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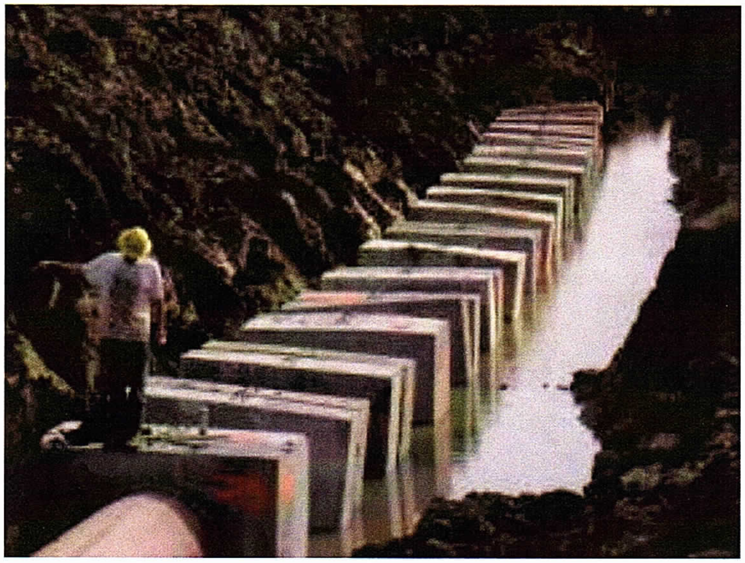

Concrete Set-on Weights

BKW Auger Anchor

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BKW, Inc. is proud to present this booklet containing engineering design and specifications for pipeline anchoring. BKW is available to provide your company with the most efficient anchoring system to meet your needs.

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TABLE OF CONTENTS

Modern Pipeline Construction

The Art Of Pipeline Anchoring

Part 1

by Brian C. Webb, *Senior Engineer, Williams Brothers Engineering Company, Tulsa, Oklahoma*

Pipeline anchoring is like any other facet of pipeline design, the more you study the subject the more you realize there is more to learn. The rule of thumb for the specific gravity of pipelines in swamps is 1.3. This is permissible if the swamp is very small. However, if the swamp crossing is half the total length of the pipeline then concern should be given to using rule of thumb formulas; in some cases, it might cost you several million dollars.

To better understand pipeline anchoring and the problems involved, a brief history is presented to show how it evolved into the present state of the art.

When pipelines were first constructed, they crossed rivers and swamps practically by themselves. If they couldn't be hung from trees, they were laid on the bottom and were repaired when washed away. The pipelines were usually liquid lines and of small diameter and would usually sink.

When sophistication was required to cross a major river, the pipeline was weighted with anything available such as concrete or cast iron weights. As pipelining techniques progressed, iron cast in the form of a bolt-on weight became popular, but as the pipeline diameters increased, the cost of cast iron increased to the point that concrete bolt-on weights began to phase them out.

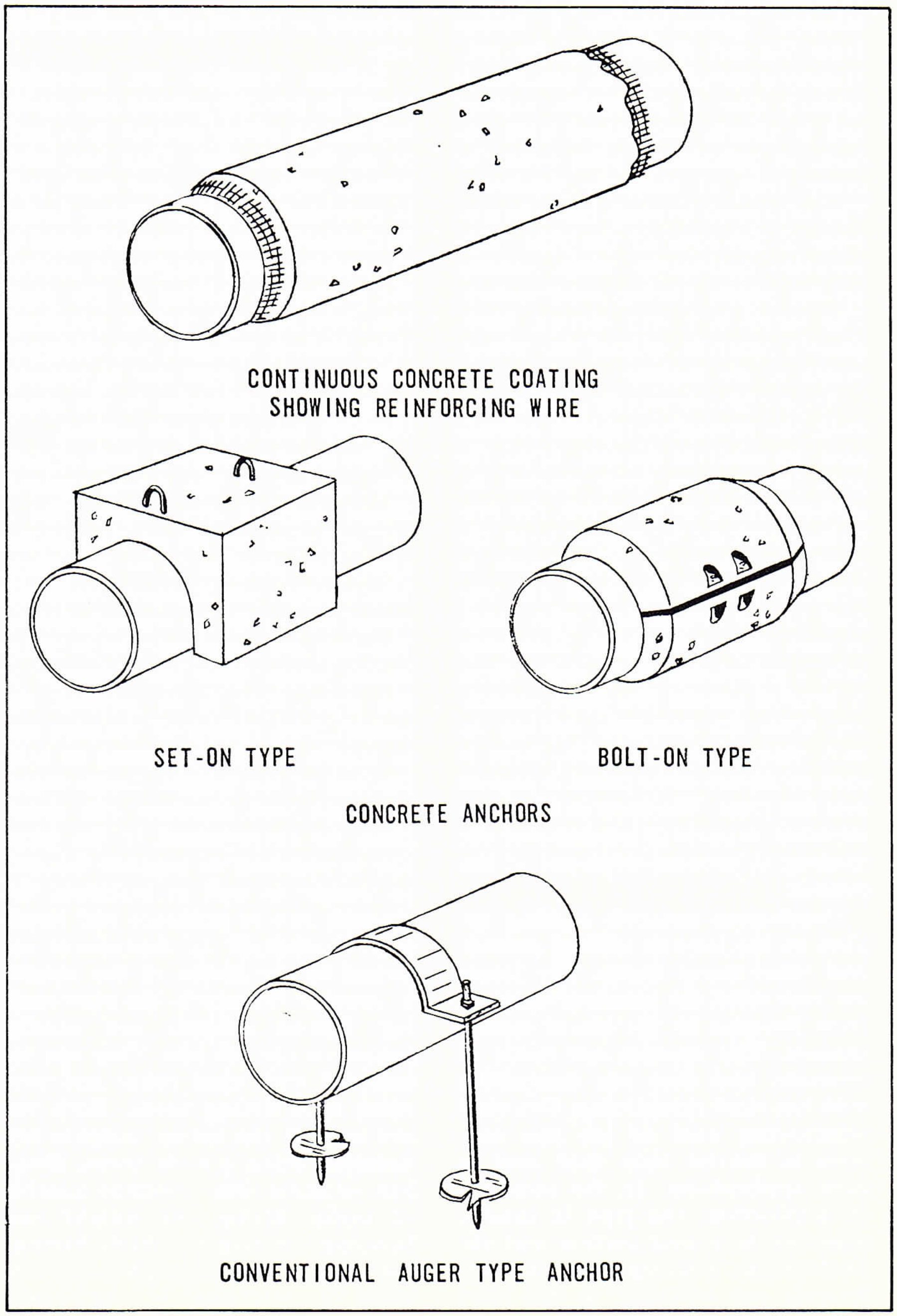
As large diameter pipelines began to cross swamp areas, the concrete bolt-on weight was replaced by concrete set-on weight because of lower costs.

The technique of offshore pipeline construction called for still another form of anchoring because present methods were not compatible with laying methods and the continuous concrete-coating anchoring system was developed.

Pipeline stabilization, or anchoring, can be defined as an anchoring system designed to maintain the pipeline in a desired position relative to the surrounding environment and subject to the various forces acting on the pipeline. Because of the many demands on the anchoring system, the anchors can take many forms and combinations.

Two Basic Types

Anchors currently available for pipelines consist of two basic types: density and mechanical. The density anchor simply consists of weight added to the pipeline to increase the average density or negative buoyancy to some acceptable level that will be stable under prevailing conditions. These anchors are usually concrete and take the form of either bolt-on weights, set-on weights, or a continuous concrete coating. In contrast, mechan-



Various types of density anchors and a conventional mechanical anchor.

ical anchors are usually fabricated from steel and not designed to add weight. They maintain a minimum hold-down force on the pipe when properly installed in the soil. Because the holding power of mechanical anchors is much greater than their own weight, they are significantly more efficient, by weight, than density anchors. As may be seen, this fact becomes very important in the design of anchoring systems for large diameter lines.

Continuous concrete coating is described as a coating of concrete completely encompassing the pipe. It can be applied either in a coating yard with special equipment or on the job site. In yard applications, continuous concrete coating can be extruded or applied with air, brushes, belts, or steam. It is terminated approximately 9 inches from the end of the joint for construction purposes. The concrete is applied over a protective coating and is usually reinforced with one layer of galvanized wire mesh for every inch of concrete thickness. The wire mesh extends past the concrete at the ends of the pipe. This provides continuity when making up the joints during construction. The result is a very strong, high-density concrete, void of any honeycombs or air pockets.

To provide continuity at the joint ends, the protective coating extends past the concrete coating. After the pipe joints have been welded together during construction, the protective coating is applied over the joint. A layer of wire mesh is wrapped around the joint and stapled to the protruding wire mesh on each side of the joint. Following this, a galvanized sheet metal form is banded around the joint extending from the concrete coating on each side of the joint. The form is open at the top and cement is poured into the form. The form is filled and vibrated. A cover is banded over the opening to prevent wash-out of the cement.

Continuous concrete coating applied at the job site utilizes galvanized sheet metal forms. The forms are separated the required distance from the pipe by the use of special spacers. The spacers are made of concrete, and they are compatible with the steel reinforcing. The steel reinforcing used in job site concrete is heavier than that used in yard applications. In the sequence of application, the pipe is usually made up in a long section and the protective coating is applied. Spacers are attached to the steel reinforcing and the steel reinforcing is wrapped around the pipe and stapled together.

Sheet metal forms are banded around the steel reinforcing with the top open. Cement is poured into the top and the forms vibrated. Covers are not necessary, and after the cement has set, the forms are removed.

Joints are prepared in the same manner as yard applied concrete. Job site continuous concrete coating is not as strong or dense as yard applied concrete, but it is adequate for anchoring.

Another type of density anchor is the bolt-on concrete weight. Bolt-on weights are built in two halves and designed to be clamped on the pipeline. The two halves are held together with long bolts. The bolts are hot dipped galvanized to prevent corrosion and eventual failure.

Bolt-on weights are manufactured by pouring cement into molds and can be either poured in a yard or on the job site. They are reinforced with rebar, and each half is provided with two lifting hooks. Rockshield is sometimes attached to the inside of the weights to protect the protective coating on the pipeline from damage during construction. Bolt-on weights are designed with bevels on each end to prevent snagging on obstacles in the event they are used on a pull section.

The most economical form of density anchor is the set-on weight. These weights are shaped like a "U" and they are set on the pipeline after the pipeline is in the ditch. The weights are designed with the center of gravity as low as possible. The legs are designed two to three inches longer than the diameter of the pipe. This is to prevent the weight from rolling off the pipe and to enable the ditch bottom to take the load of the weight. Large diameter thin wall pipelines can sometimes be overstressed if the pipeline is required to support the set-on weight as well as maintain the stresses due to pressure and bending. Rockshield is sometimes attached to the inside of the weight to prevent damage to the pipe coating. Set-on weights are usually poured on the job site. They are reinforced with steel rebar and provided with lifting hooks. Both the bolt-on and the set-on weights are installed using a slide boom, dragline, or some other machine capable of easily lifting the weight and booming out over the ditch. Stringing of the larger weights can become a problem in extremely marshy areas. The contractor will usually resort to using all-terrain vehicles (ATV) to string weights from stockpiles.

Concrete Density Important

The efficiency of density anchorage can be increased by increasing the density of the concrete. This is accomplished by increasing the density of the aggregate. Standard densities for concrete are 140#/ft^3, 165#/ft^3, and 190#/ft^3. However, any increase in density is recommended provided the cost is not prohibitive. Before selecting the density of concrete, a thorough study should be made to determine the one most efficient and economical.

Mechanical Anchors

Mechanical anchors differentiate from density anchors in that they derive their holding power from the shear strength of the soil. They are inserted into the soil and attached to the pipeline. They are usually made of steel and are either pile, auger, or expanding type.

Piles are usually made of steel pipe but they have, on occasion, been made out of wooden posts, railroad rails, and channel iron. The piles are driven alongside of the pipeline and attached to the pipe with some form of strap. Pile-type anchors are reliable, but the high cost of installation usually prohibits their use.

The most commonly used type of mechanical anchor is the auger type. This anchor consists of round steel plate shaped like an auger and attached to the end of a long steel rod. The other end of the rod is threaded for attachment to the pipeline.

This system consists of two anchors and strap shaped to fit the pipeline. Installation consists of installing an anchor on each side of the pipeline and attaching the strap to both anchors. The formed strap fits snugly over the pipeline securing it in place. The strap is usually padded to protect the corrosion control coating. The anchors and strap are hot dipper galvanized to prevent corrosion and eventual failure.

Small magnesium anodes can be attached to each anchor to increase corrosion protection. In most applications the anchor will last as long as necessary for the backfill to compact and gain sufficient shear strength to hold the pipeline in place.

The auger anchors are installed by rotating the rod. The auger shaped disk will pull the anchor into the soil to the required depth. Torque applied to the rod is usually with some type of high torque motor. In field application, the motor is powered by electricity, air or hydraulic power. In large anchor installations, the motor is sometimes hung on a sideboom or dragline because the weight of the motor cannot be handled by hand.

Auger anchors come in various sizes from 6-in. to 24-in. diameters and can be used in clays, sands, gravels, or any other unconsolidated material.

The selection of size is dependent upon the shear strength of the soil. The length of rod or depth necessary to obtain the minimum hold-down power is dependent upon the soil investigation. In most swamp areas the soil was deposited in layers and each layer will have different characteristics. Around 20 feet is the maximum depth the mechanical anchors can efficiently penetrate. If more depth is necessary, extensions can be added to acquire more penetration. However, the friction loss becomes so large that the required torque will cause failure in the rod.

Anchors should be installed a minimum of 8 feet to obtain the required hold-down. Any depth short of 8 feet, the weight of the soil overburden determines the hold-down rather than the soil shear strength.

The anchor spacing will be dependent upon the maximum hold-down strength of the soil and the selected density. Anchor size and depth should be selected that will give a minimum of 10,000-lb. hold-down. Knowing the minimum density, the spacing is easily calculated.

Expanding Anchors

Expanding mechanical anchors are used in the same manner as the auger type. The anchor rod has flukes on one end that are hinged in such a way as to expand outward from the rod. Most are expanded by turning the threaded anchor rod which is run through a nut in the center of the flukes. As the rod is turned, the flukes are pushed by the nut and are expanded by jamming against a cam plate that forces the flukes outward.

The expanding anchor is installed in two ways. One method is to bore a hole to the desired depth and drop the anchor into the hole. The anchor is then expanded and attached to the pipeline. The second method is to apply sufficient axial load to the anchor to force it to make its own hole. When forced to the desired depth, the anchor is expanded.

The axial load will be approximately 1000 to 2000 lb, depending on type of soil and anchor size.

Expanding anchors can be installed with less torque than the auger types. This is because the diameter of the expanding type is considerably less than the auger type for the same hold-down power. Expanding anchors can also be installed in areas where rocks are mixed in the soil.

In peat bog type swamps or other areas where the soil has low shear strength, the expanding anchor can be made very large with tandem flukes. This gives a large area to the anchor without sacrificing easy installation.

The efficiency of mechanical anchors is far greater than the density type. The usual minimum hold-down force in average soil for a mechanical anchor weighing 50 lb is 10,000 lb. The equivalent amount of 140 lb/ft^3 concrete to provide 10,000 lb hold-down in water is 18,000 lb. For 10,000 lb hold-down in a specific gravity medium of 1.20, the equivalent amount of concrete is 21,500 lb. As this indicates, the cost of stabilizing large diameter natural gas pipelines can be greatly reduced by using mechanical anchors.

For example, the cost of anchoring a 36-in. natural gas pipeline using density anchors is approximately \$17.00 per ft. The cost using mechanical anchors is approximately \$7.00 per ft. Therefore, the additional cost of using density anchors is approximately \$53,000.00 per mile.

Even though mechanical anchors are cheaper than density type they have not been used to any extent. The largest drawback to their acceptance is reliability. Mechanical anchors are seldom tested after installation, and whether they achieve sufficient hold-down is usually in question. Some formulation has been derived to ascertain hold-down from the torque required during installation, but this method has not been known to be completely fail-safe. In some cases the pipeline has floated after installation or density anchors were called in to replace the mechanical anchors when it was found they could not be installed. Incidences such as these have helped give mechanical anchors a bad reputation.

Another drawback to mechanical anchors is the type of soil and terrain in which installation is required. Various types of soils such as sands, clays, gravels, and peat-bogs all require a different type anchor to achieve the required hold-down. Solid rock, shale, and gravels with large boulders present installation problems.

Where To Use Anchorage

The four major areas traversed by pipelines that need stabilization are marine, rivers, swamps, and permafrost. Each area presents a different type of environment for the pipeline and a different type of construction technique. Consideration should be given to both in the design of anchorage.

Marine pipelines are considered to be those constructed in a marine or open water environment. Small diameter pipelines are usually designed with sufficient wall thickness to assure the required specific gravity. However, in large diameter pipelines the cost of increasing the wall thickness is prohibitive, thus requiring some form of additional anchorage. The most commonly used anchorage is continuous concrete coating. This anchorage is best adapted to offshore pipeline construction techniques such as the lay barge or pull methods.

The coated joints can be shipped to the lay barge or job site, welded together, and either lowered to the bottom or pulled across.

In lay barge construction, the continuous concrete coating provides a smooth, uniform surface for the pipe shoes and tensioning devices. It also serves as a protective shield against marine growth and external damage from construction and burying operations.

The design of the anchoring with continuous concrete coating begins by determining the minimum amount of concrete to provide negative buoyancy with the pipeline empty. Added to this is the amount of anchorage required to hold the pipeline in place because of the maximum anticipated current velocities and densities of the water. These currents can be caused by tides, storms, waves, or any other reason unique to the area. The density is a combination of the water and the solutes being carried by the water.

To Be Continued Next Month

The Art Of Pipeline Anchoring

Part 2

by Brian C. Webb, *Senior Engineer, Williams Brothers Engineering Company, Tulsa, Oklahoma*

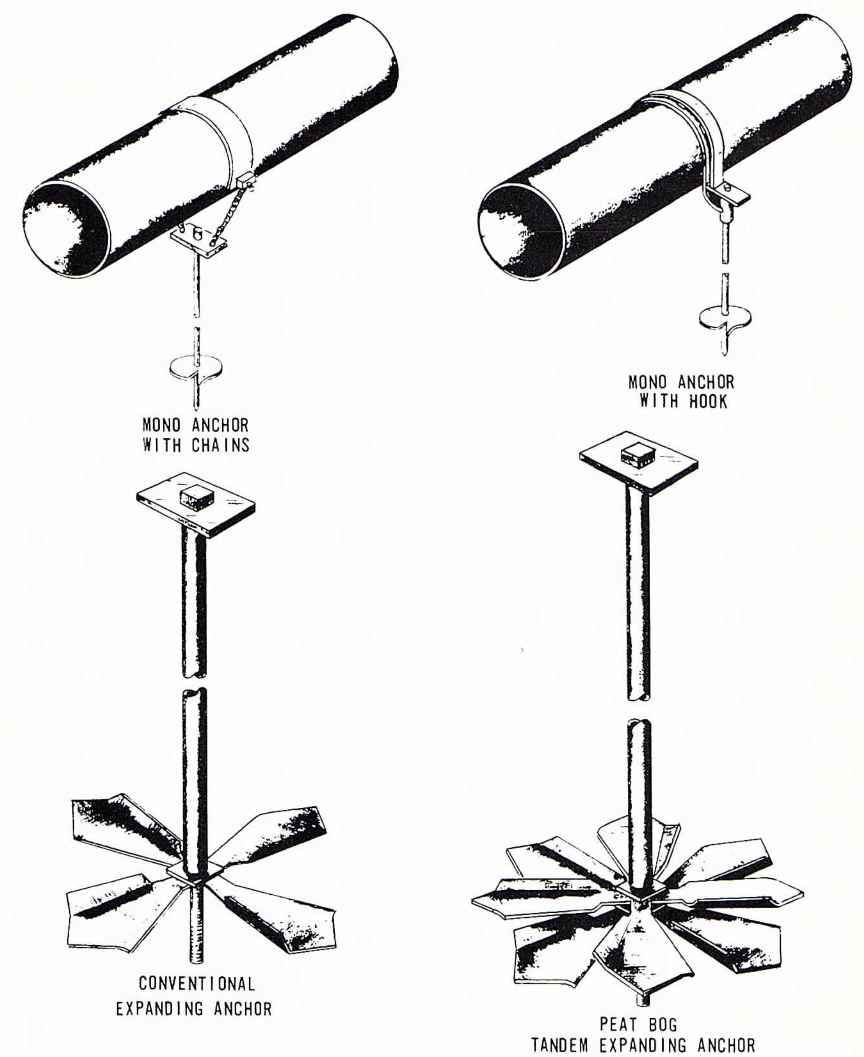
The formula for the minimum negative buoyancy required to maintain a pipe resting on the bottom expressed as a function of the current velocity vector perpendicular to the axis of the pipe is as follows:

$$W = \frac{V^2 K D \rho}{2}$$

W = negative buoyancy of pipe (lb/ft)
ρ = density of water (slugs/ft^3)
V = maximum velocity of water (ft/sec)
D = outside diameter of pipe including concrete (ft)
K = coefficient of drag, lift and friction between the bottom and the pipe.

