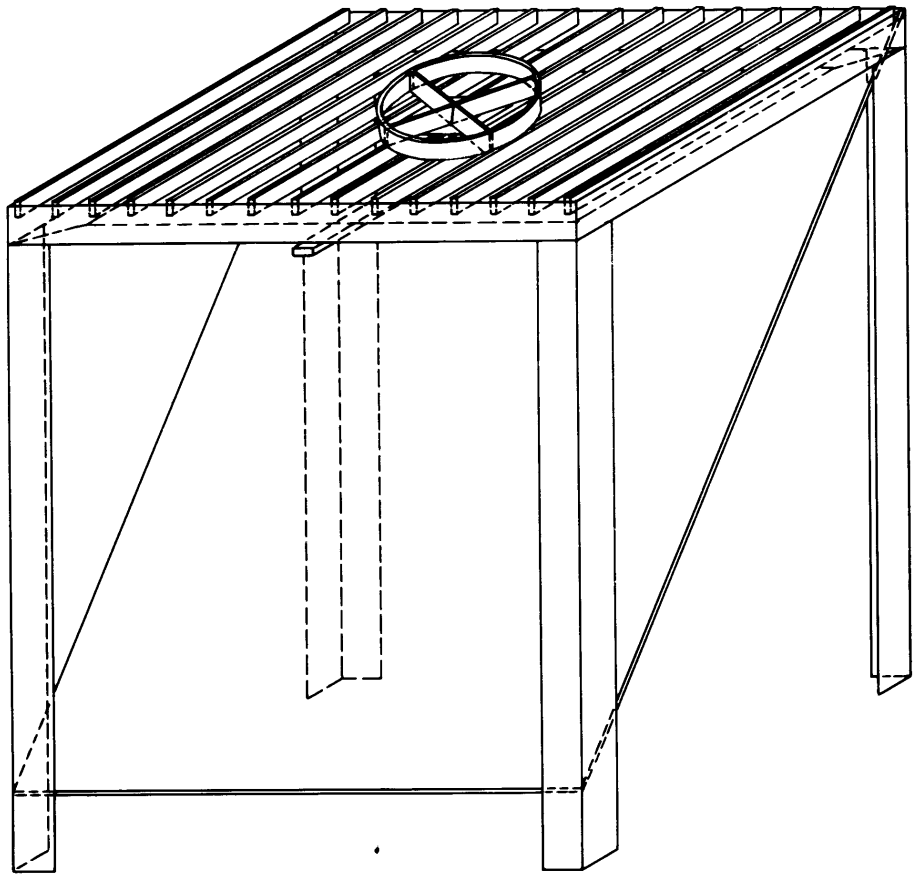
If additional information is desired regarding this idea, please write to the Project Manager, Bureau of Reclamation, Yuma Projects Office, Bin 5569, Yuma, Arizona 85364.





OXY-ACETYLENE CUTTING TABLE

Figure 13



OXY-ACETYLENE CUTTING TABLE

Figure 14

MOISTURE AND TEMPERATURE IMPORTANT FOR CHEMICAL WEED CONTROL 1/

Last spring many farmers reported both good and bad results with the same chemicals. Some corn and bean herbicides did not perform as well last year as expected, especially in Northeastern Colorado where abnormal temperature and moisture conditions prevailed through most of the spring. Knowledge of how temperature and moisture can change the killing action of a herbicide may help to explain why the same chemical will perform well one time and not another.

Moisture and temperature have much to do with the success or failure of an herbicide. It is remarkable that weed control successes are so frequent if we think of the great differences in weather conditions under which chemicals are applied. Temperatures may vary from as low as 40° F to over 100° F; soils may vary from air dry to flooded; relative humidity from 10 to 100 percent; sunlight from cloudy to bright; and wind from 0 to 50 mph. Since there is no end to weather combinations, the chances of applying a herbicide under the same conditions for two different days or two different years are very unlikely.

