How To Drive Wood Piles Through Hard Material

By T. B. Coull, Jr.

HARD STRATA need not be a deterrent to the use of wood piles. For years, contractors have been driving piles through and into soils which, at first glance, would seem to prohibit the use of a displacement pile. The equipment and techniques used for driving in such soils are virtually the same for wood piles as for other displacement piles, i.e., precast concrete, pipe or metal shell.

Quite obviously the first item to consider is the pile itself. Control in pile selection and treatment is extremely important when hard driving is expected. Attempting to drive split, badly checked, spiral grain or improperly treated piles can only lead to disaster. The architect rejects piles, the owner is dissatisfied and the contractor winds up with a costly job.

Years ago, when the wood pile was enjoying considerable prosperity at the expense of its higher priced contemporaries, steel and concrete, insufficient attention was placed on the quality of the pile shipped to the job site. On a few occasions I have seen piles, too dry when treated, literally explode under moderate driving. In recent years, however, the trend toward higher allowable capacities, along with the advent of the prestressed concrete pile, began to create an economic squeeze on the wood pile.

The treating companies, quick to realize this, initiated researches, specification revision, sales campaigns and most important, self policing of quality control, and have successfully kept wood piles in the focus of the engineer.

The maintenance of this control over production is necessary to insure continued success in the acceptance of wood piles driven into hard materials and to higher allowable bearing capacities.

As a matter of interest, the California Division of Highways, assisted by the American Wood Preservers Institute, recently issued a specification for the furnishing and driving of wood piles for the Elkhorn Ferry Bridge across the Sacramento River. Piles were Douglas fir timber, both treated and untreated, driven to a design bearing of 45 tons. Pertinent requirements, not found in their California Standard Specifications (dated July, 1964), but added to the job specifications, were:

1. Natural moisture content of untreated piles

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Some of the more interesting projects he has worked on include the Standard Oil Long Wharf — the first major oil dock made from precast concrete elements; Kelowna Bridge in British Columbia — a floating concrete bridge which was the third of its kind at the time of construction; Marine Fueling Facilities, Sequoia Oil Co., Hercules, Calif. — loading dock 7,500 feet off shore, serviced by six parallel underwater pipe lines; and Aerial Structures, San Francisco, Bay Area Rapid Transit District — furnish and drive more than 12,000 prestressed concrete piles.

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shall be not less than 18 percent at 2 inch depth.

2. Pressure-treated timber piles should be driven within six months after treatment.

3. Checks in untreated timber piles, and checks prior to treatment for treated timber piles shall not exceed ¼ inch in width or 10 feet in length. After treatment, checks shall not exceed ⅜ inch in width and 15 feet in length. Checks shall be considered continuous unless separated from other checks by at least ½ inch thickness of wood.

4. The natural moisture content of any timber pile to be treated shall be not less than 18 percent at 2 inch depth.

5. Timber piles shall be equipped with driving shoes and steel strapping. Shoes of commercial manufacture and steel straps conform to AWPI Specification for Strapping Western Specie Pressure Treated Piling except one wrap instead of two, and additional bands at 10 foot minimum spacing were required.

The balance of the Specifications adopted ASTM D-25.

Piles expected to receive hard driving should be furnished to specifications similar to these.

HARD DRIVING

What is "hard driving" as it applies to wood piles? Hard driving is a relative term depending largely on the type and energy of the hammer used, its ram weight, and the size of the pile. In the writer's opinion, ram weight and rated energy of steam hammers should not exceed 6,500 lbs. and 20,000 ft.-lbs. for Class B pile sizes or 8,000 lbs. and 24,000 ft.-lbs. for Class A pile sizes. We have found that the diesel hammers are less damaging to the heads of piles and have successfully used hammers up to 40,000 ft.-lbs. of energy. A hammer with energy rating less than 15,000 ft.-lbs. is not recommended, primarily for economic reasons. Limiting blow count should be a function of the hammer used; however, *continued* driving at more than 75 blows per foot would most likely result in damage to the pile at the tip if not at the head.

As a case in point, timber piles driven extremely hard through sand for a temporary trestle in Moss Landing, California, were found after excavation to have broken near the tip and the upper part driven past the lower portion. Thus the required penetration was never achieved. The pile heads were still in good shape. Pile damage of this sort could have been avoided by the use of several techniques described later in this article.