Other considerations will include the type of service for the pipeline and the depth of burial, if any. For example, if the pipeline is to be used in liquid service and it is to be sufficiently buried to prevent ship anchor damage instead of bottom scour, then current velocities considerations should be excluded and only sufficient negative buoyancy used to enable burial.

Another consideration is the thixotrophic characteristics of the bottom and backfill. If the backfill material becomes a liquid with a minimum of agitation, then the density of the material may become greater than the pipeline, causing it to float out of the ditch. Therefore, all marine pipelines are unique and must be carefully studied in order to obtain the most efficient method of anchorage. The following formula will provide the minimum concrete thickness required for continuous concrete coating when the minimum specific gravity is known.



Various types of mechanical anchors.

$$\text{Sp. Gr.} = \frac{\text{Wt of Pipe} + \text{Concrete}}{\text{Wt of Water Displaced}}$$

$$\text{Concrete Thickness} = \frac{\sqrt{\dfrac{4W_p - \pi (D_i)^2 (D_c)}{\pi (S.G.)(D_w) - \pi (D_c)}} - D_i}{2}$$

W_p = wt of pipe and coating per foot
D_c = density of concrete
D_w = density of water
D_i = inside diameter of concrete
S.G. = specific gravity

The design of anchorage for pipelines crossing rivers is similar to those offshore. The size of the river and the anticipated construction technique is to be considered when selecting a type of anchorage. For small rivers and streams, the construction technique is usually to make up the river section on the bank and then walk the section across the river with side booms. Concrete bolt-on weights are usually used for this type of anchorage. These weights can be either manufactured on the job site or shipped in from a plant and attached to the river section. It is generally more economical than continuous concrete coating if applied at the job site.

The pipeline should be wrapped

with rockshield before attaching the weights in order to prevent damage to the protective coating.

A major river crossing is one in which the river section must be pulled across instead of walked across with side booms. The selection of anchorage in this case is usually continuous concrete coating. In some cases, concrete bolt-on weights are used, but the dangers of hanging a weight on a submerged object and sliding the weights on the pipeline usually rule out concrete bolt-ons. If they are selected for use, it is important that they be secured to the pipe by the use of a steel cable attached to each weight. This is in addition to the wood lattice separating each weight. Unless the cost is prohibitive, most pull sections should be anchored with continuous concrete coating.

River crossings are designed to be stable during periods of the maximum velocity of the water. This maximum velocity occurs when the river is on the rise and cresting. During this period, the bottom of the river drops because of the scouring action of the water. The pipeline should be buried to a depth below the maximum scour depth. On rare occasions, some major rivers can scour to depths of 100 ft. Design for this condition is prohibitive but it does indicate the importance of extensive investigation of each river crossing.

In calculating the negative buoyancy, the additional density of the water resulting from bottom movement is very important. The minimum negative buoyancy of the pipeline as a function of current velocity is the same as for offshore. Another consideration is the density of the backfill. If it is a type of soil that becomes soupy when moved, it will float the pipeline out of the ditch unless sufficient anchorage is provided.

Swamp Pipelines

Swamp pipelines are probably the most underdesigned of the three areas needing pipeline anchorage. There are two types of swamps to be considered. The first is the type that has a clay or sand soil covered with a thin layer of low shear strength mud. This type of swamp is usually in a flood plain and is formed as a sedimentary deposit from a river. It is usually found in the southern part of the United States.

The other type of swamp is the so-called peat bog, which consists of a deep layer of semi-decomposed organic material which cannot complete decomposition because of cold climates. This type of swamp is not associated with a river but is usually a low spot in the terrain formed by glacial action. This low spot is usually in the process of filling up with some type of organic material. Peat bogs will sometimes have some clays and sands mixed in giving the soil some shear strength. The bottoms of peat bogs or the underlying soil with good shear strengths can range as deep as 80 to 90 ft. This type of swamp is found in the northern United States.

The design of anchorage in swamps is based entirely on densities and methods of construction. In areas where the pipeline is to be pulled or laid from a lay barge, the pipe is usually anchored with continuous concrete coating. This type of anchorage is most compatible with construction operations. In areas where the pipeline is to be constructed using conventional land lay methods, the anchoring is usually concrete set-on weights.

Selecting the density in either case is dependent upon the density of the environment, whether the pipeline is to be backfilled or not. For pipelines to be left open, the soil composition of the ditch wall and any soil likely to settle on the pipeline should be investigated. The shear strength of the ditch walls should be considered to determine if sluffing will float the pipe up. Ditch design will affect the amount of wall sluffing and anchorage necessary to obtain stabilization.

For pipelines to be backfilled, the density and shear strength of the backfill should be considered. Whether the pipeline is backfilled or left open, the density of the pipeline should be sufficient to keep it from floating in the event the backfill or ditch walls should become a soupy mud. Careful investigation should be made to determine the properties of the soil and the amount of agitation necessary to make it thixotropic. If the shear strength of the soil with anticipated agitation remains high, the total density of the pipeline can be reduced with a considerable savings in anchorage cost.

In peat swamps, settling of the pipeline must be considered. The soils in these areas sometimes have no shear strength, and anchoring the pipeline in these swamps is similar to attempting to suspend a pipeline under the surface of the water. In this case, the density of the swamp must be considered, and the pipeline density must be only slightly negative. This can be especially difficult when designing anchorage for liquids pipeline, since the pipeline must remain stable both empty and full.

In some cases, the ditch across swamps can be full of water. If this condition is known beforehand and the section is very long, it might be necessary to use bolt-on weights. Set-on weights can be used providing the water depth is not too deep; however, caution should be exercised when installing the weights so the pipe coating is not damaged. In some cases, the pipeline may have to be flooded to get the line into the required position. This occurs when the soil is too soft to hold up ditch walls and the line has already been laid and raised by sluffing.

The following formulas can be of help in determining spacing for concrete bolt-on or set-on weights.

$$\text{Sp. gr.} = \frac{\text{Wt of Pipe} + \text{Concrete}}{\text{Wt of Water Displaced}}$$

$$\text{S. G.} = \frac{(\text{Wt. of Pipe/ft})\,(\text{ft}) + (\text{Wt. of conc wt.})}{\left[(\text{Vol. of Pipe/ft})\,(\text{ft}) + \left(\frac{\text{Wt. of conc. wt.}}{\text{Den. of conc.}}\right)\right]\text{Density of water}}$$

$$\text{Spacing (ft)} = \frac{(\text{Wt}_c) - (\text{S.G.})\,(D_w)\left(\frac{\text{Wt}_c}{D_c}\right)}{(\text{S.G.})\,(D_w)\,(\text{V p/ft}) - (\text{W p/ft})}$$

Wt_c = total weight of concrete weight in air.

S. G. = desired specific gravity.

D_w = density of water.

D_c = density of concrete.

V p/ft = volume of outside diameter of pipe per foot.

W p/ft = weight of pipe per foot.

(NOTE: The buoyancy effect of the coating material has been neglected.)

In the design of anchorage for swamps, mechanical anchors should be used whenever possible since the installed cost of mechanical anchors is approximately half the installed cost of concrete set-on weights. The specific gravity for mechanical anchors is determined in the same manner as for density anchors. The formula for determining the spacing of mechanical anchors is as follows:

$$\text{Specific Gravity} = \frac{(\text{Wt of Pipe/ft})(\text{Anchor Spacing}) + \text{Anchor Hold Down}}{\text{Wt. of Water Displaced}}$$

$$\text{Anchor Spacing} = \frac{(A_p)}{\frac{\pi}{4}(\text{S.G.})D^2D_w - \text{W p/ft}}$$

A_p = minimum anchor hold down power
S. G. = specific gravity
D = outside diameter of the pipe plus coating
D_w = density of water
W p/ft = weight of pipe plus coating per foot

Spacing of the mechanical anchors in small diameter pipelines is sometimes limited to the bending moments of the pipe. If a high specific gravity is anticipated, the stress due to anchor bending moments plus the stress from internal pressure may exceed the allowance set by the design codes.

Permafrost Anchoring

Anchoring pipelines in permafrost areas differs from other environments because the primary reason for anchoring is not hydraulic. Hydraulic anchoring is used only on below ground installations and under rivers and streams. Since the permafrost is frozen most of the year, flotation is only one of the forces affecting the pipe. Other forces affecting the pipeline are frost heaves and restraining forces due to expansion and contraction of the pipeline because of temperature change.

The active layer of the permafrost has very little shear strength when it is thawed. Because of this, the soil backfill cannot be depended upon to compact and increase in shear strength as time goes on. Therefore, the design of the anchoring system must be capable of lasting as long as the life of the pipeline.

Frost heave and pipeline restraining loads should be carefully considered if incorporated into the anchoring system. This is a special design problem and not within the scope of this article.

Mechanical anchors used in permafrost on hot oil or gas pipelines should be insulated from the pipeline. The heat will conduct down the anchor rod and eventually thaw the soil surrounding the anchor and cause failure.

Mechanical anchors are installed in permafrost by boring a hole with a boring tool or by using a steam lance. After the hole has been made the anchor is lowered to the desired depth and allowed to freeze. After the anchor has frozen to the soil it is ready to be connected to the pipeline.

Mechanical Anchor Installation

In an effort to solve the major problems with mechanical anchors, a new system has been developed for the pipeline business. The system is unique in that it is an engineered system designed to give the reliability of density anchors at the cost of mechanical anchors. It is an anchoring system that is designed to use standard pipeline equipment and techniques for installation purposes. A description of the system is as follows:

A hydraulic backhoe is the instrument used for installation. The backhoe is highly mobile and is capable of traversing swamp areas. The backhoe also provides the power necessary to activate the installation tools and it is the size commonly used in pipeline construction. The bucket is removed from the hoe, and an anchor installation tool is attached in its place. This tool is a special piece of equipment that is designed to install both expanding and auger-type anchors. It is all-hydraulic operated, and it can provide the required torque.

Hydraulic lines are attached to the boom and run from the cab of the hoe to the tool. A console is attached inside the cab and hydraulic lines attached to the console. Hydraulic lines are also tied-in to the hydraulic system of the backhoe. The console contains all the control valves for the anchoring tool and it has a load gage and load recorder. The installation tool has a built-in load cell to record upward force on the tool, and the cell is connected to the gage and recorder.

A sled loaded with anchors is attached to the hoe, and the hoe pulls the sled down the right-of-way. When the hoe reaches a location requiring an anchor, the hoe swings around, picks up an anchor from the sled, and swings out over the ditch. It places the anchor in the desired location and installs the anchor to the desired depth by applying a downward force and rotating the anchor, forcing the anchor to bore its own hole.

When the anchor is installed, the hoe exerts an upward force on the anchor and preloads it. The force is increased to the minimum required, and it is recorded on the load recorder. The station number is written on the recording chart, giving a permanent record of the minimum load, location, and day. It is then signed by the company representative as a witness.

During installation, the mechanical anchor is preloaded. This prevents a rise in the pipeline because of anchor loading. A mechanical anchor will usually travel from 4 to 6 inches before the soil has compressed sufficiently to obtain the required minimum hold down.

Following the installation and testing of the anchor, the process is repeated at the next anchor location.

Various methods of attaching the anchor to the pipeline are available with the system. Since the system can install either auger or expanding-type anchors, the methods of attaching anchors can use either type.

The first method for attaching the anchors to the pipeline is the conventional method. This method has been described previously.

The second method is designed for use in northern areas where winter construction is necessary. It is called the "mono anchor with chains." In this method, the anchor is installed immediately following the ditching operation and before the ditch has had time to freeze to the point the anchors cannot penetrate the ground. Two chains are attached to the top of the anchor, and the ends of the chains are staked to each side of the ditch. After the pipeline has been constructed and laid in the ditch, a second backhoe with a special tool installs a strap.

This special tool is an all-hydraulic tool equipped with two winches designed to be compatible with winching chains. The backhoe also pulls a sled loaded with straps. The hoe swings around and attaches a strap to the tool. The hoe swings over the ditch, and swamps run the chains through a ratchet latch on the strap and attach the chains to the winches.

The hoe will winch the strap onto the pipe, making a snug fit. The tool is equipped with chain shears and will shear the chain to free the tool from the pipe and anchor. The hoe will then swing the tool to a swamper at the sled who will remove the excess chain, and the process will be repeated.

The third method is for small diameter pipelines of 24-in. O.D. and less and is for use in areas with good soil. The system is called "mono anchor with hook." It uses a single anchor installed next to the pipeline. This anchor has a padded hook at the top that is shaped to fit the pipe, and the hook is set over the pipeline.

The hook is designed in such a way that in the event the pipeline attempts to float, the anchor will equalize the hold-down force with the buoyancy force. An advantage to this anchor is that it requires less anchor spacing than the more conventional dual attachments. This makes a more efficient anchoring system and reduces the cost of anchoring because it does not require personnel in the ditch.

Mechanical anchors can make a considerable savings in cost of pipeline anchoring. However, before the selection of any type anchoring system, a thorough soil survey must be made to determine the feasibility of anchors.

A general outline of the steps necessary to design an efficient and economical anchoring system is as follows:

1. Determine terrain, environment, and total responsibilities of the anchoring system.
2. Determine type of construction best suitable for the job and select the anchoring system most compatible.
3. Run an extensive soils survey to determine the anchoring system compatible with the various areas. The exact quantity and type of anchor should be known for the various locations requiring stabilization.
4. Consult with the anchor manufacturers for standard sizes and practices.
5. Maintain good construction inspection.

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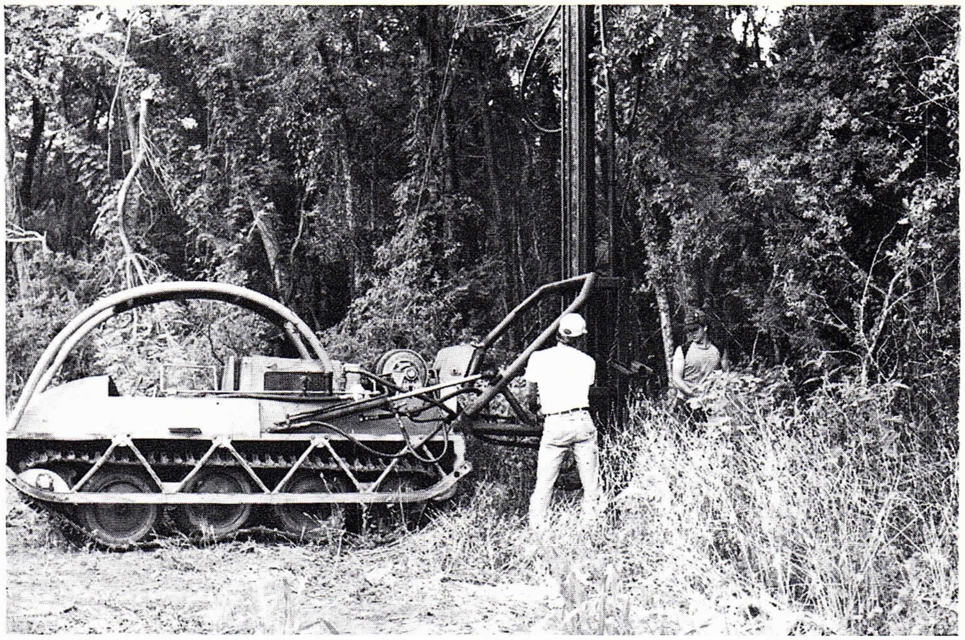

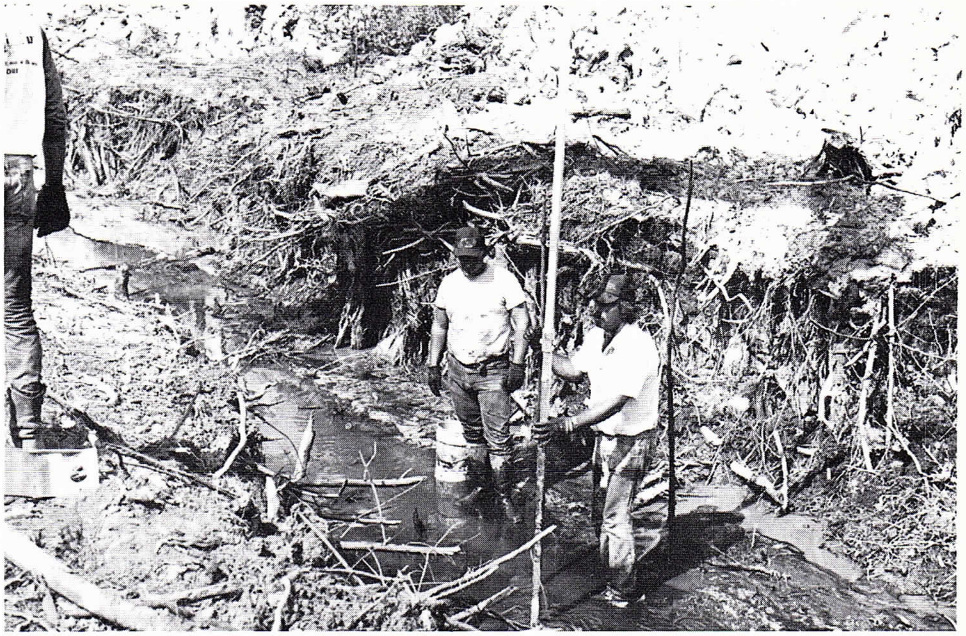

Here's an update on pipeline anchoring

Brian C. Webb
Webb Services Inc.
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This article updates the status of pipeline anchoring with mechanical anchors (Figs. 1 and 2). Over the past several years the technique of using mechanical pipeline anchors has advanced considerably. Reference 1 presents some basic background, design formulas, and discussions concerning the use of both density and mechanical type of pipeline anchors.

Mechanical anchors are recommended for stabilizing pipelines in any area requiring hold-down. As in all pipeline design, a successful anchoring system depends on adequate design data, experience, and judgment.

Adequate design data require thorough soil survey. Experience determines the technique of construction for the particular area being crossed by the pipeline. Good judgment determines the type of anchoring to adequately hold-down the pipeline. A procedure for designing a mechanical anchor system is presented here.

Field data. The initial step in designing an anchor system is to determine all the factors that affect the particular pipeline. Some of the major factors that determine anchor design are soil shear strengths, size and service of the pipeline, current velocity for river crossings or offshore areas, soil densities, ditch condition (dry or flooded), and construction techniques.

An on-site investigation will provide the engineer with the type of construction technique that most probably will be used by the contractor. For example: consider a 36-in. (91.4 cm) diameter pipeline located in Minnesota which crosses a flooded swamp that cannot be rip-rapped or crossed with heavy equipment. The contractor in this instance will probably pull the section of pipe across the swamp. Pulled sections will usually require continuous concrete coating.

If the same job can be rip-rapped, then the pipe will be installed in the ditch and flooded to sink the pipe. Following this, concrete set-on weights or auger anchors will be used for hold-down. If the job can be rip-rapped and the ditch is dry, then the pipe will be installed and auger anchors used.

A good soil survey will provide sufficient data to adequately design an anchor system. The survey should include soil densities for determining pipeline specific gravities, and anchor pull-tests for size, type, location, and design loads.

The anchor pull-test consists of placing a full-size anchor to the depth that the anchor will be installed on the pipeline, then applying an upward pull test. Pull-test results and station numbers are recorded during the survey. Spacing for the pull test will depend on the soil conditions.

Areas in the north that are a result of glacial deposits may require pull-tests every 100 to 200 ft because the soil changes type and consistency very rapidly. In areas such as south Louisiana, where the soil is more homogeneous, the spacing can be increased from 300 to 500 ft.

Technique of setting anchors using a sideboom tractor (Fig. 1).