Many things must happen for a chemical to kill weeds. With postemergence applications, the spray droplets must be caught and held by the leaf; the chemical must penetrate into the leaf through a waxy surface and move through the plant to parts where the killing action occurs. Temperature and moisture act on the chemical and the plant. Weather conditions that increase the amount of spray caught and absorbed by the plant or that improve the rate of movement in the plant will increase the weeds killed.

Temperature

Weed control is best when temperatures before spraying have favored uniform weed germination and rapid growth. The thickness and chemical composition of the cuticle of the leaf differs with temperature. Cool nights and moderate day temperatures favor greater cuticle thickness in some plants. High temperatures generally increase the activity of herbicides. Temperature affects the rate of herbicide uptake by plants. High temperatures favor more rapid movement of chemical into the plant. Generally, more favorable weed control is obtained if the temperature is high at time of application.

Temperatures have important effects on the dissipation or loss of herbicides from plant foliage or from soil. Chemicals such as trifluralin, EPTC and some esters of 2,4-D evaporate readily. When

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these herbicides are applied to plants or soil, their loss as vapors is quite rapid at high temperatures. Soil incorporation of these herbicides reduce the evaporation loss; only 1/3 as much chemical is required for satisfactory weed control with Trifluralin & EPTC when they are incorporated into the soil. Triazine herbicides are more rapidly destroyed by a chemical reaction in moist soil at temperatures above 75° F while destruction is very slow below this temperature. This is one reason atrazine residues are not as serious in the south as in the north. But even in the Northern United States, where soil temperatures are relatively cool, 2,4-D persists only a few weeks during the summer.

Moisture

Good soil moisture stimulates uniform germination and vigorous growth of weeds. Chemical applications under these conditions are more likely to succeed than when the soil has been dry before treatment. Dry conditions cause uneven germination of weeds; as a result, proper timing of postemergence spray application is difficult. Rainfall and winds before treatment cause weathering of the waxy layer on leaf surfaces. A greater amount of weed spray is caught and taken up by weathered leaves, resulting in better weed control but also more chance of crop injury. Humidity at the time of herbicide application and for several days afterwards greatly affects weed control. When the air is moist, more herbicide penetrates the leaves and more weeds are killed. Leaves in dry air absorb less herbicide, thereby reducing the plant response to the spray treatment.

The killing action of some chemicals applied to the soil can be affected by the moisture content of the air. If the soil is wet while the moisture in the air is low, plants give off great amounts of water. Roots absorb water from the soil to replace water loss from the plant. Since herbicides in the soil move toward the roots with water, soil applied herbicides are more readily taken up when water is moving into the plant at a high rate. Dry soil can have the opposite effect; when soil becomes so dry that the water lost from the leaves cannot be replaced by uptake through the roots, the leaf stomata close, resulting in slow water movement through the plant and reduced herbicide uptake.

Heavy rainfall shortly after a foliage spray of herbicide is applied, may wash the chemical from the leaves before it can be taken up. The most critical period for rainfall is within the first half hour after spraying. It was found that 50% of the chemical of any amine salt of 2,4-D applied to redroot pigweed was taken up by the leaf within 30 minutes when the air was moist and the temperature 70° F. 65% was taken up in the first hour and 80% was absorbed in 12 hours. Other weed killers are probably not absorbed as rapidly as 2,4-D - less than 15% of foliarly - applied atrazine was found within the plant 7 days

after treatment. Therefore, rain could wash off substantial amounts of atrazine from leaves for considerable periods of time after treatment. Rainfall is essential for good weed control from most soil-applied herbicides; the amount of rainfall required varies with the chemical used. But heavy rainfall, several inches or more, soon after a herbicide is applied to soil for preemergence weed control, can be detrimental. It may carry the chemical to a depth of the crop seed, resulting in crop injury (if crop safety depends on separation of the chemical from the crop-seed by a layer of soil), or poor weed control may result if the herbicide is leached below the level where most annual weedseeds germinate. A delay in rainfall for more than a few days following application of atrazine will usually reduce its performance. During dry periods, some of the chemical may be destroyed by sunlight or weeds may germinate and grow before the herbicide has a chance to act.

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