EQUIPMENT

The equipment used to drive wood piles should be suitable to accomplish the task to which it is put. It might be possible, as is occasionally done on smaller jobs, to get by with "jury-rigged" equipment; however, by and large, the equipment should be well designed and constructed.

Driving heads, preferably cast, should be well fitted, properly mounted and contained to prevent their becoming "cocked" on the pile head.

Leads should be straight and stiff, and secured in such a manner so as to prevent the inducement of lateral loads into the piles during driving. Long piles, especially when driven on a batter, should be supported at intermediate points.

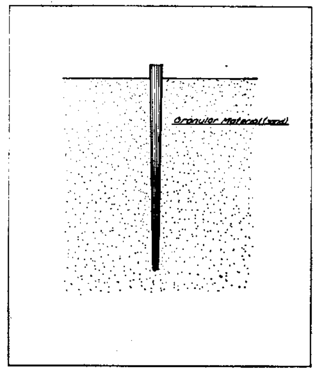


Figure 1

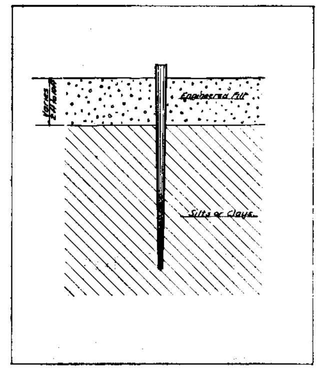


Figure 2

Cranes or derricks should be of sufficient capacity to maintain proper alignment of the leads and pile.

Other equipment as described elsewhere in this article.

INSTALLATION TECHNIQUES

To properly treat the various circumstances and conditions surrounding difficult driving, it might be well to divide piles into four separate groups.

A. Piles entirely in granular material. (Figure 1)

B. Piles driven through a hard surface layer. (Figure 2)

C. Piles which encounter high resistance to driving at mid-depths. (Figure 3)

D. Piles whose tips found in hard material. (Figure 4)

A. Piles driven their entire length in granular material generally are of the friction pile type, and must be installed to specified depths to satisfy soil design criteria. Drilling, jetting, or both, are practical means of accomplishing this task. Several methods of drilling are available to the pile driving contractor.

One, utilizing a hollow, rotating drill stem with a *fish-tail bit* simply churns the soil into a "quick" state prior to driving, permitting the pile to be driven through the liquified material. Water, to which bentonite* or drillers mud is frequently added, can be pumped through the drill stem to assist in the liquification, to prevent too rapid a lateral escape of the water, and to prevent the sides from sloughing. Drill-

*Bentonite, used for drilling, is an extremely absorbent sodium clay found in Wyoming and South Dakota. With water, it forms a gel which has the property of maintaining itself and other solids in solution. It weighs approximately 54 pounds per cubic foot and costs about $15.00 per ton, F.O.B. South Dakota. Proportion of bentonite to water for a given job is largely a matter of job site trial and error.