Table 1

Pipeline anchoring parameters

Pipe OD, in. (mm)	Pipe wall thickness, in. (mm)	Pipe specification API 5 LX	Specific gravity (Water 1.0)	Hold down, lb/ft (kg/m)	Anchor spacing, bending, ft (m)	Anchor spacing, deflection, ft (m)	Required anchor hold down,* lb (kg)
10.750 (273)	.279 (7.1)	×60	1.25	18.1 (26.9)	216 (66)	129 (39)	2,335 (1,059)
12.750 (322)	.250 (6.3)	×42	1.30	38.0 (57.4)	141 (43)	119 (36)	4,522 (2,051)
16.000 (406)	.281 (7.1)	×52	1.40	74.6 (111.0)	150 (46)	123 (37)	9.176 (4,161)
24.000 (610)	.339 (8.6)	×65	1.25	162 (241)	187 (57)	144 (44)	23,328 (10,579)
30.000 (752)	.348 (8.8)	×60	1.25	274 (408)	176 (54)	150 (46)	41,100 (18,639)
36.000 (914)	.500 (12.7)	×65	1.25	362 (539)	231 (70)	177 (54)	64,074 (29,057)

*Anchor hold down based on the minimum required anchor spacing (i.e., deflection or bending).

The survey is not intended to guarantee 100% accuracy, but rather to reduce the margin of error to within acceptable limits. A few adjustments made in the field during pipeline construction are cheaper than the additional cost of a survey which provides 100% accuracy.

Design requirements. In swamps, the required hold-down is a function of the specific gravity of the soil. Soil density tests are made along the proposed route to determine the minimum required specific gravity of the pipeline. A density of 1.25 is adequate in most areas. If a safety factor is desired, then the specific gravity should be increased instead of using some other means such as adding a predetermined pounds-per-foot to the hold-down.

Paper titled "Art of Pipeline Anchoring—Update 1982" presented at a Pipeline Engineering Symposium, sponsored by the ASME Petroleum Div., at the Energy-sources Technology Conference, Houston, Tex., Jan. 30-Feb. 3, 1983.

In rivers and offshore service, the maximum anticipated current velocity should be considered in calculating the required hold-down. Current velocity can require more hold-down than the soil specific gravity. The hold-down is the force per unit length (lb/ft or kg/m) along the pipeline required to keep the pipe in place for a particular backfill specific gravity.

Maximum spacing for mechanical anchors should be calculated for both bending stress and deflection of the pipe. The pipe is considered as being suspended in a low shear strength mud of the design specific gravity (Fig. 3).

The pipe takes the form of a beam with fixed ends, with the ends at the location of the anchors, and has a continuous loading as a result of the buoyancy force. The buoyancy is equal to the water displaced by the pipe times the specific gravity of the surrounding mud, less the weight of the pipe.

Calculations are based on bare pipe, since most protective coatings are heavier than water and have a

Nomenclature

- W = Buoyancy force
- W_w = Weight of water displaced
- S.G. = Design specific gravity
- Wp = Weight of pipe
- S = Maximum allowable bending stress
- I = Moment of inertia
- C = Outside radius of pipe
- L = Anchor spacing
- E = Modulus of elasticity
- D = Maximum allowable deflection
- A = Anchor hold down

maximum thickness of 5/32 in. The need for more exacting calculation when dealing with soil is not practical. Thus:

$$W = (Ww)(S.G.) - Wp$$

The maximum allowable spacing as a function of bending is determined with the following formula:

$$L = \sqrt{\frac{12\,SI}{WC}}$$

The maximum allowable spacing as a function of deflection is determined with the following formula:

$$L = \sqrt[4]{\frac{384\,EID}{W}}$$

Maximum allowable stress is considered as 60% of the specified minimum yield strength (SMYS) of the pipe. This is based on years of experience in the design of river crossings and other water crossings using natural sags instead of bending the pipe. Considerations that may decrease the maximum allowable stress are earthquake zones, thermal loading, and excessive internal pressures.

In the design of mechanical anchors, the engineer has to be practical. The possibility of the pipeline ever approaching the 60% stress level is remote for two reasons. First, the safety factor used in selecting the soil specific gravity is conservative, and second the restraint from the backfill on the pipe tends to prevent pipe movement.

The maximum allowable deflection is selected as 6 in. Small diameter pipelines could possibly approach 6-in. deflection if the pipe could move through the backfill. On small-diameter pipelines (30 in. or less) the deflection is the limiting factor for anchor spacing. However, in large diameter (above 30 in.) pipelines the limiting factor is anchor hold-down capacity, and the maximum spacing as a function of deflection or bending is rarely achieved.

Some selected diameters, and anchor-spacing requirements are presented in Table 1 to give an indication of the major factors affecting pipeline anchor systems. All are based on 60% SMYS and a 6-in. deflection of the pipe.

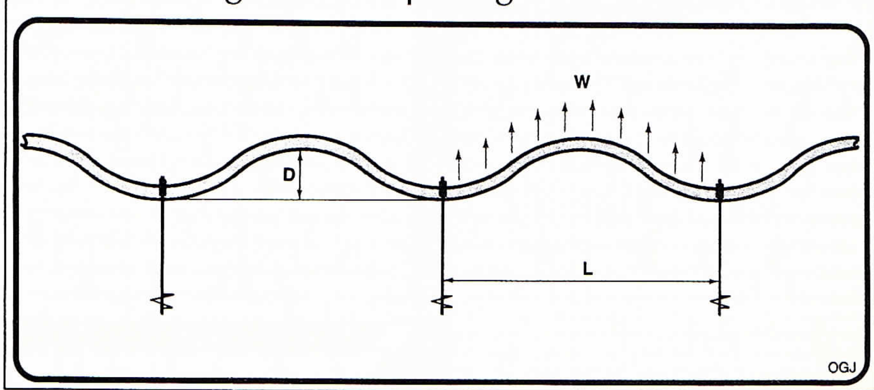
For 30-in. diameter and larger pipelines, the maximum spacing will not be achievable because of anchor hold-down limitations. Anchors used on pipelines will have a holding capacity of approximately 18,000 lb each or 36,000 lb/set.

Construction equipment used for

Bombardier vehicle equipped with a boom being used for installing and testing full-size auger anchors (Fig. 2).

Determining anchor spacing

Fig. 3



setting anchors can be used to test anchors to approximately 20,000 lb when boomed out. Therefore, during preliminary design and cost estimating, the engineer should never use over 36,000 lb/set. If the soil conditions are unknown, 20,000 lb/set should be used. Following the soil survey, a more exacting design can be made.

Cost comparisons between concrete anchor systems and auger anchor systems should be made to determine the most efficient system. The general rule of thumb indicates that the total installed cost for a set-on weight is approximately the same as for an auger anchor set.

Thus a cost savings can be achieved because of wider spacing of the auger anchors.

Anchor installation. Pipeline construction equipment used for installing auger anchors are sidebooms and hydraulic backhoes. If anchors are going to be installed every day, the backhoe is by far the best equipment. It is faster, more flexible, and can exert a downward force for installing anchors in hard soils.

The number of laborers required in the crew is also reduced. In areas where only occasional anchors are going to be installed, the sideboom is usually selected.

Anchors available to the engineer for design considerations include the dual anchor set and the hook anchor. The dual anchor set uses two anchors and a strap while the hook anchor uses only one anchor and a structural hook for attachment to the pipe. Refer to Fig. 4 for illustrations of the types of hook anchor.

When installing the hook anchors, the pipe is already in place in the ditch and the anchors are installed along the side of the pipe. As a result of the anchors being installed at the side of the pipe, the buoyancy force of the pipe is not aligned with the hold-down force of the anchor.

As the buoyancy force increases, the pipe has a tendency to align the two forces.

When the forces approach the design limits, the anchor rod will bend, thus aligning the buoyancy force with the anchor hold-down force. Rod bending is designed into the anchor system.

In buried pipelines, the backfill will restrain the pipe movement somewhat, and rod bending will be reduced. If desired, a pipe clasp can be furnished for trapping the pipe inside the hook.

On small-diameter pipelines, including up to 24 in. in diameter, the hook anchor can be used more effectively than dual anchors. On larger diameter pipelines, the dual set is used since it results in additional hold-down capacity. However, if the pipeline is submerged under water, the hook-type anchor is more adaptable for all diameters because it can be attached to the pipe without the use of divers.

A new anchor fluke has recently been developed, called the "beveled fluke." This type is designed for penetrating soils containing small rocks up to 12 in. in diameter. The beveled fluke kicks the rock aside, thus allowing the anchor to drive into the soil. Areas containing these rocks are located in the parts of the country where soils were deposited by glaciers (Figs. 5 and 6).

The design of the anchor system must be kept as simple as possible unless qualified technical personnel are available to supervise the installation of the anchors. For instance, the anchors should all be of one size and length unless the soil survey indicates that use of one type will not be effective.

In this latter case, the construction specifications should very clearly indicate the locations of each type of anchor that is to be used.

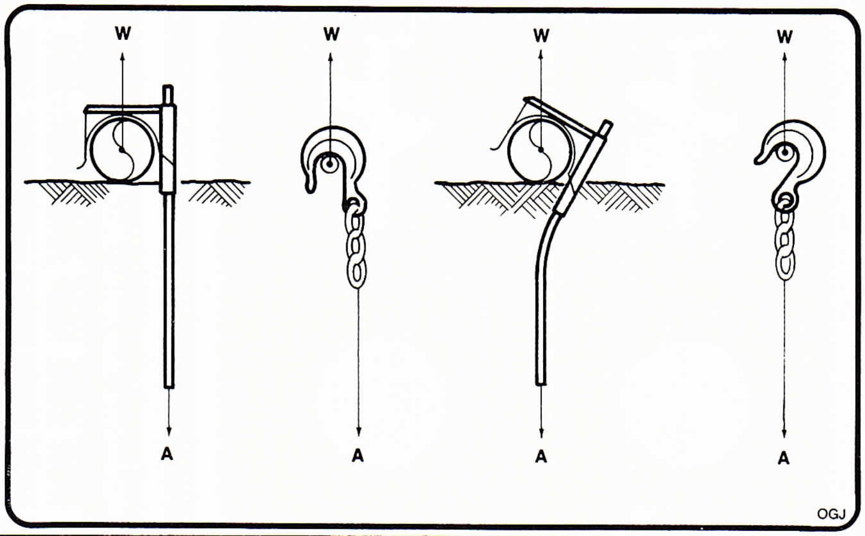
Anchor rod lengths should never exceed 10 ft when installed with a sideboom because of the boom length. Unless an extra long boom is used or the ditch is extra deep the 10-ft length is maximum. For smaller diameter pipelines where the contractor is using a standard Cat 561 sideboom, the maximum rod length should be 8 ft.

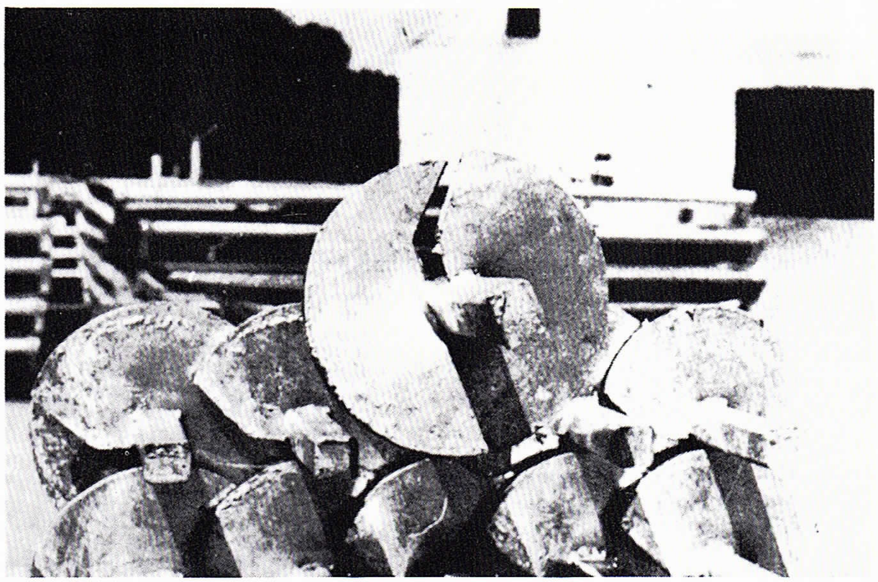
Standard sidebooms have boom lengths of 18 to 21 ft.

The crown block, traveling block, and installation tool will total approxi-

Types of hook anchor

Fig. 4





Newly developed beveled fluke on anchors for use in glacial soils (Fig. 5).

Fig. 6

Pipeline anchor designs

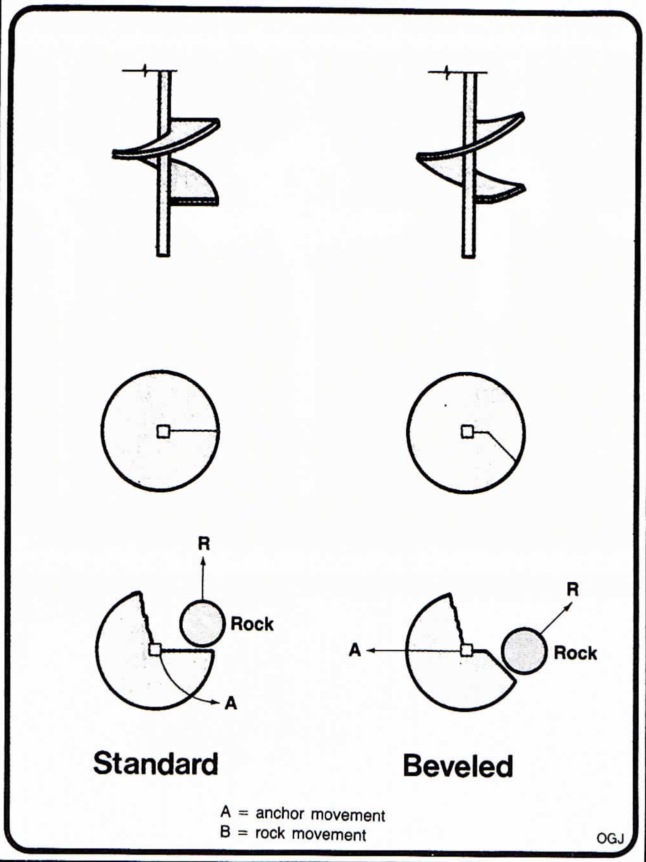
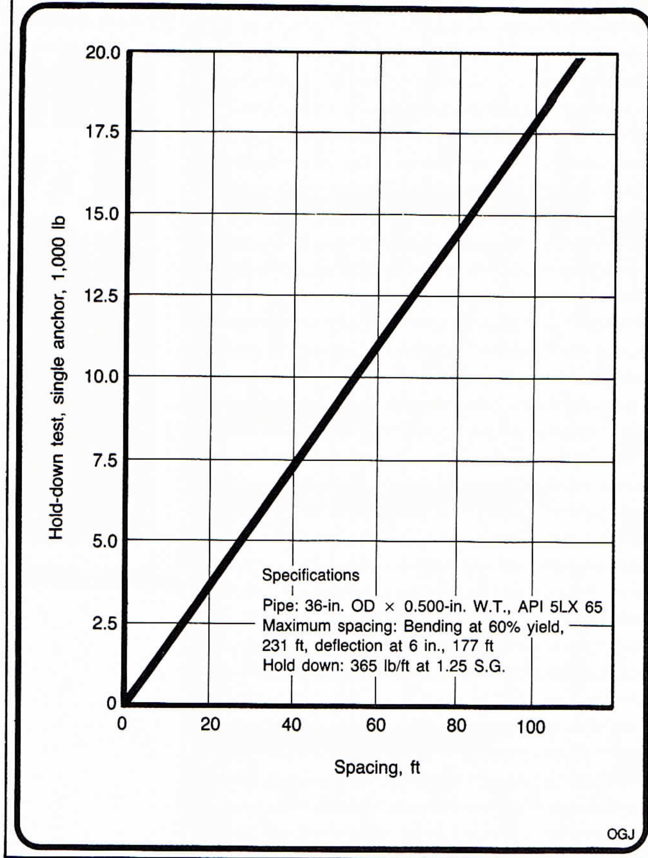


Fig. 7

Anchor hold down vs. spacing



mately 10 ft in length. When using a hydraulic backhoe for installing anchors, the rod length can be increased to 16 ft because the boom is approximately 25 ft in length.

Installation techniques consist of installing the anchor and immediately applying a pull test to determine the maximum hold-down capacity of the anchor. A pull test will consist of applying an upward load on the anchor. If the anchor breaks loose, the load will be reduced until the anchor no longer has upward movement or creep.

The load at which the anchor has no movement is the hold-down capability of the anchor. In most cases, the second anchor in a set will test approximately 2,000 lb less than the first anchor, so the hold-down of the anchor set is determined by the lowest test.

In order to meet the design criteria for both maximum spacing and required hold-down per foot, the anchor inspector is provided with a graph that is a function of hold-down test and anchor spacing (Fig. 7). If the anchor pull test indicates that the maximum spacing cannot be achieved, the spacing to the next anchor is reduced to provide the required hold-down per foot, e.g., a pipeline requiring 200 lb/ft and a maximum deflection spacing of 150 ft has a maximum anchor set hold-down of 30,000 lb.

If the lowest anchor test is 10,000 lb or 20,000 lb for the set, then the spacing to the next anchor is reduced to 100 ft.

This adjustment can be accomplished in the field without technical supervision.

Documentation by the inspector will consist of recording the test results for both anchors in a set, the station number, spacing to the next anchor, and the date. This documentation protects both the pipeline company and the contractor in the event of an anchor failure.

The author...

Webb

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Summary. The following outline should be followed in the design of pipeline anchor systems: investigate the site and determine the technique of construction, type of anchoring and tentative specific gravity of the pipeline, perform cost estimates comparing density type anchoring to mechanical type anchoring, perform an adequate soil survey for maximum design anchor hold-down, and verify the specific gravity of pipeline backfill. Also determine the hold-down of the pipe in pounds per foot (or kilograms per meter) to meet specific gravity requirements, determine the maximum anchor spacing as a function of pipe bending stress and maximum deflection, and maintain adequate inspection and documentation record during construction.

Acknowledgments

The author wishes to express appreciation for the able assistance of Crest Engineering and Butler & Associates in the preparation of this paper.

References

1. ASCE Paper presented in July 1973 by the author titled "Art of Pipeline Anchoring."

Soil survey determines auger anchor locations

New technique determines if auger anchors can be used to hold down pipe

B. Webb, Webb Services, Inc., Tulsa, Okla.

PIPE LINES TRAVERSING northern Minnesota's lake and swamp areas require extensive anchoring to obtain the necessary negative buoyancy for the buried pipe. Methods used to anchor the pipe vary from continuous concrete coating, concrete saddle weights, auger anchors or a combination of the three procedures.

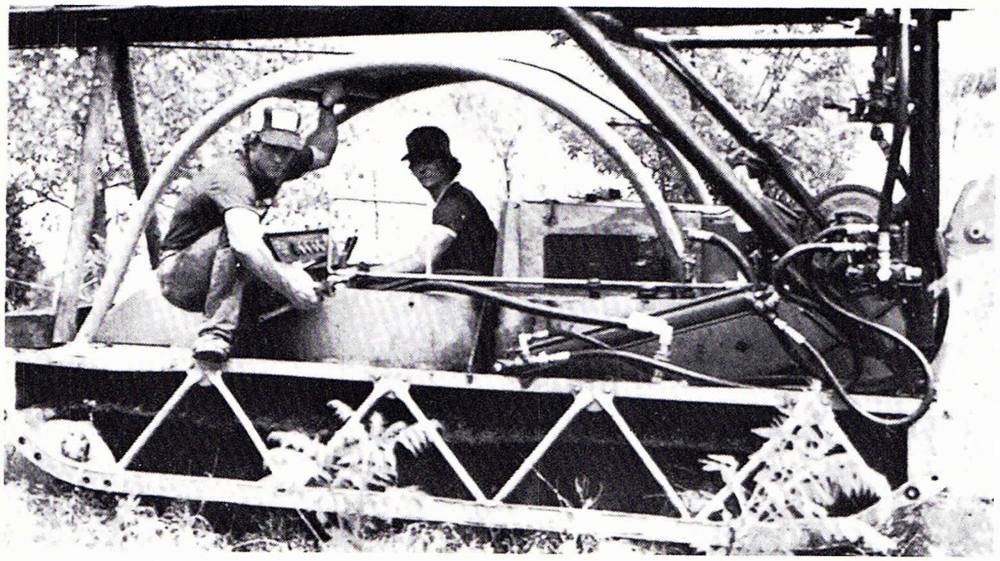
Lakes and swamps in northern Minnesota were formed during the glacial period. As the glaciers melted, the entrapped soil was deposited in ridges. The pot holes formed later became lakes. Since the glacial period, the lakes have been filling with decayed organic material along with sand and gravel washed in from the ridges.