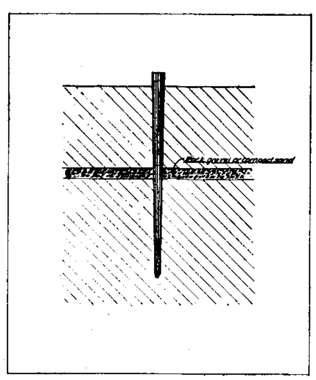


Figure 3

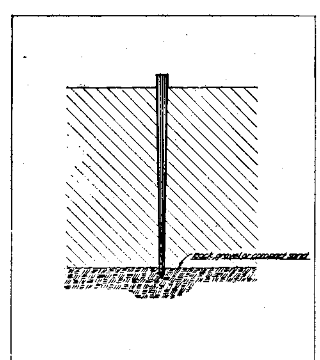
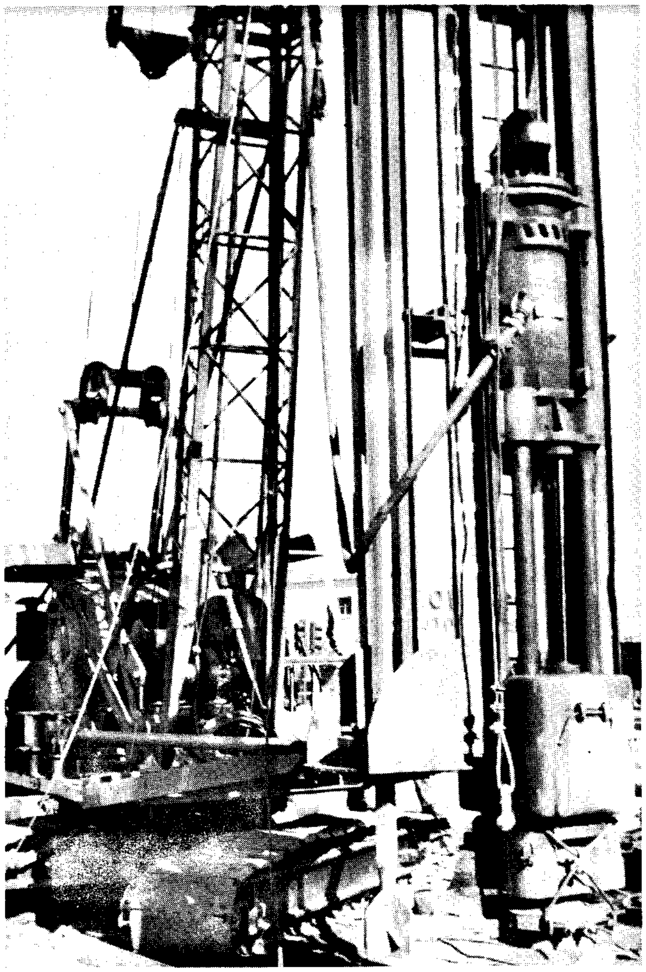


Figure 4



Fishtail bit mounted on side of pile driver leads. Power is supplied from the crane to the turntable of the drill. Drill is 12 inches in diameter and comprises four prongs.

ing in this manner does not produce spoil which must be removed, other than the displaced mud solution. The solution can be channeled to and collected in a retaining pond where it is reclaimed and reused.

The *auger method of drilling*, using either partial or full flight augers brings the soil to the surface, producing an open hole along which the pile is driven. The diameter of the hole may vary from a few inches to very nearly the maximum diameter of the pile. A bentonite solution frequently is used to keep the hole open, when the water table is high and there is possibility of sloughing.

Air, steam, electrical or hydraulic motors are available to power both the hollow stem fish-tail bit drill and the auger, with the nod going to hydraulic power, in the writer's opinion, because of control and adaptability.

A *rotary bucket rig* can be used economically for predrilling where the material is relatively hard and stable. In this method and that of the auger, provisions must be made for the disposal of the removed material.

Drilling can be performed with a separate drill rig working ahead of the pile driver, or the drill can be mounted on a steel H-beam, which in turn is fastened to the side of the pile leads. In the case of the latter, drilling and driving is done by the same rig. There are significant advantages to the driver mounted drill: one rig instead of two, reduction in labor force, the elimination of confusion and difficulty in coordination associated with too many pieces of equipment, and the hole needs to stand open for a shorter period of time, lessening the chance of cave-in.

Each job must be analyzed separately, however, to determine the best combination of drilling and driving operations.

The use of predrilled holes need not be used only for hard driving, but occasionally can be used to advantage to increase production when driving is moderate.

Drills for pile driving are largely custom made to satisfy the needs of a particular contractor — usually from standard drill components. A drill supply firm on the West Coast has recently interjected itself into the field of pile driving drills and furnishes a more or less standard leads-mounted drill using a rotating drill table, hydraulically powered, with a hydraulic swivel and hollow drill stem. The stem is flanged below the table to permit the attachment of various types of bits and augers. The crowd is either by gravity, cable or hydraulic. The cost of such a drill will vary with the size, speed and power required, but as an example, one which will produce 10,000 ft.-lbs. of torque would run in the neighborhood of $35,000.

The practice of predrilling is increasing in the San Francisco Bay Area. Piles installed in the sandy soils under the buildings of the Golden Gateway Project, Standard Oil Company, Wells Fargo Building Annex and other structures in the lower Market Street Area in San Francisco were driven in predrilled holes. Piles for these buildings were concrete; however, the techniques of installation were the same as they would have been for wood piles.