The soil strength in these swamps ranges from soupy to firm. In very short distances, glacial-deposited soils change composition and shear strengths. This creates expensive conditions in order to hold down pipe lines crossing such areas.

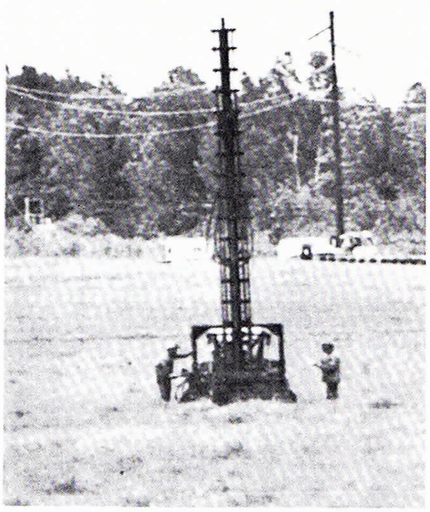
The difference in installed cost between concrete saddle weights and auger anchors is approximately $35 per lineal ft for 36-in. pipe. An extensive soil survey, to determine where auger anchors can be used, can effect considerable savings.

Different soil survey. Soil surveys in the past have consisted of making torque tests on small diameter probe rods as they were inserted into the

Wet footing. Bombardier muskeg tractor crosses wet areas in making soil survey in Minnesota swamps. Vertical boom carries hydraulic powered drill.



Dry land work. With boom retracted, the muskeg tractor crosses higher ground to make another test on auger anchors.



Using pull. After the auger anchor has been inserted into soil to full depth, a pull is made to determine hold down capacity.

soil. This has proven unreliable in soils in glacial areas.

In many cases, torque tests indicate auger anchors would hold down the pipe. After installation of auger anchors, it was found that the equipment would not hold down the pipe. This required an expensive replacement of auger anchors with concrete saddle weights.

A soil survey method was developed to overcome this problem. A full size auger anchor was installed to the same depth that it would be installed on a pipe line. A pull test then was made on the installed anchor to determine if sufficient hold down capacity was achieved. If hold down capacity was less than required, additional rod was installed to give more depth to the auger and another pull test made.

Results indicated about 50 percent of the installations recorded higher pull tests. In some isolated cases, pull tests were lower. Various sizes of flukes and combinations of flukes were tested for effectiveness in different types of soils.

This soil survey method was used on the route of a proposed 13-mi, 36-in. gas transmission loop line in northern Michigan for a major pipe line company. The proposed route indicated that hold downs would be required on about 4.5 mi of swamp crossings.

Pull test results. Pull tests indicated that auger anchors could be used in about 46 percent of the route surveyed to hold down the pipe. This would provide a cost savings of about $382,000. The tests were so enlightening that an additional 3,700 ft were added to the survey.

The equipment used to perform the survey consisted of a Bombardier muskeg tractor with vertical drill mounted on the back. The Bombardier is capable of crossing swamps of very low shear strength, similar to that of chocolate pudding. Pull test results ranged from 0 to 22,000 lb. Readout was direct from a gauge.

The tests were made on 125-ft spacing to provide as much reliability as possible in this type of soil. Torque readings were made in an attempt to correlate pull tests to torque readings. The torque readings proved very disappointing. The pull tests proved quite successful.

The water in the swamp was 6-in. higher than normal because of recent rains. This did not affect the pull test because of the depth of the tests.

Some areas had a large amount of rock which had a tendency to bend the flukes. Adequate hold down could be achieved in some of these rock areas, but auger anchors were not recommended.

The slope of the ridges surrounding the swamps were followed into the swamps and were similar to following the slope into a lake. Some gravel deposits were difficult to penetrate and provided an inadequate hold down.

Anchor spacing report. A report recommended the location, type of anchoring and spacing. The recommended spacing was preliminary and only used for ordering anchors.

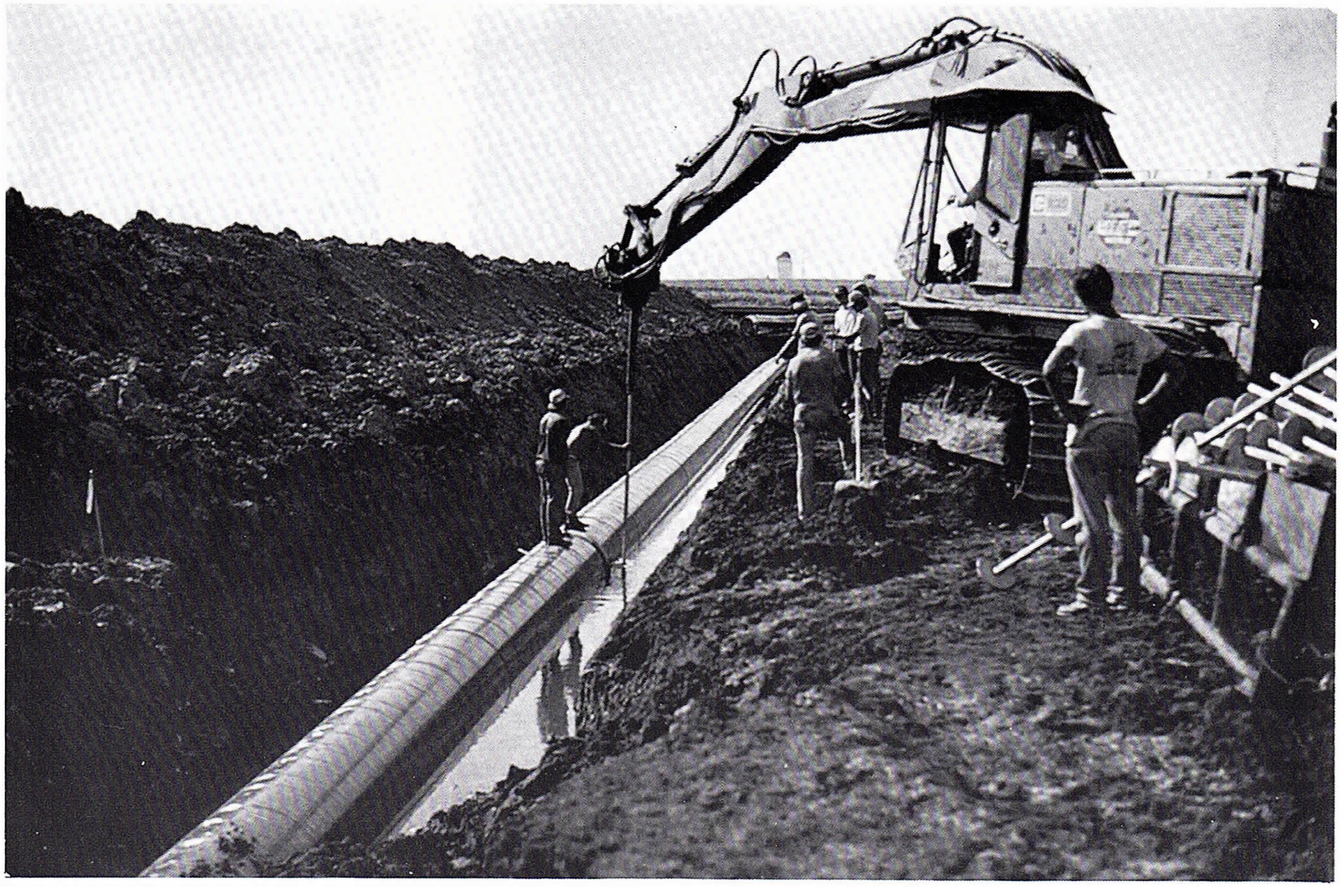
The pipe for this project was API 5LX-65, 36-in. OD by 0.375 in. WT. A specific gravity of 1.25 was selected for the swamp crossings. This required a hold down of 403 lb/ft. Maximum spacing for auger anchors, as a function of bending moment, is 189 ft and maximum spacing, as a function of deflection, is 160 ft. Spacing for 8,000-lb concrete set-on weights is 10 ft.

Graph shows locations. During construction, the procedure for installing auger anchors requires a pull test on each anchor immediately after installation.

The soil survey report provided a graph showing the anchor spacing as a function of the test results on the anchor after installation. The graph is based on the pipe characteristics, specific gravity and maximum allowable spacing. If the minimum required hold down cannot be achieved for the required spacing in actual installation then the spacing to the next anchor will be reduced in accordance with the graph. This procedure will provide the required 403 lb/ft hold down capacity.

The proposed installation procedure, when used in conjunction with the soil survey, has reduced the margin of error for auger anchors and has pinpointed the type, size and spacing for their use. It has also provided the reliability of concrete weights at the cost of auger anchors. ■

Modern Pipeline Methods



Hydraulic anchor installation tool mounted on backhoe boom turns spiral-type auger anchor into soil; anchors are 10-ft long.

Auger Anchors Produce Major Cost Savings

by B.C. Webb, President,/*Webb Services Inc., Tulsa, Oklahoma*

A new major gas pipeline company installing large diameter pipe is enjoying "windfall" cost savings by using auger anchors in place of concrete set-on anchors.

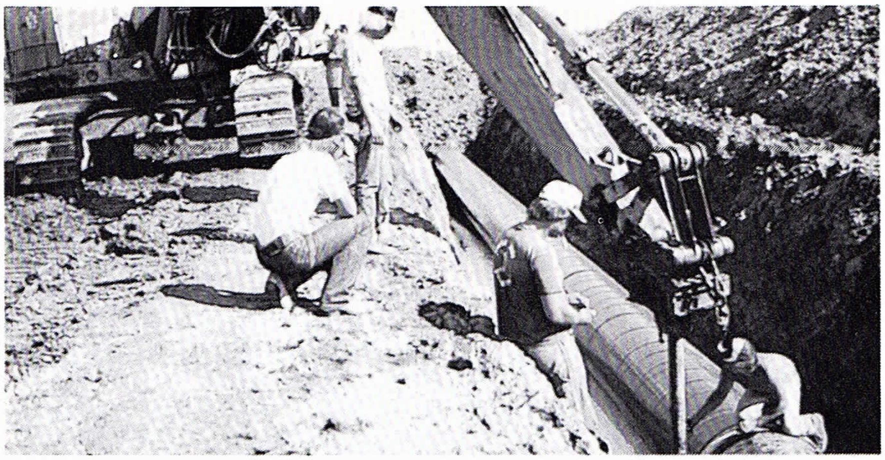
Pipeline companies installing large diameter thin wall pipe are discovering the cost of anchoring for buoyancy is approaching the cost of the pipe. Such is the case on a new cross country pipeline currently being constructed in the northern area of the U.S. The pipeline consists of 42-in. pipe with 0.598-in. wall thickness. The pipe requires 425 lb per ft of anchor hold-down to meet the required specific gravity.

The pipeline is located in a section of the U.S. that is primarily glacial deposits with numerous pot holes, peat swamps and low-lying areas. The underlying soil strata consists of everything from low shear strength organic deposits to sand, gravel with intermediate rocks, shales and high shear strength clays. In addition to the large variation in soil types, the soil's composition can sometimes change every 10 ft.

Surveys were conducted to determine the location of areas requiring anchoring. These areas were based on high water tables, swamps, and potential wet spots. The type of anchors selected consisted of auger anchors for areas with soils of acceptable shear strength and concrete set-on anchors for areas where auger anchors would not hold.

The set-on weights consisted of 10,500 lb of 140 lb per cu ft concrete on 12-ft center-to-center spacing.

The auger anchor sets consisted of



Once anchor is in place, it is tested for pull-out force. Maximum hold-down for each anchor is 18,100 lb; minimum is 6000 lb.

Two anchors make up a set. Once both anchors are installed and tested, a pipe strap is attached to the anchors. Strap rests on a pad to prevent damage to coating.

two auger anchors, 10-ft long with a 6-in wide strap. Auger anchors are on 85-ft spacing.

Approximate installed cost per ft of pipeline for the set-on weights is $80 and $8 for auger anchors. This provided a cost savings of around $380,000 per mile that, even in terms of large projects, is substantial money.

To obtain the integrity of concrete set-on weights the company required each auger anchor to be tested after installation. Maximum hold down for each anchor set was 36,200 lb or 18,100 lb on each auger, with a minimum of 6000 lb on each auger. If the 6000 lb minimum could not be met, the set-on weights were installed.

Two spreads utilized a patented anchor installation tool provided by Webb Services Inc.; one spread used the tool on a Cat 235 backhoe and the other spread used a Cat 583 sideboom. The sideboom used the installation tool in the conventional manner while the backhoe used the tool in place of the bucket. Both pieces of equipment are capable of producing a lifting force of 18,100 lb when boomed out to the maximum.

The technique of installing the anchors included attaching the anchor to the tool and boring the anchor to the required depth. The anchor was then tested for hold down strength. If the anchor held 18,100 lb the tool was disconnected and the mating anchor installed and tested. If the second anchor met the test, then the pipe strap was attached to the anchors and the crew moved ahead to the next location.

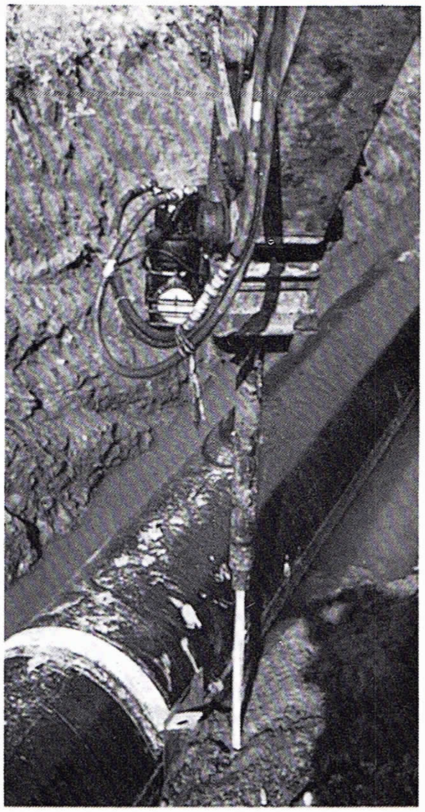
The tool utilizes a strain gage to measure the pulling force.

In some locations the soils did not meet the 18,100 lb test. The load was applied to the anchor and at some point the anchor would fail and begin to pull up. The anchor would raise until the load was reduced approximately 3000 lb. At this point the anchor would hold steady. If an additional load was applied the anchor would raise until the load was reduced to the same load at which it held before.

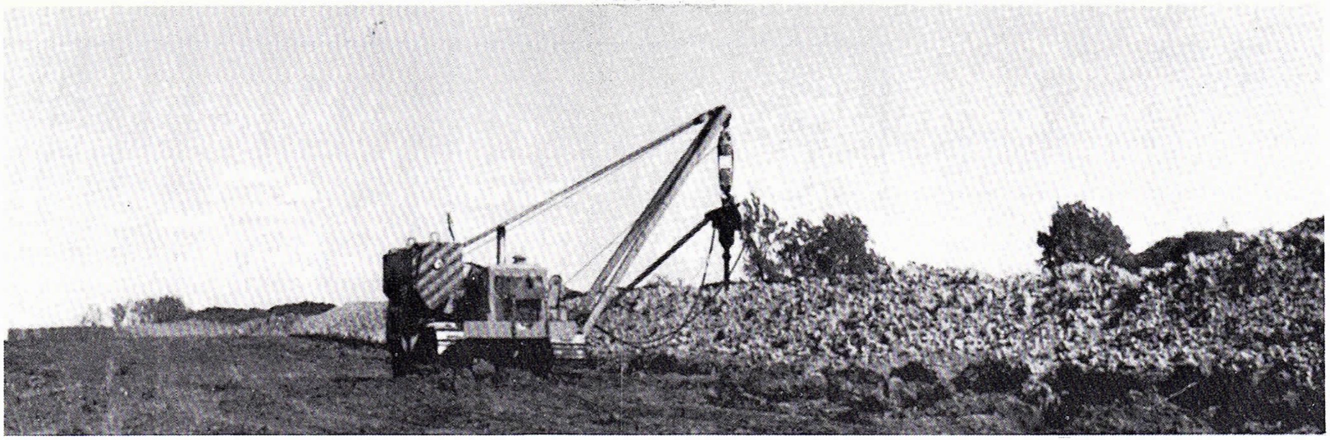
As an example, an anchor would fail at 15,000 lb and raise until the load was reduced to 12,000 lb. If additional load was applied, the anchor would again raise until the 12,000 lb load was obtained. The anchor was then classified as a 12,000 lb or a 24,000 lb anchor set.

A chart was provided to the field crew that gave the anchor spacing as a function of anchor hold down for the required specific gravity. In the case of a 24,000 lb anchor hold down, the spacing was 56 ft to the next anchor.

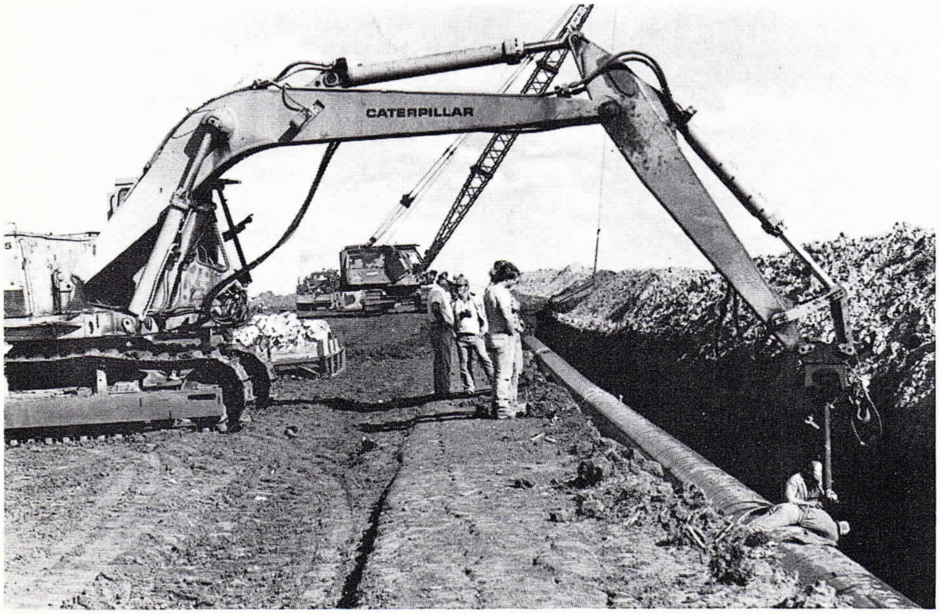
The second anchor in a set usually would not test as high as the first



Patented anchor installation tool mounted on backhoe. Device can also be mounted from tractor sideboom. Unit connects hydraulic system of either tractor or backhoe.



Tool can also be mounted on a sideboom tractor, as shown here.



anchor. The shear cone effect from the first anchor appeared to interfere with the shear cone of the second anchor. Therefore, the second anchor usually dictated the anchor spacing.

The comparison between a side boom and a backhoe for installing anchors is determined by the number of anchors to be installed. On a cross-country pipeline, where occasional anchors are to be installed, the side boom offers more flexibility because the tool is easily disconnected from the block and a quick disconnect removes the hydraulic lines. The tool can be laid aside and the side boom used for tie-ins, installing set-on weights or general use.

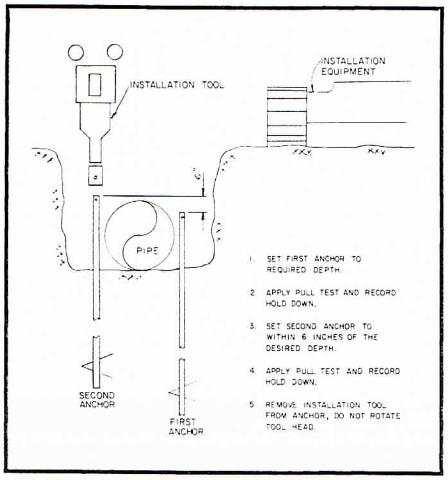
The backhoe is recommended for areas where anchors will be installed every day. The backhoe has more flexibility for installing anchors and can install the anchors at a faster rate. In hard material the backhoe can exert a downward force, thus forcing the anchor to auger down. The time required to convert the backhoe to other work is somewhat longer than the conversion for the sideboom. Should the need arise to use the backhoe for other work, dismantling the tool from the backhoe and adding a bucket for ditch work takes approximately 20 minutes.

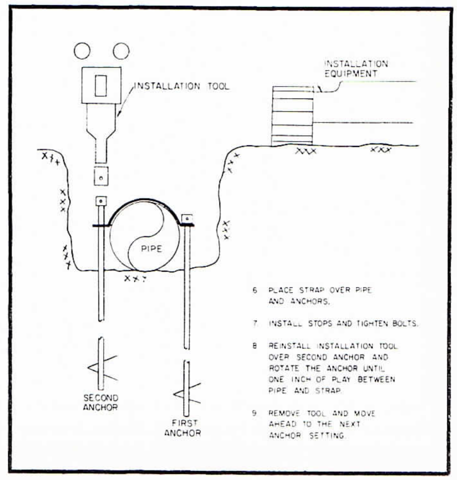
The torque required to install the anchor was recorded to determine the hold down of the anchor. The correlation between torque and hold-down was not always useful because the soil strata changed at different depths. For example, a hard gravel would be sometimes encountered at the beginning of anchor installation requiring a high torque. However, towards the final depth the anchor would go through the gravel and into a soft, low shear strength soil strata. The pull test would then show a much lower anchor hold-down than the torque indicated.

This project has demonstrated the cost savings and installation efficiency of using auger anchors in place of concrete set-on anchors. By testing each anchor the company has satisfied the reliability requirements, ensuring a sound anchor system. **P&GJ**

Auger Anchoring Pipelines Can Be Simple

Brian "Butch" Webb
Webb Services Inc.





Mechanical auger anchors, instead of concrete, for pipeline hold-down, are being used increasingly by pipeline companies. Unfortunately, some of the contractors bidding on these jobs don't have experience in setting auger anchors, with the result that contractors are putting in too much money for risk factors. Installing auger anchors is not difficult and should be approached in the same manner as any other type of pipeline operation, which is: Good Planning.

Anchors vary greatly in style. Each is used in a different type of soil, in various kinds of terrain, and for different pipe diameters. Crew size, type of equipment and anchor setting time also will vary with each job. However, such variations are the same with any other type of pipeline operation, and should not be considered unique with anchoring.

The first step in bidding a job to install auger anchors is to determine the equipment required for installation. The backhoe is usually selected for areas where a large number of anchors are to be installed and a high production rate is needed, as the backhoe is faster and requires fewer crew members. Since the Northern Border Pipeline Project proved the versatility and speed of the backhoe in installing a large number of anchors, most pipeline contractors now use the hydraulic backhoe for that purpose. In this process, the bucket is removed and the anchor installation tool is installed in place of it. Hydraulic hoses are then run along the boom to a valve located in the backhoe cab, with the hydraulic power coming from the swing pump on the backhoe or some other source.

The sideboom is the other most common type of equipment used. It is used for areas that require a few isolated anchors in several locations because the sideboom will be a part of the tie-in gang which usually does not have a backhoe.

A standard anchor set consists of two anchors and one strap that goes over the pipe. The anchor rods go through a hole in the strap and are attached to it by washers or stops bolted to the top of the anchor rod, preventing the rod from sliding through the strap hole. The anchor itself consists of steel rods with spiral flukes on the bottom that pull the anchor into the soil as the anchor is rotated.

In the installation procedure, the backhoe or sideboom pulls a sled loaded with anchors. After the anchor is installed at the required depth, a pull test is made and the inspector or crew foreman records the test. Following this, the second anchor is installed to within a depth of 6 inches of the first one, after which a pull test is made on the second and recorded. The installation tool is removed, but the head is not rotated. After the tool is removed from the second anchor, the strap is placed over the anchors and pipe. The tie-down stops, and bolts are installed and tightened; after which, the tool is again attached to the second anchor which is 6 inches too high and the anchor is rotated by the tool until the strap has about one inch of play over the pipe. This loose strap prevents damage to the protective coating should the pipe shift during the back-fill operation.

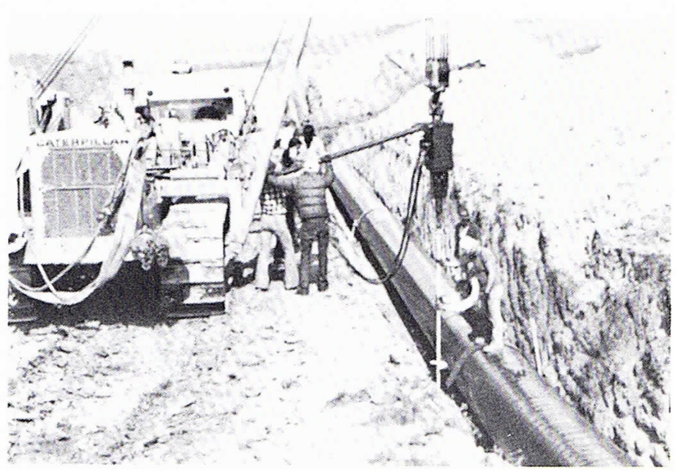
All anchors must be tested by the contractor to ensure adequate hold-down. Should the pipeline float, the test puts the responsibility of the failure on the pipeline company.

For the sake of definition, hold-down is the weight per foot required to hold the pipeline in place when buried in mud; therefore, the spacing between anchors is based on the anchor test and the required hold-down.

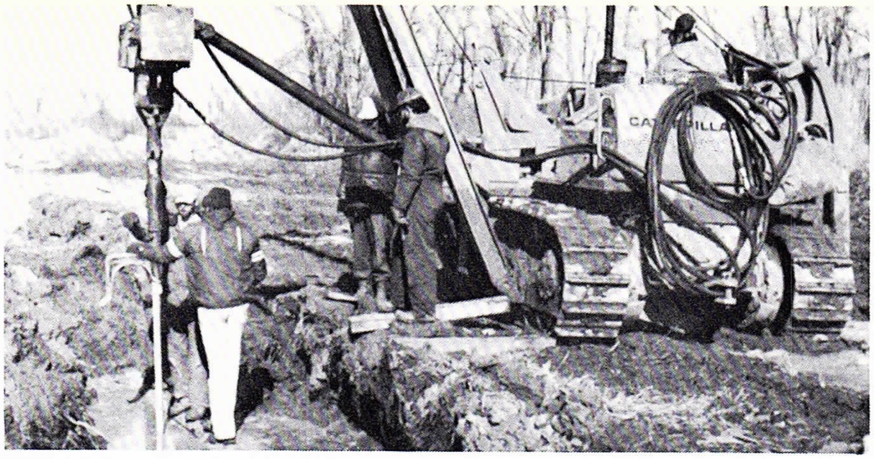
Each anchor is pull-tested, and the spacing is based on the anchor in the set having the lowest pull test results. For example, if a pipeline requires 200 pounds per foot hold-down and the anchor set tests to 20,000 pounds, the spacing to the next anchor is 100 feet. A graph showing the spacing vs. pull tests and the forms for recording pull tests can be obtained from the anchor manufacturer.

In contrast to concrete for hold-down, the economics of auger anchors is becoming so attractive to the pipeline companies that these anchors are now being considered on more jobs. As a result, it is important that pipeline contractors become familiar with auger anchors in order to make competitive bids.

Cat 235 Backhoe used to install anchors on 42" Northern Border Pipeline in Iowa.



Anchoring pipeline in North Dakota with Cat 583 sideboom.



Hook anchor being installed on 10-inch pipeline crossing job.

Augur Anchors Used to Secure Oklahoma River Crossing

Flood plains and river crossing approaches can prove costly when the water table is within two feet of the ground surface. Such was the case when a major gas company crossed the South Canadian river near Norman, Oklahoma. The company was expanding its gas operations and a new section of pipeline was routed across the river. The pipeline consisted of approximately 3200 feet of 10-inch and was located inside a meander loop.

The soil in the river crossing and flood plain consisted of very loose sand and hydrographic surveys indicated the bottom would scour approximately 4 feet during a flood. In addition the river was meandering south at a rate of 9 feet per year.

The pipe installed in the river crossing consisted of 10.750 inch outside diameter with 0.344-inch wall thickness and a grade of API5LX 42. Specific gravity of 1.35 was selected for the pipeline in the river crossing and the flood plain. This required a hold down of 10.6 pounds per foot to maintain stability. Concrete bolt-on weights were used for hold down in the river crossing section of the pipeline. These consisted of 1040 pound weights on 29 foot spacing.

A cost study was made for the flood plain using concrete set-on weights as opposed to auger anchors. The set on weights selected were 1160 pound on 35 foot spacing. Total installed cost was approximately $9.00 per foot for the set-on weights and $3.00 per foot for the auger anchors.

The spacing for auger anchors was based on the maximum allowable stress in the pipeline as a result of bending moment and deflection caused by a 1.35 specific gravity mud. The pipe was considered a beam with fixed ends and a uniform load. The anchors would be located at the fixed ends. The maximum pipe stress as a result of bending moments occurs at the anchor locations. The maximum pipe stress was considered at 60 percent of the minimum specified yield strength of the steel.

To prevent the pipeline from looking like a roller coaster a maximum deflection of 6 inches was selected. Calculations indicated the maximum spacing for the bending moment stress was 250 feet and 150 feet for deflection. The maximum spacing for the anchors was specified at 150 feet with a minimum anchor hold down test of 1600 pounds.

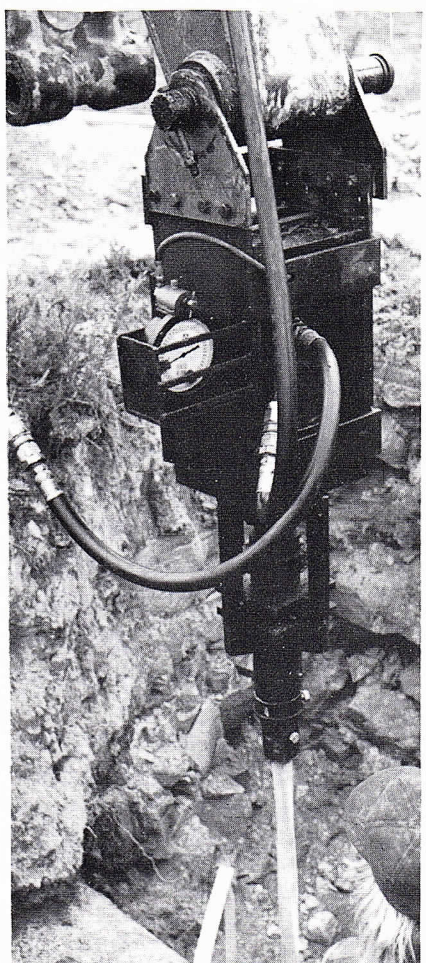
The anchor selected for this crossing was a newly developed anchor called a "Hook Anchor." This anchor used only one auger anchor and attaches to the pipeline using a structural hook. The anchors consisted of one square foot rod 10 foot long with two 10 inch diameter flukes plus the pipe hook. Rockshield was used to protect the pipe coating from damage. Advantages of the hook anchor over other type anchors are: the installation costs are less, deeper penetration can be obtained using the same weight of material and it can be installed underwater without the use of divers.

Here is the hook anchor installed on Canadian River crossing job.

The auger anchors were installed using a Cat 561 sideboom and the W.S.I. anchor installation tool. Each anchor was pull tested after installation tool to ensure the integrity of the anchor system. When the minimum anchor hold down was not achieved, the spacing was reduced to the next anchor to provide the 10.6 pounds per foot required hold down.

The hook anchors can be used for any pipe diameter size if the anchor installation has to be made under water such as in marsh and offshore areas. Hold down limits are in the 20,000 pound range for each anchor and this hold down is sufficient for 20-inch diameter pipe and smaller in both under water and dry installations. For dry installation and 24 inch diameter pipe and larger the conventional dual anchor sets are more efficient because of the additional anchor. The extra anchor allows a total of 40,000 pound per anchor set hold down.

Anchors and installation equipment were supplied bv Webb Services, Inc., P.O. Box 15282, Tulsa, Okla. 74112.



PIPELINE DESIGN FOR MECHANICAL ANCHORS

Mechanical anchors are designed primarily for use in flood plains, swamps, marshes, offshore and in other areas subject to inundation. Two types of mechanical anchors are available. One is the conventional dual auger anchor that has an anchor on each side of the pipe that is attached to a hold down strap. The second type is a single auger anchor utilizing a structural hook for attaching the pipe. WSI has a patent applied for on the hook anchor.

The dual anchor type is for holding large loads and is basically used on large diameter pipelines. The single anchor type or hook anchor is used for small diameter pipelines and in areas where the pipeline is submerged. The hook anchor can be installed under water without the use of divers.

Design of a pipeline anchor system is as follows:

1. Determine the hold down required to keep the pipe stabilized. Hold down is given in pounds per foot. This is a function of pipe diameter, wall thickness and specific gravity. The specific gravity is determined from the density of the soil being transversed by the pipeline. Soil surveys are used to test the soil for density. The design engineer will use the soil density to determine the specific gravity and the required hold down of the pipeline. The specific gravity of the pipeline is the function that should be increased if additional hold down is required for a larger safety factor.

2. The maximum allowable anchor spacing is determined by two conditions. One is the maximum allowable stress in the pipeline and the second is the maximum hold down of the anchors. Anchor spacing will never exceed the maximum spacing as a result of pipe stress. Therefore, the anchor spacing will be a function of anchor hold down with a maximum spacing determined by pipe stress.

3. Spacing as a function of pipe strength is determined for two conditions. One is bending moments in the pipeline at the anchor locations and in the center between anchors. The second is pipe deflection between anchors. The pipe diameter, wall thickness and grade of steel is required to determine these calculations. Safety factors include a 60 percent of the minimum specified yield strength to determine the maximum allowable stress in bending. For deflection a maximum of 6 inches is allowed between anchors.

4. Anchors can be designed to hold up to 35,000 pounds on each anchor. However, the most common anchor is designed to hold a maximum of 20,000 pounds or a total of 40,000 pounds for dual anchor. On large diameter pipelines the anchor spacing is a function of anchor hold down. On small diameter pipelines the anchor spacing is a function of pipe stress or deflection.

SPECIFICATION FOR INSTALLING PIPELINE AUGER ANCHORS

Mechanical Anchors

Where mechanical anchoring of pipe is specified, Contractor shall comply with these specifications:

Contractor shall install the size and type of mechanical anchors in the locations shown on the plans. Mechanical anchors shall be furnished by the company. Contractor shall furnish ⅜" thick rockshield to pad the pipe. Rockshield shall extend 3 inches on all sides of the anchor strap.

Contractor shall furnish an anchor installation tool for installing the anchors. The tool shall be capable of making a pull test on each anchor immediately following installation. Pull tests shall range from 0 to 20,000 pounds.

During installation Contractor shall take precautions that the protective coating is not damaged. Should damage occur, the coating shall be repaired in accordance with the coating specifications. When installing multiple fluke anchors, Contractor shall furnish a steel shield to protect the coating.

Contractor shall install each anchor to the depth required to attach the anchor to the pipe strap. After installation a pull test shall be made on each anchor. A pull test will consist of applying an upward load on the anchor. If the anchor breaks loose the load will be reduced until the anchor no longer has upward movement or creep. The load at which the anchor has no movement is the hold down capability of the anchor.

If the minimum specified hold down capability can not be achieved by the anchor and extensions have been recommended, then extensions will be installed and tested in the same manner as the anchors. Additional extensions may be required to achieve the minimum hold down. When installing anchor sets with dual anchors the anchor with the smaller hold down test shall determine anchor spacing.

Maximum pull test will not exceed 20,000 pounds. Anchor spacing will be determined by the pull test. A graph will be supplied by the Company showing the anchor spacing vs anchor hold down. Following the anchor pull test the contractor will determine the spacing to the next anchor and proceed with installation. Contractor shall record the station number of each anchor, type of anchor, pull results, resultant spacing and date. This data will be given to the Company on a daily basis.

Granular Sandy Soils Create Stability Problems

Vibrating Pipelines

MODERN PIPELINE ENGINEERING

by Brian C. Webb,
President, Webb Services Inc., Tulsa, Oklahoma

Pipelines crossing rivers, swamps and marine areas that consist of sandy soils with low or zero shear strength will experience a lifting effect if the pipeline is subject to movement or vibration.

Considerable information is available concerning marine pipelines that encounter liquefaction of backfill as a result of earthquake or wave action. The liquefaction effect can cause pipelines to rise in the backfill when sufficient hold-down is not provided.

However, the situation is not so well-known when it comes to river crossings consisting of sand. A number of tests have been conducted to determine the effects of vibration on the stability of pipelines with various specific gravities in granular sand.

Arkansas River crossing. A 10-in. natural gas pipeline was laid in 1986 across the Arkansas River in Oklahoma, where the low-profile river bed consisted of a granular sand (Fig. 1). The crossing was approximately 1,700 ft from bank to bank.

The river bed was dry sand, with narrow channels approximately 30 ft wide and 3 ft deep. These channels carried the river flow except during times of high runoff. Over a period of time, the channels would meander from bank to bank. The entire river bed would be submerged during high-water periods and during flood stage the river would extend beyond the banks to inundate the flood plain.

The bed had a hard shale bottom, with sand overburden ranging from 3 to 9 ft deep. The pipeline crossing consisted of API 5LX42 line pipe, with a 10.750-in. O.D. and an 0.365-in. W.T. Concrete bolt-on weights, weighing 830 lb each on a 28-ft spacing, gave the empty pipeline a specific gravity of 1.35 (Fig. 2). The construction specifications called for the pipeline crossing to be nested in a 3-ft deep trench in the shale bed.

Floating pipeline. In time, the flow channel exposed the pipeline and within six weeks of construction the pipeline had floated to the surface. Additional bolt-on weights increased the specific gravity to 1.5, and the pipeline was stripped and lowered into place. The pipeline was again at the surface in about two weeks.

Following the second incident, investigations were begun to determine why the line was floating to the surface. An existing 6-in. pipeline was discovered during construction of the 10-in. pipeline that added some history to the phenomenon of crossing sandy soils.

The 6-in. line had cast-iron weights for hold-down. This dated the line to pre-1940 construction, meaning that the pipeline crossing had existed for at least 46 years.

Over the past 46 years, the flow channels would have meandered completely across the river bed and in theory should have caused the exposed pipeline to sink to the shale bottom. In addition, flood stages would have scoured the sand bottom to the shale and caused the entire pipeline crossing to sink. However, the existing 6-in. pipeline was still located at the same elevation as the water surface in the flow channels and the water table in the dry sand bed.

Theory. The 10-in. line was buried to the specified depth, but was raised to some limit when exposed to the current flow. It is assumed that the current flow caused the pipeline to vibrate. This vibration was the result of vortex shedding, causing the pipeline to move up and down (Fig. 3).

Magnification and duration of the vibration would depend upon pipe span, mass, resistance to movement and current velocity. The up-and-down vibration would cause the sand particles to move from the top of the pipe to the bottom of the pipe. The moving pipe would leave a void at the bottom that would be filled by sand displaced by sand from the sides and top of the pipe.

The low shear strength of the sand would allow unrestricted movement of the sand. This movement, added to the buoyancy of the water, would force the pipe up (Fig. 4).

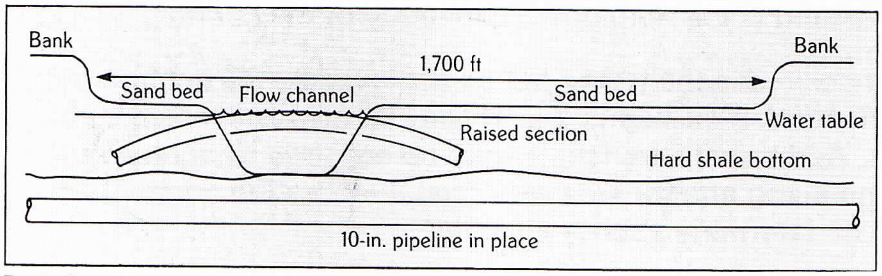


Fig. 1. Crossing stretched 1,700 ft from bank to bank: dotted line shows how pipe moved to water table elevation in the flow channel.