Pressure-creosoted wood piles for the approaches of a California Highway Bridge across the Sacramento River near Elkhorn were driven in predrilled holes. A fish-tail bit was used. Just as a matter of interest, the design bearing capacity of these piles was 45 tons.

When the specifications permit or require *jetting*, several methods are offered to the contractor. Similar to fish-tail bit drilling, pre-jetting can be used to "quicken" the soil. Working the jet pipe up and down in the location of the pile prior to driving is the most acceptable method of jetting, since it helps to maintain vertical alignment. It might be necessary to jet along the lower portion of the pile during driving. Care must be exercised in jetting in this manner since the pile tends to work sideways towards the jet. A double jet is preferable. Charges of compressed air can be introduced into the jet line to assist in the lubrication of the upper portion of the pile.

The *jet plant* must be large enough to do the job. The old adage — "don't send a boy to do a man's job" — is very apropos here. Too often a contractor will attempt to jet with undersized equipment. The writer recommends that the jet pump be capable of delivering a minimum of 700 GPM, preferably 1,000 GPM, at a pressure of 200-250 psi. Two or more pumps may be coupled in series or parallel to meet these requirements. Volume is generally more important than pressure. Three to four inch extra heavy pipe serves as a suitable jet, supplied by three inch hose. Double jacketed fire hose is relatively inexpensive and quite resistant to wear. If more volume is required, two hoses connected with a Siamese Coupling at the jet pipe can be used. Nozzle sizes will vary from ¾ inch to 1¼ inches diameter, depending on the pump size, quantity of water and pressure desired.

Larger jet plants are available. The plant described, however, would satisfy most requirements for wood piles.

Over jetting can be harmful in some soils where the fines are washed away leaving coarse, poorly graded sand or gravel, extremely hard to jet and drive through.

A unique method of jetting was utilized in driving wood piles for the three large piers of the W-X Bridge over the Sacramento River at Sacramento. The 40 foot long piles were to be driven through the silty sands of the river bed to a cut-off elevation of some 25 feet below the water surface. An underwater hammer was used, guided by a set of telescoping leads. The leaders of the telescope section were the jet pipes and preceded the pile tip by several feet. Jet water was shut off near the pile tip elevation and the piles driven the rest of the way with an underwater hammer.

B. The problem created by a hard stratum at the surface is generally easier to deal with. The hard stratum most frequently takes the form of an engineered fill placed over poor subsoil to support all but structure or other concentrated loads. In some instances instead of engineered fill, an old dump ground might be encountered. The ingredients of a dump are well known; brick, broken concrete, car bodies and the like. The depth of strata considered here can range from two to 20 feet.

Spudding is the most effective means to penetrate the hard layer. A short, strong, relatively heavy length of pipe or boxed H-beam equipped with proper head and point is driven through the fill and withdrawn. The pile is then driven through the resulting hole. To avoid "sticking" the spud it is good practice to drive and pull the spud in several short increments rather than driving full depth at the outset.

Predrilling holes with a bucket drill or auger works satisfactorily but is generally more expensive. This type of drilling can be done ahead of the pile driver since the holes are not deep. In the compacted fill the holes remain open for a considerable length of time.

The size of the drilled holes is generally a few inches less than the largest diameter of the pile.

If large rocks are encountered, a cable tool rig can be used to drill through, or the rocks removed by excavation.

It is frequently possible to drive piles through several feet of compacted fill without spudding or drilling provided the piles are not too long. Pile tips should be protected with shoes.

The contractor has a choice of shoes or pile tips from which to select. The preferred type for punching through thin hard layers or for seating in rock is shown in Figure 5. This is a pressed metal type, inexpensive and easy to install, nailing on to the tip which has been shaped to a four sided point by axe or saw.

The pointed type of shoe is more subject to deflection by obstructions than other shoes, and if large rocks or other similar obstructions are anticipated, the flat plate shoe, Figure 6, could be used.

Cladding the tip of the pile with several thicknesses of wire mesh, Figure 7, has been used recently but reports of the results are not sufficiently conclusive to comment on.

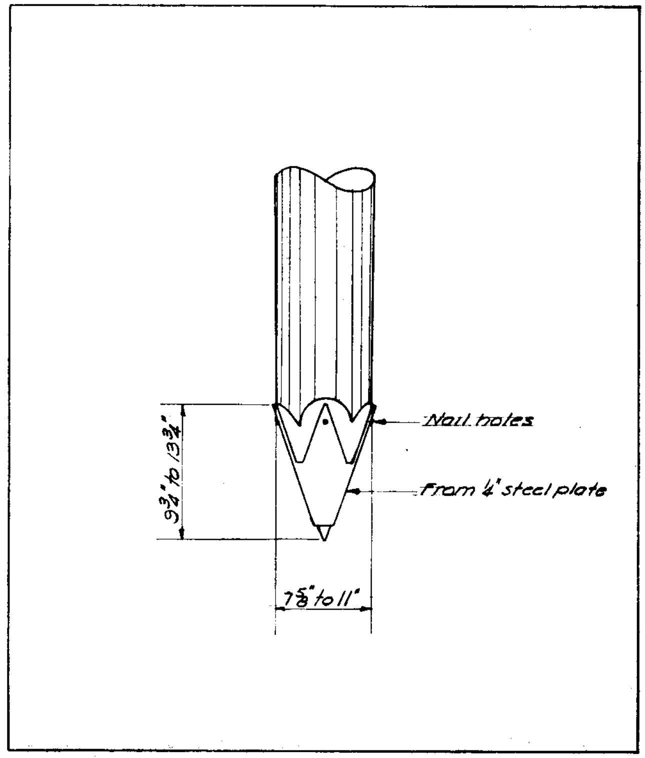


Figure 5

A type of shoe consisting of a short pipe sleeve inserted on the pile requires cutting and shaping so piles thus shod frequently break just above the pipe. This practice is not recommended.

Because many buildings and structures are located on soft marine or alluvial deposits reclaimed through the use of surface fills, this type of pile installation is very common and satisfactory.

An example of spudding in reverse was the case of the test piles on the Embarcadero Freeway in San Francisco. The test piles were 14 inch H-pile sections over 200 feet long to be driven through 60 to 70 feet of very soft "bay-mud" at the surface. Since the "gatherings" of many years (old ship hulls, logs, dump grounds, rocks, etc.) were expected to make driving difficult, the specifications called for spudding to 60 feet before driving. The contractor successfully used a *large wood pile* 70 feet long as a spud. The tip was not protected and the spud used several times with no damage.

C. Hard layers encountered at elevations too deep to spud through are troublesome, to say the least, no matter what type of pile is used. These hard layers are generally either rock, rock-like material, sand or gravel. If rock or cobble-type gravel is met, the writer can offer no practical solution. Sand and reasonably small gravel layers can be jetted through. In some cases drilling without the removal of the material as previously described can be employed, or the piles can be driven through the layer of hard material if not too thick. Timber foundation piles for a structure in the Port of Sacramento were successfully driven through a

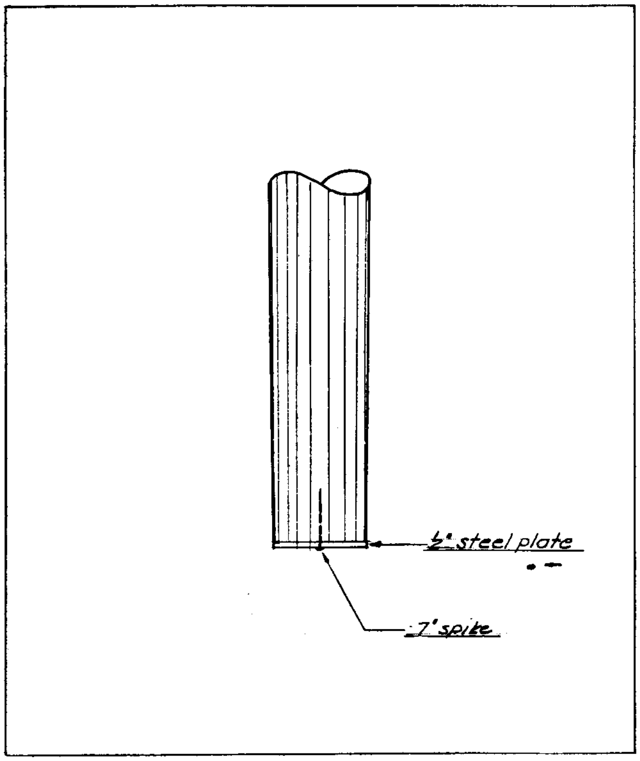


Figure 6

hard layer met about 30 to 40 feet below the surface with blow counts to 150 per foot with a 24,000 ft.-lb. hammer. Pile shoes are preferable for installations of this sort.