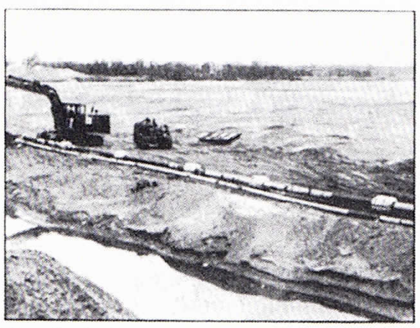


Fig. 2. Bolt-on concrete weights, which weighed 830 lb each, were not sufficient to prevent the pipeline from coming out.

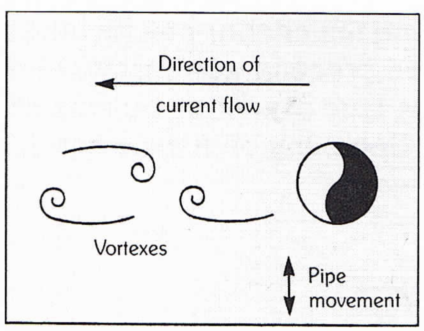


Fig. 3. Vibration caused by vortex shedding in the current flow causes the pipeline to move up and down.

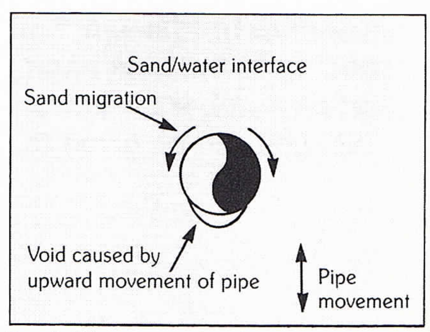


Fig. 4. Vibrating pipeline leaves a void at the bottom, which will be filled by sand from the top and sides of the pipe.

Two conditions existed for the combined density.

The first condition was sand covered by water. Pipe with 1.35 specific gravity would rise to the sand/water interface until the displaced water and the displaced sand-water mix equaled 1.35 specific gravity.

The second condition was sand not covered with water, but having a water table at some elevation below the surface of the sand. The pipeline would rise until the buoyancy force of the water in the sand was equaled by the weight of the pipe.

Tests. Density of the river sand when saturated with water was 122.7 lb per ft^3, for a specific gravity of 1.97. The particle size of the sand is shown in Table 1:

Table 1. Percentage Of Sand Passing Through Sieve

Sieve Size	Percent Passing
3/8	100%
4	97%
10	80%
40	14%
80	1%
200	0.5%

This sand is the type suitable for use in concrete without washing out the fines.

Tests were conducted using a fish aquarium, river sand, a vibrator and a plastic pipe specimen (Fig. 5). The plastic pipe was 19-in. long, 4.5-in. O.D. and 0.237-in. W.T.

Magnitude of the vibrations was approximately 0.001- to 0.002-in. The pipe was weighted with lead to the desired specific gravity and the ends sealed. The pipe was placed on the bottom of the aquarium, covered with sand and flooded with water.

A range of specific gravities were used during the test:

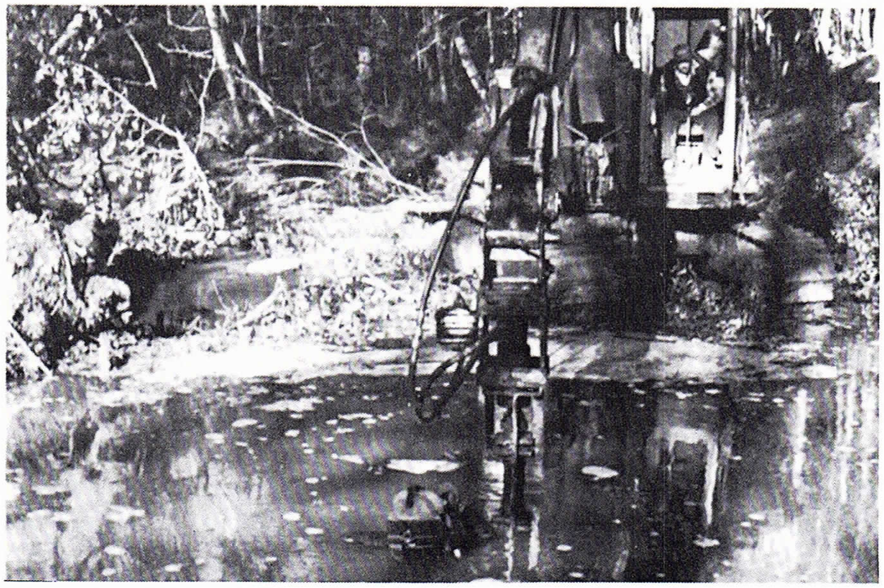
Table 2. Specific Gravities Used In The Test

Specific Gravity	Weight Of Test Pipe	Resulting Density
1.0	10.91 lb	62.4 lb/ft^3
1.35	14.72 lb	84.2 lb/ft^3
1.5	16.37 lb	93.6 lb/ft^3
1.7	18.55 lb	106.1 lb/ft^3
1.9	20.73 lb	118.6 lb/ft^3
2.1	22.91 lb	131.0 lb/ft^3

Results. The unvibrated pipe specimen covered with a sand-water mix would remain on the bottom of the aquarium indefinitely for all specific gravities from 1.0 to 1.9. When the vibrator was activated, the pipe would begin to rise to the surface of the sand/water interface. Time required ranged from 2 hr for the 1.0 specific gravity to 36 hr for the 1.9 specific gravity. The pipe would rise until its density would be approximately equal to the density of the mix surrounding the pipe.

The 1.0 to 1.5 specific gravity tests would rise to a point above the calculated combined density by as much as 85%, indicating the vibration would give the sand additional lift to the pipe. An additional test was added to determine if the pipe would sink to the same elevation as a pipe would rise from the bottom. Results indicated that the vibration would not cause the pipe to sink.

The 1.7 and 1.9 specific gravity tests would not rise to the calculated combined density elevation by 91%. This was caused by the very slow movement of the pipe allowing the vibration to tightly compact the sand against the pipe and aquarium walls. Foam discs were used to fill the void between the pipe ends and the aquarium walls to prevent sand from compacting at the ends. This improved the tests, but vibration still compacted the sand between the sides of the pipe and the aquarium wall. This indicated the aquarium was too small.



Results. Tests indicated that pipe buried in granular sand and saturated with water will rise if subjected to movement or vibration. Pipe movement can be caused by compressor and pump station surges, storm wave action, expansion and contraction and exposure to current flow.

The tests did not consider the effects of depth of burial, magnitude or frequency of pipe movement, length of pipe, ratio of the size of sand particles to pipe diameter or depth of water. Additional testing will be required to determine the effects on the pipeline caused by these considerations.

The current solution to prevent a pipeline from floating in backfill in to determine the specific gravity of the backfill and add sufficient hold-down to equal the specific gravity. However, most soils do not have the same problem as granular sand does and it would be cost-prohibitive to add hold-down equal to the soil's specific gravity. Granular sand crossings should be studied for extra hold-down. **P&GJ**

(The author acknowledges the able assistance of Willbros Butler Engineers Inc. and Pioneer Survey in preparation of this article.)

Anchoring Existing Lines Underwater Simplified

by Brian "Butch" Webb
Webb Services Inc.

An oil company located in the California coastal area was in a drilling program that substantially increased production in the area. The company found it was necessary to expand its transportation facilities to accommodate this increase in oil production. It utilized ocean barges for transporting the crude oil from production areas to the market.

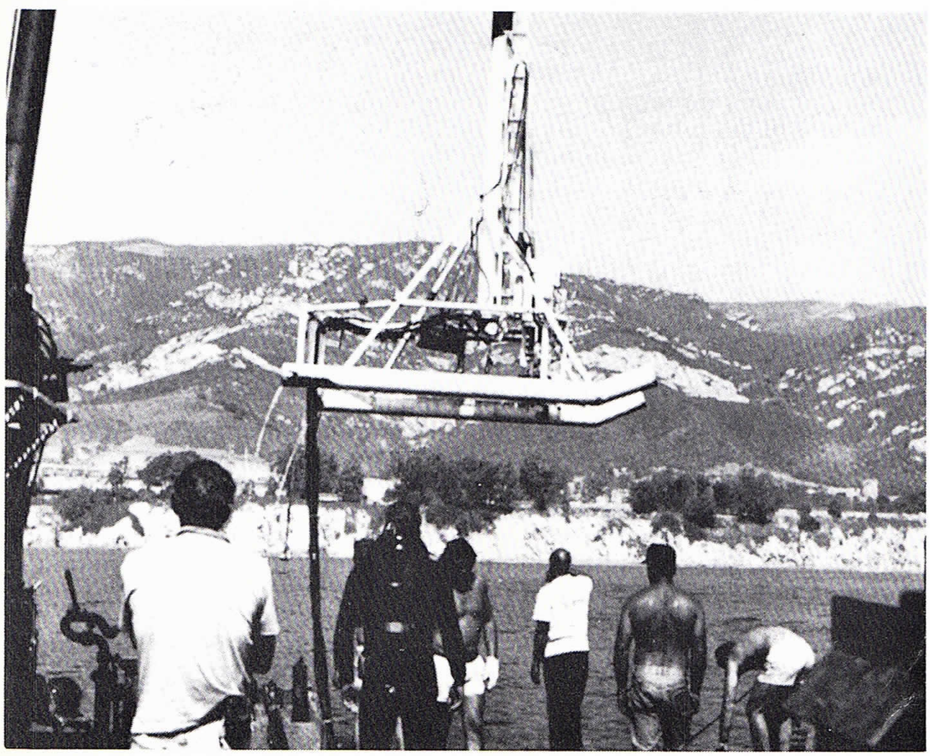
A barge loading terminal was used that consisted of oil storage tanks and related equipment located on shore and two sea lines that extended 2,000 feet offshore to a barge loading area. The two sea lines consisted of 12-inch steel pipe coated with mastic for weight control. Spacing between the piping varied from 0.5 to five feet. Maximum water depth at the PLEM was 45 feet.

A new 30-inch sea loading line was going to be installed to replace the two existing 12-inch loading lines. The 12-inch lines were to be converted into vapor recovery lines for removing the displaced air during loading of the barges. The 12-inch lines would have a 10-inch polyethylene plastic pipe inserted inside them to eliminate any possible leaks.

An engineering study indicated the dual 12-inch vapor lines would require additional hold down to prevent movement because of the displaced liquid inside the pipe. The required hold down calculated to be 41 pounds per foot. A cost study was made using various kinds of weighting that included grout, bags, concrete weights and auger anchors. The use of auger anchors was determined to be the most economical.

A preliminary soil survey was made at the site using full size anchors. Pull tests on the anchors were made to determine hold down. Several types of anchors were installed. These consisted of anchors with various fluke diameters and length of anchor rods.

The shore approach for the load lines was located in a dry wash which over the years deposited stones, cobbles and gravel from the beach to approximately 1,000 feet offshore. Sand overlay varied in thickness from one to four feet thick. Pull tests indicated adequate hold down could be obtained in the rock using an anchor shaft five feet long with a six-inch diameter fluke. Minimum hold down capacity of the anchors was determined to be 3,960 pounds with an anchor spacing of 90 feet. Extra anchors 10 feet long with ten-inch flukes would be provided in case the sand layer thickness increased above four feet.



View of the skid mounted anchor installation tool used on dual lines offshore California.

A quick disconnect was added to the anchor installation tool to provide a quick release from the anchor. All hydraulic controls for operating the tool were located on deck at the power pack. The skid was designed specifically for the Webb Services patented "Hook Anchor" allowing for the anchor to be offset on either side of the pipe.

The section of pipe in the area between high tide and low tide required a Cat 225 backhoe to locate the skid over the pipe. The anchors in this area were installed during the period of maximum low tide. Pull tests were made on the anchors immediately following installation. These tests were recorded and documented.

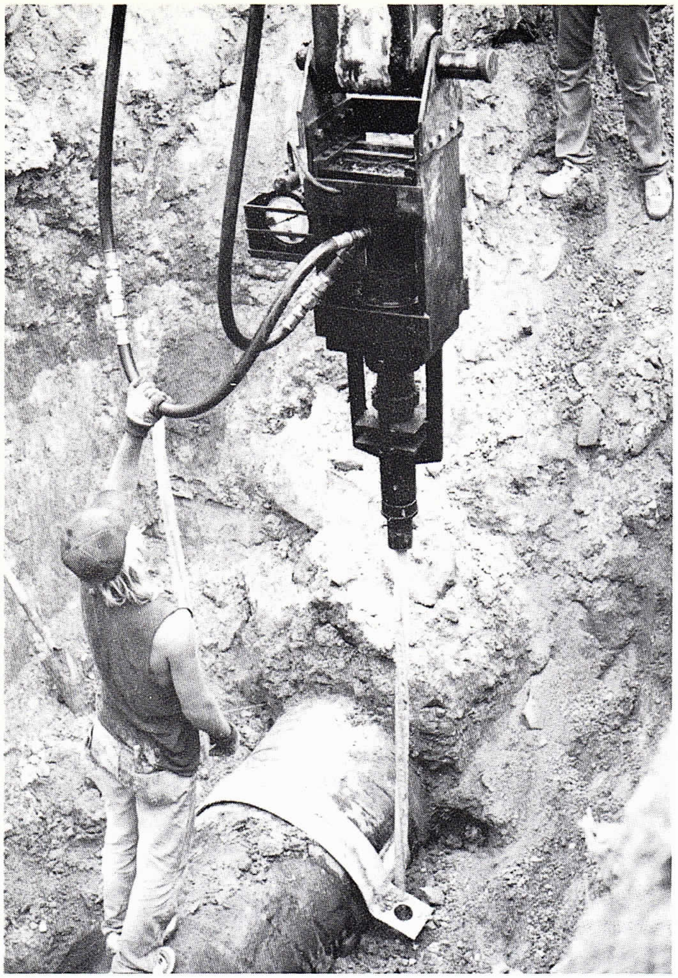
Anchor Installation

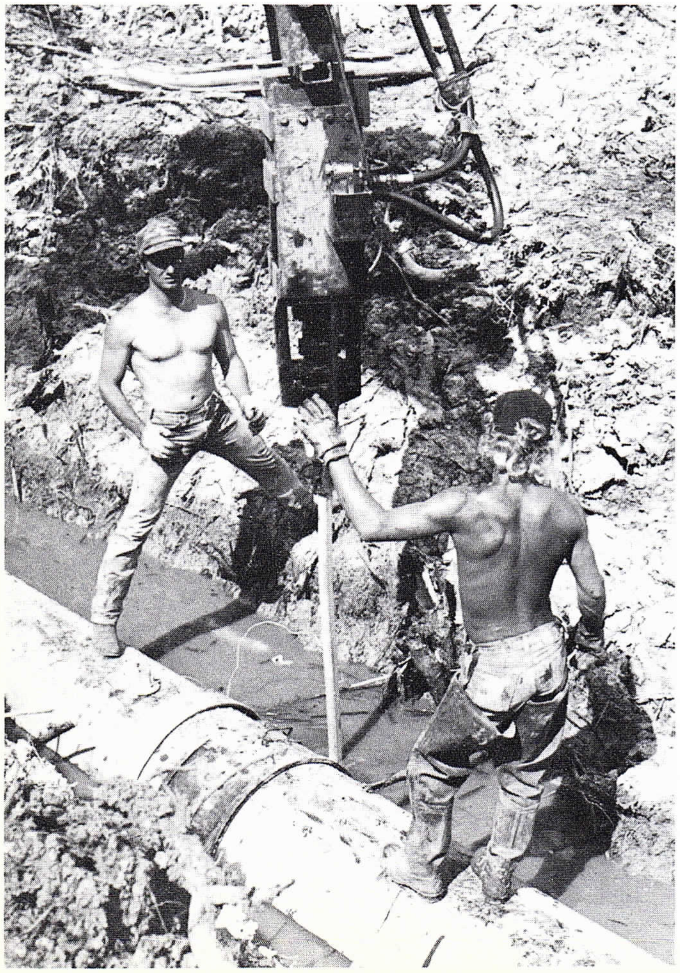
The offshore section of pipeline required an installation procedure that would install an anchor on each pipeline while the skid was on the bottom. This would save time by allowing the installation of two anchors before moving the tender to the next location. The procedure for anchor installation was to load an anchor in the tool and to attach the second anchor on the skid. The tendor crane would lift the skid from the deck and lower the skid to the bottom of the ocean. A diver would be on the bottom ready to receive the skid and would guide the skid over the pipeline.

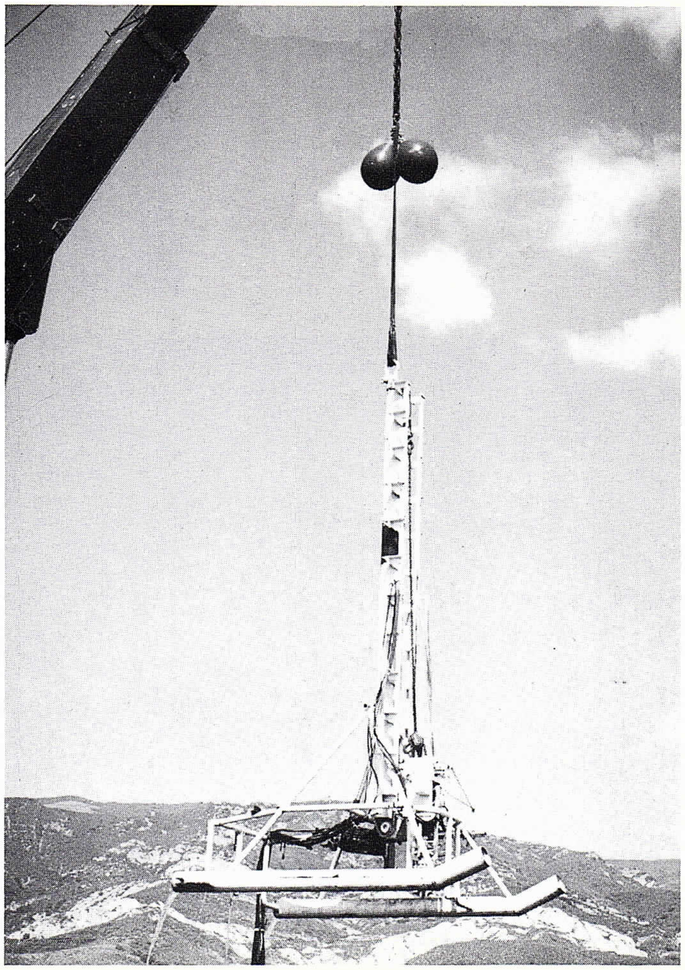
After centering the skid over the pipeline the diver would give instructions to the power pack operator to begin installing the anchor. When the anchor was installed the diver would notify the power pack operator to pull test the anchor.

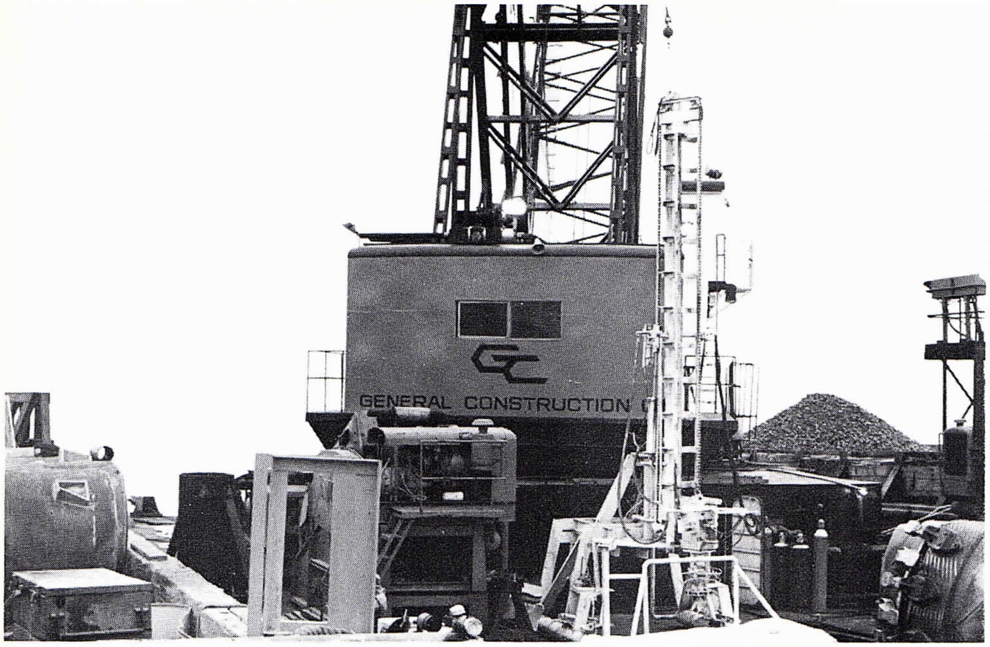
Following the pull test the skid would be moved over to the adjacent pipeline and lowered over the pipe. The diver would load the anchor in the tool, and the installation procedure would be repeated. After the second anchor was installed and tested, the skid would be raised on the deck of the tender and the tender would be moved ahead to the next location.