D. When wood piles are driven into hard layers at their tips, two important rules must be adhered to. The piles must not be overdriven in attempting to achieve penetration, and the pile tips should be protected. A properly shaped pile head and a well fitting driving head will protect the pile from damage at the top. However, when a greater part of the driving energy is transmitted to the tip, considerable damage can result. Those people who write piling specifications should be cognizant of this possibility and not specify excessive penetration into hard material, i.e., "three feet into bed rock." As previously discussed, no general rule of thumb maximum blow count can be given here, since bearing capacity, size and type of hammer, and soil characteristics must all be taken into consideration. In no case, however, should the blow count be so severe as to damage the pile tip.

While the writer's experience is limited as to the use of vibratory hammer, except in the case of wood pile extraction, this type of hammer should not be overlooked as a solution of hard driving problems.

There are two items which, although not in the same category as hammers, drills or soils, are nonetheless vitally related to the subject. They are *soils reports* and *inspection.*

Careful analysis of the soils report made for a particular job will assist in the selection of the proper tools for driving. Realizing that sometimes there is a lack of similarity between soil descriptions on the drill logs and what might actually be encountered in the field, or that insufficient borings were taken to permit even a general extrapolation, the soils report still remains the best guide for a contractor faced with driving piles in a new area.

Pile driving inspection by untrained and inexperienced people can nullify all the careful plans and procedures made to that point to insure the proper installation of piles. At times, it seems almost common practice for soils firms to place newly-hired engineers on pile driving jobs to "cut their teeth" in the soils business. It is a frustrating experience to be required to beat a pile to pieces in order to get that last three inches of penetration — or conversely, to stand by with an idle crew and driver waiting for the inspector to return from his office with the decision as to whether or not the pile you have driven is acceptable. Experienced inspection is just as much a tool in getting piles down in hard material as is a drill, spud, pile shoe or jet.

SUMMARY

In summary, then, to insure the successful installation of timber piles in hard materials, the following rules should be observed:

1. Use piles of the best quality with bands at head and tip. Provide shoes if piles are to be driven through or into hard material.
2. Read the soils report and study the drill logs.
3. Use properly designed driving equipment compatible with the pile to be driven, its required capacity and the soils through which it must penetrate. A well fitted and guided driving head is most important.
4. Use well engineered installation aids, drilling, spudding, jetting, etc., as required.
5. Employ experienced foremen and insist on competent pile inspectors. ■

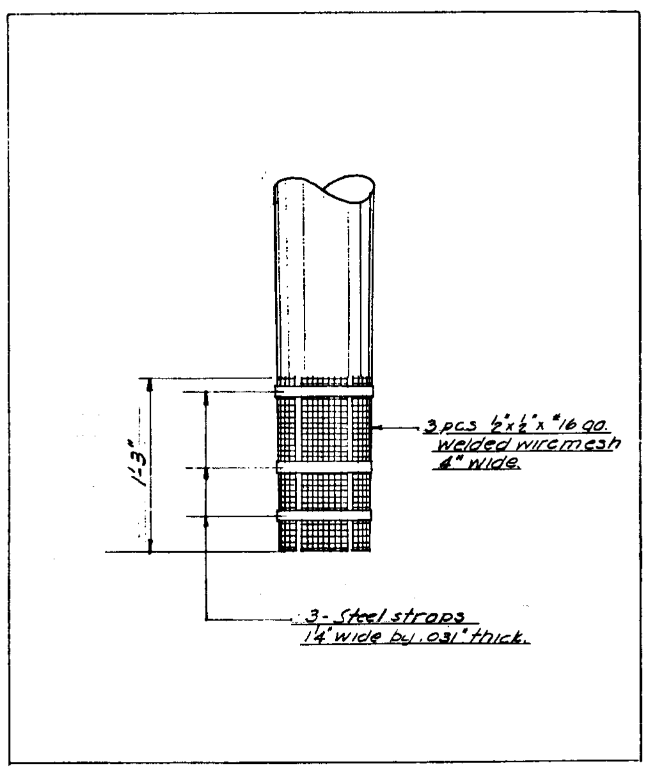


Figure 7