During installation of anchors in the deep water, several types of soils were encountered that ranged from loose rock to soft clays. These soils were not consistent from one end of the pipeline to the other but would be layered. Thus the ability to change the style of anchor to fit the soil condition enabled the contractor to install an adequate anchor system with a minimum of down time.








GENERAL CONSTRUCTION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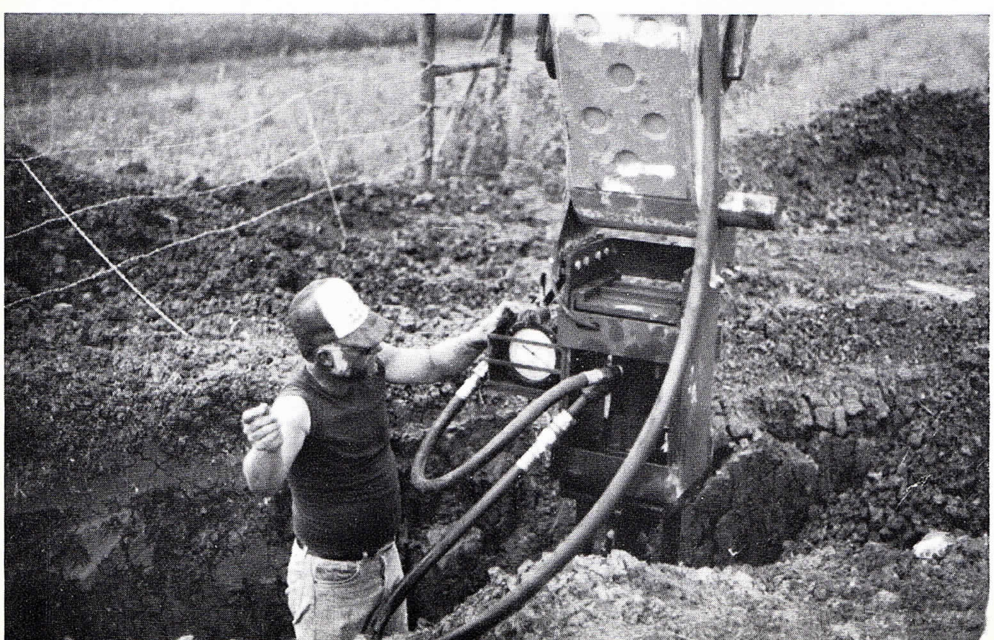


Anchor System Stabilizes Columbia River Outfall

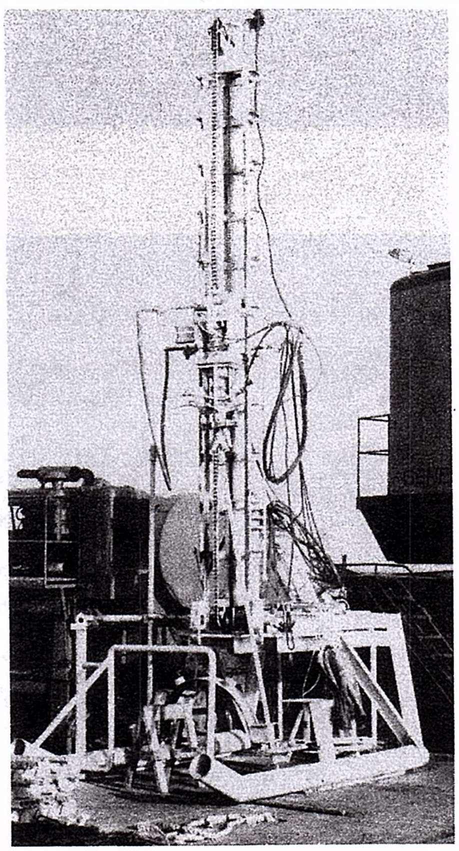
A paper mill located on the Columbia River in the State of Washington required the installation of an outfall as part of a new wastewater treatment facility. This outfall consisted of 9,000 feet of 42-inch diameter concrete pipe, which was to be installed on the bottom of the river with two feet of cover. Water depths varied from five feet at the shore to a maximum of 64 feet at the discharge end.

Design considerations for outfalls of this type include the effects of current velocities and wastewater foam. Wastewater foam tends to collect in the high spots of the pipe, so the design for hold down considers that the pipeline is filled with air. The required hold down is then determined as a function of the maximum current velocity on the pipe when empty. The hold down required for this job was determined to be 337.8 pounds per foot.

Cost studies for pipeline hold down included additional wall thickness for the concrete pipe, set-on weights and auger anchors. The cost of additional wall thickness was prohibitive because of the extra costs of transporting the pipe to the job site by truck. Set-on weights consisted of 20,000 pound weights with a spacing of 33 feet. Cost of building and installing set-on weights were seven times greater than installing auger anchors.

A dam on the river had formed a lake where the outfall was located. Prior to the lake being formed, the terrain near the river consisted of two flood plains with a cap rock separating them. Clay and sand sediments were laid on top of the flood plains, and these sediments varied in shear strengths. Soil borings indicated anchor hold down would vary with the different soil types.

Two methods of anchor hold down will solve a variable shear strength soil problem. The first method is to use various types of anchors at constant spacing to match the different soils. This presents a logistics problem because several types of anchors have to be on the job site to meet the selected hold down. The second method is to use only one type anchor and to vary the spacing to get the required hold down. The maximum spacing selected was 64 feet, requiring 21,619 pounds per anchor set or 10,809 pounds per anchor.



Webb Services skid-mounted anchor installation tool shown on a recent project. The skid straddles the pipe, allowing the tool to install the dual anchors required. This assembly was also used to pull test the anchors after installation.

The auger anchors selected for this job consisted of a set of dual 10-foot-long anchors with one 12-inch diameter fluke and a pipe strap. Corrosion protection consisted of hot dipped galvanized with two 3-pound anodes attached to the strap.

The anchors were installed using the Webb Services Inc. patented installation tool capable of pull testing each anchor after installation. Since dual anchors are required on large diameter pipe, a single installation tool is needed to install both anchors. To accomplish this, an innovative approach for installing anchors was conceived using a skid that straddles the pipe to support the tool. The skid featured a derrick that would move from one side of the pipe to the other side of the pipe to install the anchors. The derrick was equipped to pull test each anchor to 15,000 pounds after anchor installation. All skid controls were mounted on the hydraulic power pack located on the deck to minimize diver work.

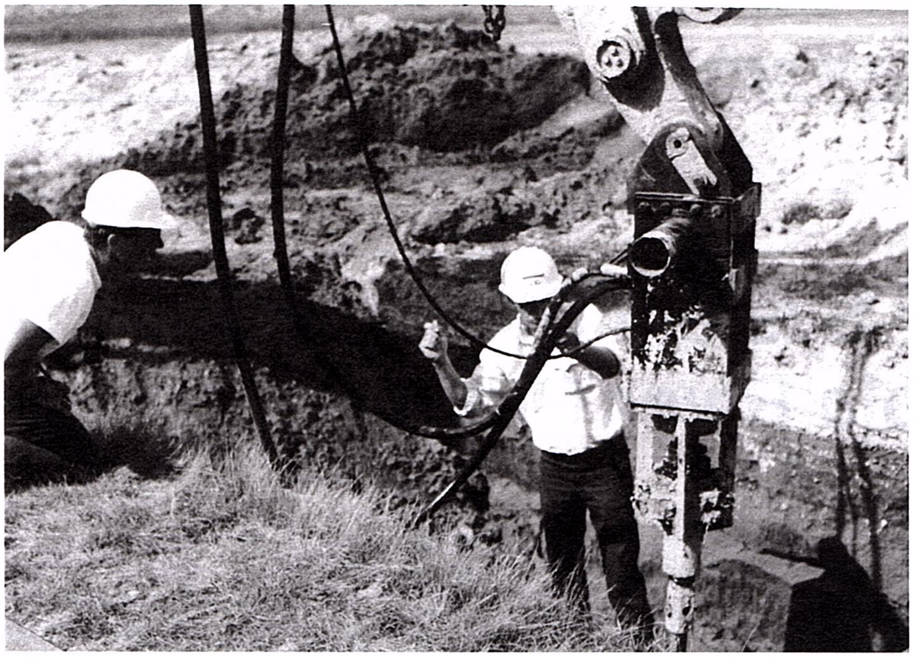
A spud barge with a drag line is used to handle the skid. This technique minimizes the effects of wave action during anchor installation, because the skid is resting on the bottom rather than suspended from the barge.

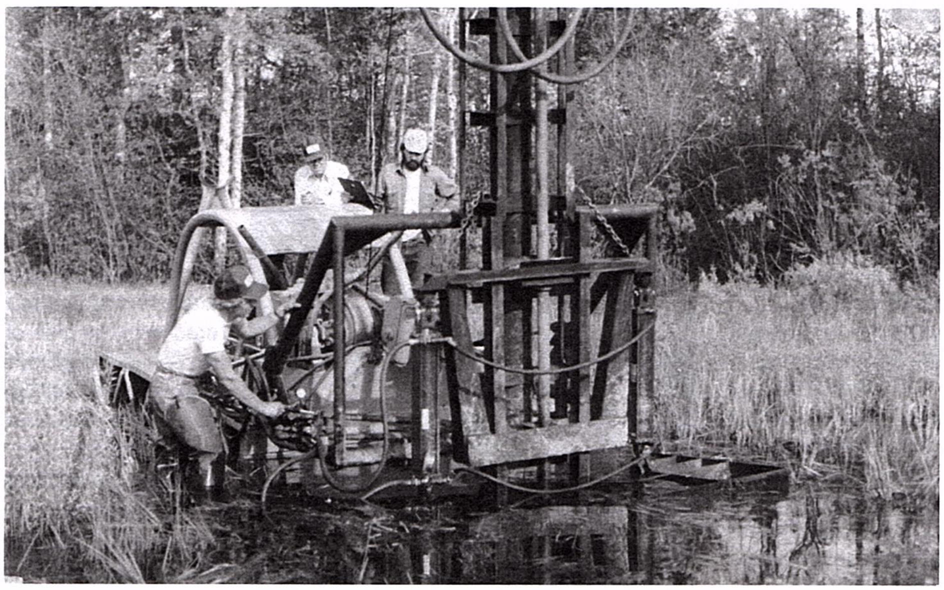
The procedure for installing an anchor set begins with loading the skid on deck with two anchors and a strap. The skid is then lowered over the side of the barge, and a diver is required to guide the skid over the pipe. Following the setting of the skid, the diver is required to guide the second anchor into the installation tool and to give instructions for installing the anchors.

After the skid is on location, the diver instructs the installation of the anchor. When the anchor is to depth, it is pull tested, and the results recorded. The tool is then disconnected from the anchor with a quick disconnect and located over the second anchor with the installation procedure repeated. Following the installation of the second anchor, the skid is returned to the deck. Time required to install one anchor set is approximately 15 minutes.

Anchor pull tests were recorded on inspection forms. If soft soil was encountered and the minimum pull test of 10,809 pounds was not achieved, then the spacing to the next anchor was reduced to obtain the required hold down.

Lessons learned on this job determined that this skid and the installation technique would be suitable for installing anchors in deep water offshore. Certain modifications would be included that would eliminate the use of divers. In addition, magazines for multiple anchor set loading would be included to reduce skid handling time.





Remotely installed supports help remedy seabed pipeline spans

Brian C. Webb
BKW

Pipeline supports show ability to [illegible] pipeline in emergencies.

Underwater pipe spans can occur during the installation of pipelines or anytime afterwards as a result of currents scouring the bottom. These spans can produce excessive pipe stresses, and if allowed to increase in length, can cause pipe failure. In addition, the spans are subject to currents that can create vortices, which will cause pipe vibrations and pipe failure due to fatigue.

During construction, pipe spans are usually created when the pipe is laid across a rock outcrop that protrudes above the bottom of the ocean or when the natural sag of the pipeline will not allow the pipe to remain in contact with the bottom for support. When this occurs in deep water, telescoping pipe supports can provide the necessary support.

The design of the support will consider pipe diameters, desired specific gravity of the pipeline, current velocities and direction, bottom conditions, and fishing trawler activity.

When the design is complete, the supports are installed using a surface vessel, installation tool, and a remotely operated vehicle (ROV).

The installation tool is equipped with the required hydraulic functions for installing the pipe support and expanding the legs. A lifting device located on the surface vessel is used to lower and raise the tool during pipe support installation. On the surface vessel, the tool is attached to the pipe support and lowered to the pipe span.

When the installation tool and pipe support are on location, the pipe support is attached to the pipe using the ROV. The ROV is equipped with a hydraulic power pack. The support legs are extended to the bottom to raise the pipe to the desired elevation to reduce pipe stress. The tool is then disconnected from the pipe support and raised to the surface vessel for reloading another pipe support. The installation procedure is then repeated until the pipe span has been stabilized.

The telescoping pipe supports have successfully demonstrated the ability to provide adequate pipe support during emergencies. The supports were used in various pipeline river crossings in Missouri and Texas during times of flooding. The selection of telescoping pipe supports was based on low cost, quick deployment, and a minimum of equipment required for installation.

River crossings

During the 1993 US floods on the Missouri River near St. Louis, several pipelines were effected by washouts. These pipelines were located on the flood plain, some as much as a mile from the river channel. Two of the pipelines were owned by Explorer Pipeline and Koch.

The two pipelines crossed a farm levee that just happened to blow out at the pipeline crossing and caused a washout 420 ft long and 85 ft deep. This created a 420-ft long span on both pipelines. Accessibility was limited to helicopters, because the flood plain was inundated with floor waters and the US Corps of Engineers' levee blocked boat traffic.

Several options were considered for supporting the pipe spans.

Each option would have to consider the length of span and the pipe stresses as a function of span length to air and water. Other considerations were the flood water current velocity, should heavy rains cause additional flooding, and the ability of a support system to raise the pipe span to reduce pipe stresses to acceptable limits.

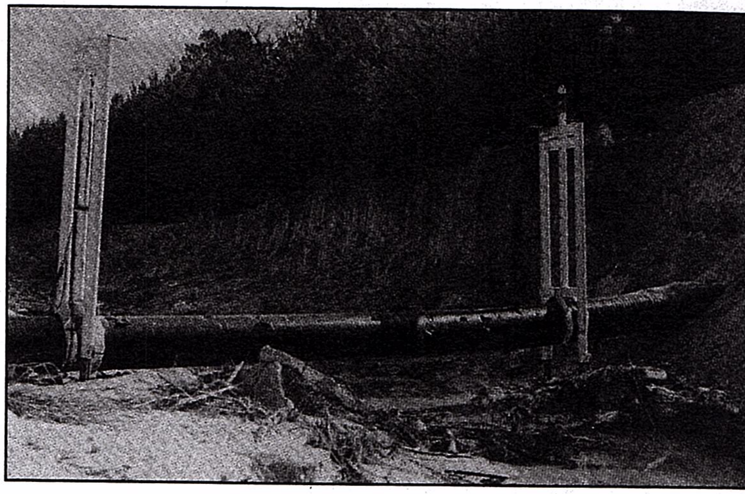
Options considered included pipe clamp-equipped piles that could be driven into the bottom. This method could not be used because heavy equipment such as barges and cranes would be required and accessibility was limited to helicopters.

Cement bags were considered, but the cost and time required to airlift the cement bags was prohibitive. Five concrete bag supports would be required and the height of the support would be 65 ft with a base of 130 ft square using a one-to-one slope. In addition, air bags or some other means of lifting the pipe would be required to take the sag out of the pipe span prior to completing the cement bag supports. A means of attaching the pipe to the supports would be required because of the possibility of renewed flooding. This would cause a strong current that would wash the pipe off the supports.

The option selected was a telescoping pipe support developed by BKW, which included an installation system using a small barge. The barge, pipe supports, diving equipment and personnel were airlifted to the location and the supports installed. The telescoping pipe supports were a single leg design and the telescoping feature was designed to raise the pipe, thereby reducing the pipe stress.

The weight of the pipe filled with liquid in air was the basis of design. Calculations were made to determine pipe support spacing and the minimum allowable deflection.

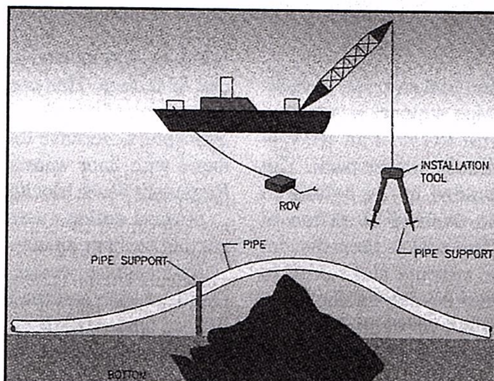
Some minute stress would occur as a result of the single leg supports leaning away from the centerline of the pipeline.



During a flood, long sections of pipelines were washed out, leaving unsupported spans. BKW pipe devices were deployed to support the pipelines.

The single leg support included a mud pad and cleat on the bottom of the support, and a pipe clamp and fill valve at the top. A buoy was attached to keep the pipe support in the vertical position when the helicopter dropped the pipe support on location. A work barge equipped with a hand winch was lowered on location by the helicopter.

The installation procedure included the placing of the pipe supports and work barge on location. The work barge would be tied to the pipeline at the point to be supported. A work boat would bring the pipe support buoy alongside the work barge and the pipe support connected to the winch on the work boat.



Pipe supports are lowered to brace a pipeline installed over a rock outcrop or left stranded as a result of a washout around the outcrop.

The pipe support buoy would be cut free and the pipe support clamped to the pipeline. A water pump on board the work barge would be used to expand the telescoping pipe support to the desired elevation. A range rod would be used to measure the elevation.

Adjustments could be made on the pipe supports at a latter date should span conditions change.

Explorer Pipeline also had a washout approximately 40 miles west of the earlier washout that caused two spans that were 180 ft each. Maximum depth of the bottom was 10 ft below the pipe.

However, this washout was connected to the river and when the river receded, the pipe in the washout would be exposed, thus creating a stress problem. A one-size-fits-all dual leg telescoping pipe support was installed at this location.

The installation included the use of the small barge and helicopter used on the first job. Post pads were used on these pipe supports because the legs were required to penetrate the bottom. This was to give support to the pipe in case the river current scoured the bottom to additional lengths.

The post pads were installed after legs penetrated to refusal to give additional support in case the legs settled. The pipe elevation was determined using a survey instrument, and when the flood water receded below the pipeline, the pipe elevation was adjusted.

Emergency deployment

During the 1994 San Jacinto river floods, the Explorer Pipeline washed out causing a 270-ft span. The one-size fits all supports left over from the Missouri washouts, and the work barge were shipped to Houston.

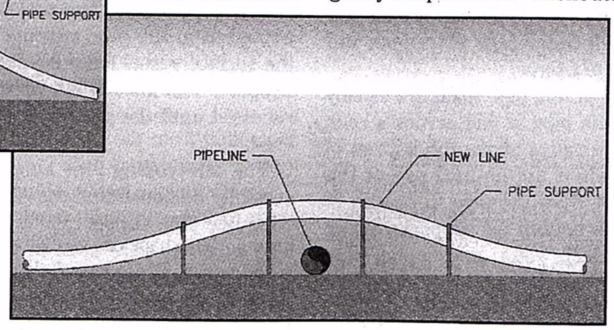
On October 23, 1994, the flood waters had receded to the point that the washout site and pipe could be examined using divers. Temporary cement bag supports were installed. A plan was established to provide a more stable support to the pipe.

The next day, the pipe supports were installed by helicopter in four hours and the pipeline system was sufficiently supported for service by the afternoon of October 24, 1994, only 36 hours after the flood waters went down.

In addition, an eight-inch pipeline was supported at the same washout location using single-leg telescoping supports. These pipe supports and an installation tower had to be fabricated and shipped from Tulsa, Oklahoma. Supports were installed on October 27, using two 14-ft boats and the installation tower. The tower legs straddled the pipe and was supported by the two boats.

Also during the Houston floods, Explorer Pipeline had a pipeline exposed in a drainage ditch. Two of the dual leg supports were installed as a precautionary measure in case additional rains would enlarge the ditch, and increase the span length. These supports were installed using a large crane. Divers were not required.

As a result of the four washouts experienced by Explorer Pipeline, the emergency response for washouts includes several dual-leg telescoping pipe supports that are stockpiled at a central location. These supports are modified for long-term storage and are ready for rapid deployment.Δ



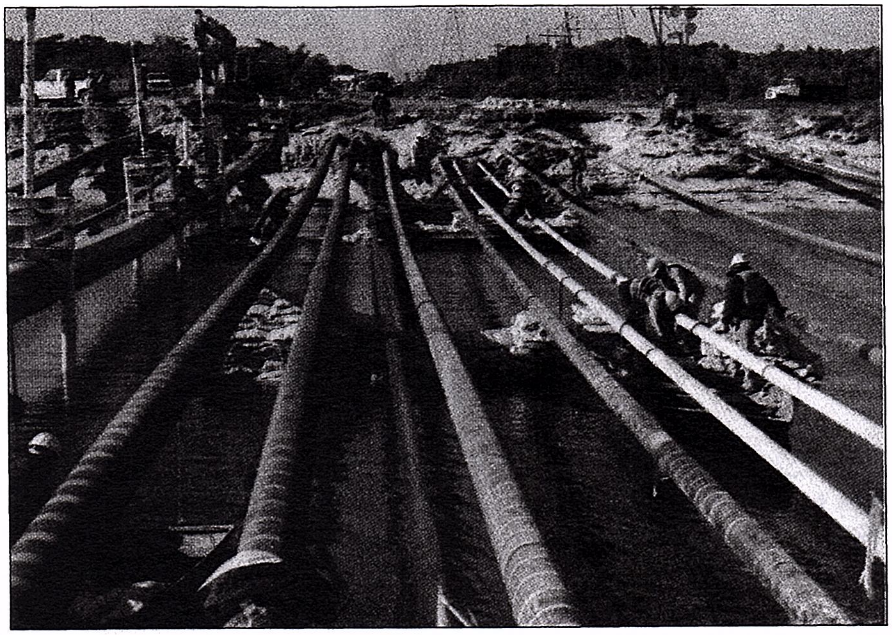
A pipeline crossing is dealt with by deploying pipe supports.

AUTHOR

Brian C. Webb is a principal in BKW, a Tulsa-based engineering company.

Editor's Note: Parts of this article were presented at the International Workshop on Damage to Underwater Pipelines, sponsored by the US Department of Transportation and held earlier this year in New Orleans.

Pipeline Supports Save Pipelines From Flood-Induced Ruptures



Redi-mix concrete pillars were used for temporary support of washed out pipelines caused by heavy flooding.

by Brian Webb,
BKW, Inc., Tulsa, OK

One of the worst nightmares for a pipeline operating company is washing out of soil and fill around the pipeline during heavy rains and floods. When this happens, spans of the pipeline are unsupported and can rupture from the induced stresses after the water recedes.

During the floods of 1993, several wash outs occurred and exposed several pipelines, including one owned by Explorer Pipeline Co. Some washouts were located up to a half mile from the nearest river channel along a 40 mile section of Explorer's 24-in. products pipeline near St. Charles, MO. This 24-in. pipeline parallels the Missouri River for several miles and was constructed on a broad flood plain. Along most of this route, It was protected by levees built by the Corps of Engineers. However, these levees were not built to accommodate large amounts of run off water from the heavy rains, and therefore suffered severe, water-induced erosion damage.

The first pipeline washout was found under a secondary farm levee which was inside a primary levee. At this location, Explorer's pipeline paralleled two other pipelines. The farm levee failed when erosion caused complete failure of the primary levee. The resulting rush of water created a hole that was 320 ft. long, 200 ft. wide, and 50 ft. deep and exposed a 260-ft. length of pipe span. Soil in this location was a sandy, hard clay which eroded quite easily.

Water head drop at the levee failure increased water velocities which washed away soil from both upstream and downstream of the farm levee. Since the soil was washed downstream and carried away, there was no spoil bank in the area for backfill. Re-filling the washout with backfill required shipping soil from other areas and sources.

The pipeline span was declared as "suspect" with data obtained during pipeline patrols and, as a precautionary measure, the system was shut down. Once the exposed pipe was located, it was surveyed with sonar devices and divers which provided a pipeline profile and an assessment of the pipe for possible damage. After the survey determined overall span lengths and determined conditions where the pipe entered the soil, an engineering study was commissioned for determining actual stresses on the span. With data from this study, Explorer could evaluate and implement procedures to assure integrity of the pipeline and ultimately, resume flow of products

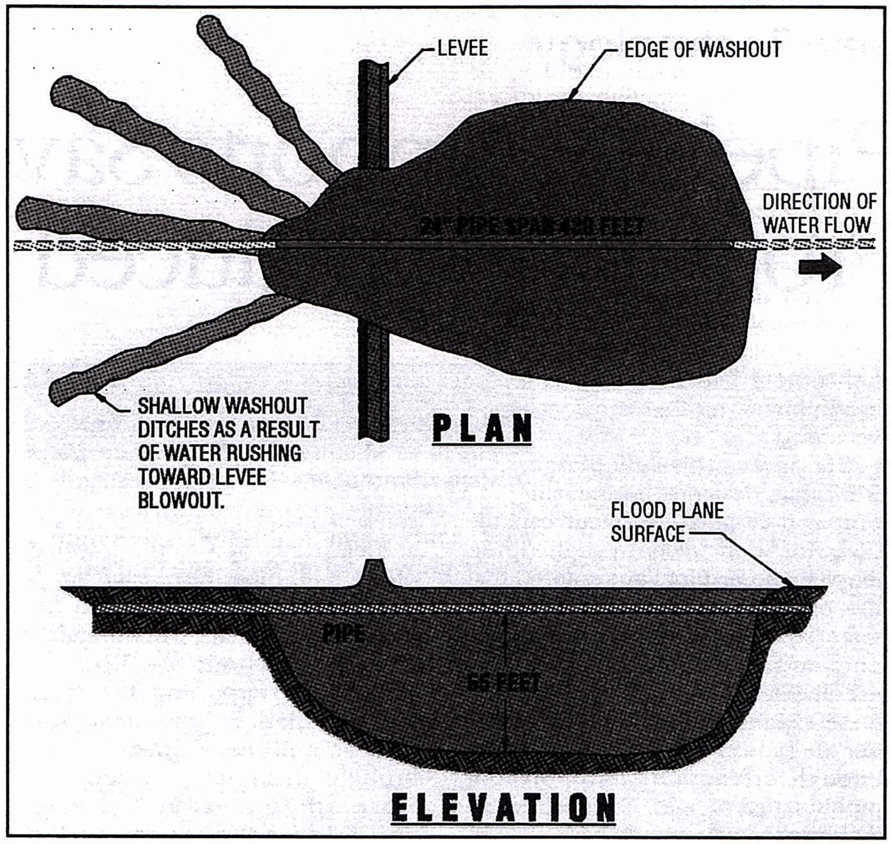
The actual centerline of the exposed pipe paralleled direction of water flow through the levee failure which reduced possible pipe vibrations caused by vortices. Also, this mode of water flow reduced possibilities of trees and other debris catching on the pipeline and causing excessive loads.

Stress calculations were derived and based on the highest density product in the pipeline and operating at various pressures. These calculations showed that the pipeline could return to operation at reduced pressures if it remained submerged. However, water levels in the river ultimately would retreat and re-expose the pipe. If this occurred, another shut down would be needed or the pipeline span would have to be supported to resume operations.

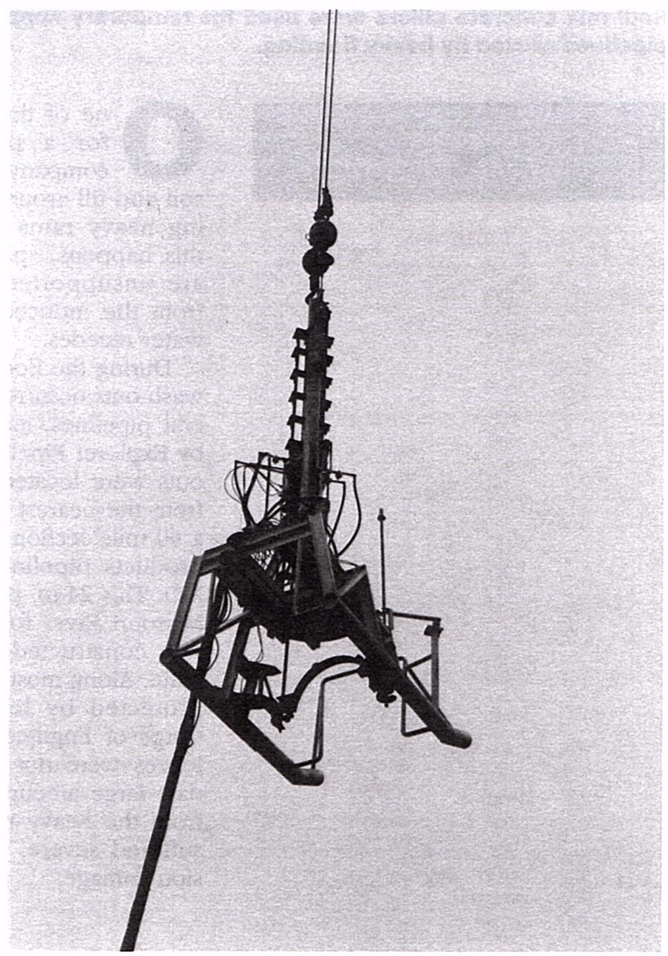
Options For Temporary Support

Several options for temporary support of the span were considered and were limited since levee area access was by helicopter only. Roads in the area were heavily flooded and the remaining levees prohibited reaching the site by boat. Diver boats, survey boats, and additional equipment were air-lifted by helicopter.

First option considered was the use sandbag columns on 50 ft. spacings. However, if a column height of 50 ft. was required, then a large number of sandbags would have to be air-lifted. Installing redi-mix concrete bag supports was considered

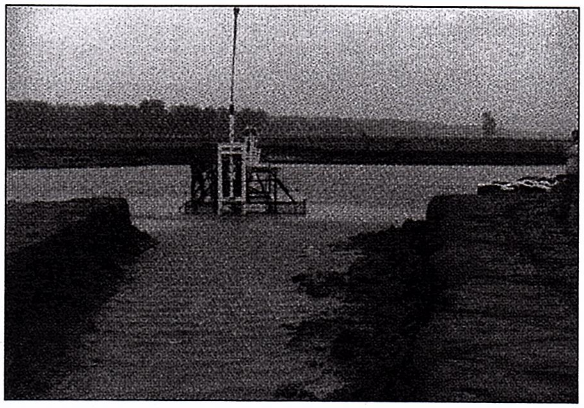


Levee failure and resultant washout hole as a result of increased water velocity through the levee failure.



extremely expensive and installation time requirements required urgent, immediate actions. Also, the pipeline could not be raised to its original elevation with sandbags alone to alleviate induced stresses.

Auger anchors and structures such as pipe piles were considered, as well. Since this choice required necessary equipment to be mobilized in an inaccessible job site and the available helicopters had limited lifting capabilities, another approach was needed.



Dual-leg support was needed in some areas because of shallow conditions and perpendicular water flow of the Missouri River.

To meet this challenge, BKW, Inc. designed a pipe support and installation barge capable of being delivered by helicopter. Since Explorer Pipeline required that the pipeline be supported to minimize stress, telescoping pipe supports were designed and installed in a collapsed mode. These supports were expanded after installation under the pipe and were designed with enough strength to support the pipe's actual weight. Connections to the pipeline were made with a structural clamp which also was fully capable of supporting pipe in the air if water levels dropped below the pipe elevation.

BKW's pipe supports consisted of 6-in. pipe cylinders with a 5-in. internal pipes to act as the telescoping support. Clamps for attachment were on top and on one side. A valve located at the top controlled water filling for expanding a support. Stability and load bearing from the bottom soil was maintained with a mud pad and cleat attached to the lower end of the 5-in. pipe. Also, each support had with a temporary float for holding it in a vertical position after delivery to the job site.

Before completing fabrication and installation of the pipe supports, additional heavy rains brought the river to flood stage. Since the previously-damaged levees had not been repaired, the additional flooding increased the pipe span from 260 ft. to 430 ft. and enlarged hole depth to 65 ft. under the pipeline. To compensate, shipped pipe supports included extra 5-in. pipe for job site modifications.

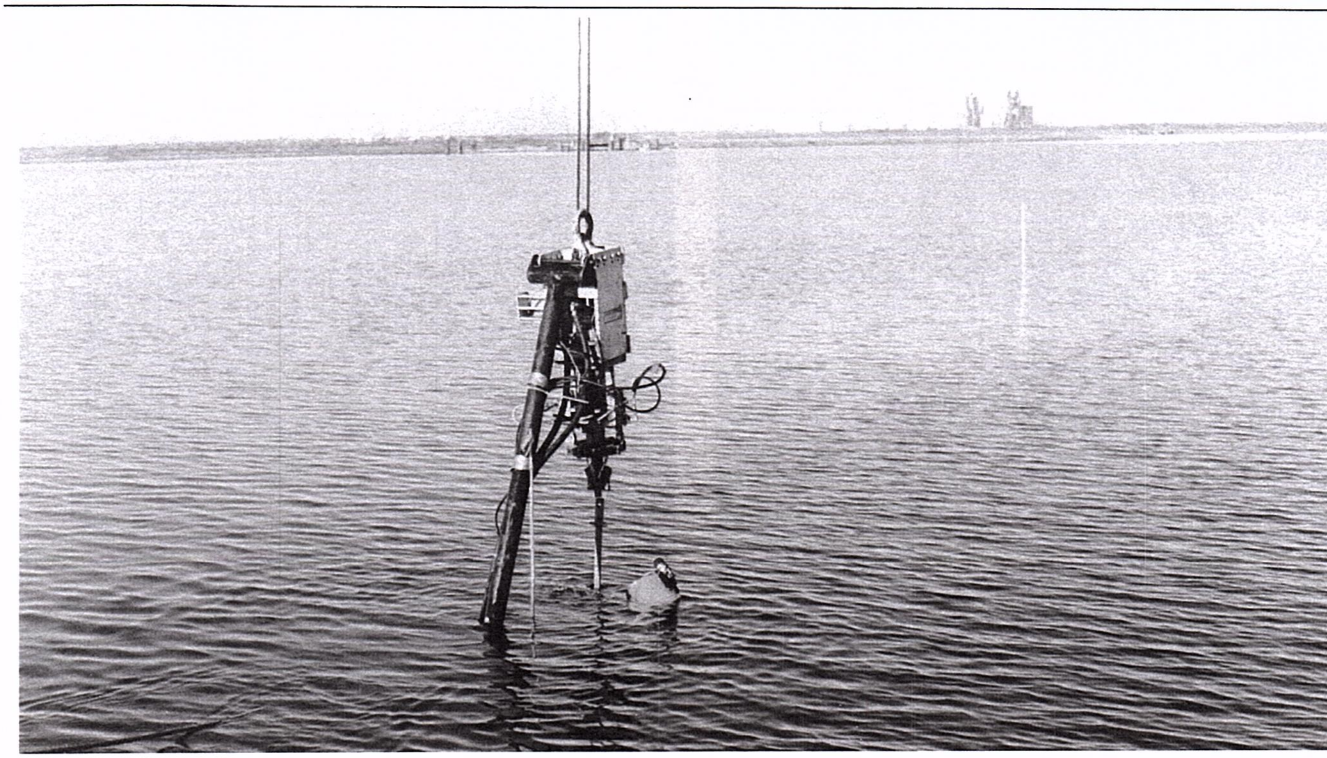
Installing Supports

Logistics included a staging area for off-loading supports and other equipment from trucks was included in the project support plan. A helicopter pad was called out for delivery of pipe supports and setting them in place. Other equipment including an installation barge was delivered to the span site. Diver boats maneuvered it into position for installing the supports.

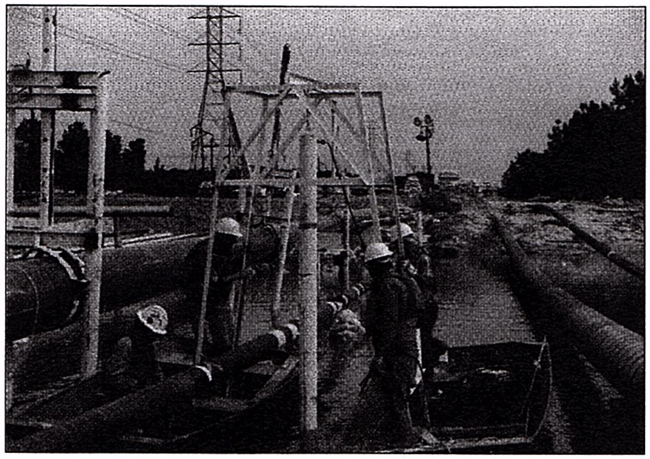
During installation, this barge is connected to the pipeline and a pipe support floated to it. Then a winch on the barge connects to the pipe support and the float is cut loose. A pipe support also is maneuvered and clamped to the pipeline by divers.

In this operation, a hose from a water pump on the barge was attached and delivered water for filling and expanding the support until the pipeline was raised to required elevation. After expansion and filling, the valve was closed and a rod clamp tightened to assure position. Divers also checked the bottom pad to see if enough support was being attained from the river bottom. After this verification, a support is released from the winch and the barge moves to the next location. This procedure is repeated until all supports are installed.

Also included in the equipment were Danforth anchors which are used for lateral support. In this project, they were installed on the periphery of a washout so that ropes could be connected to the pipeline at the pipe support locations. This arrangement produced additional



lateral stability and would minimize possible side effects of river current vortices if additional rains came.



Telescoping pipe supports were designed and installed in a collapsed mode and then expanded. Supports were connected with a clamp which was capable of supporting the pipe in air if water level dropped.

Second Washout Challenges

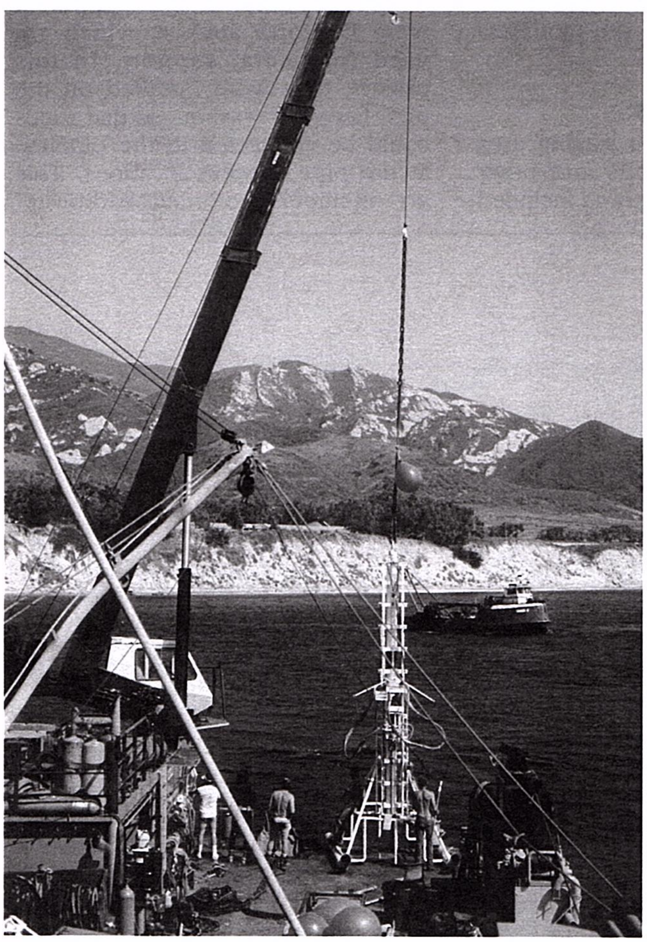
A second washout was found 40 miles upstream. At this location, a Corps. of Engineers' levee had failed about a half mile from the pipeline. Also, the Missouri River had tried to change course by creating a channel from itself to the pipeline. Bottom of the hole was about 10 ft. below the pipeline and current flow was perpendicular. In this case, pipe supports were needed for support and vibration elimination. As a complication, the newly-created channel was split and had exposed two pipe spans with lengths of 200 ft. with an island in between.

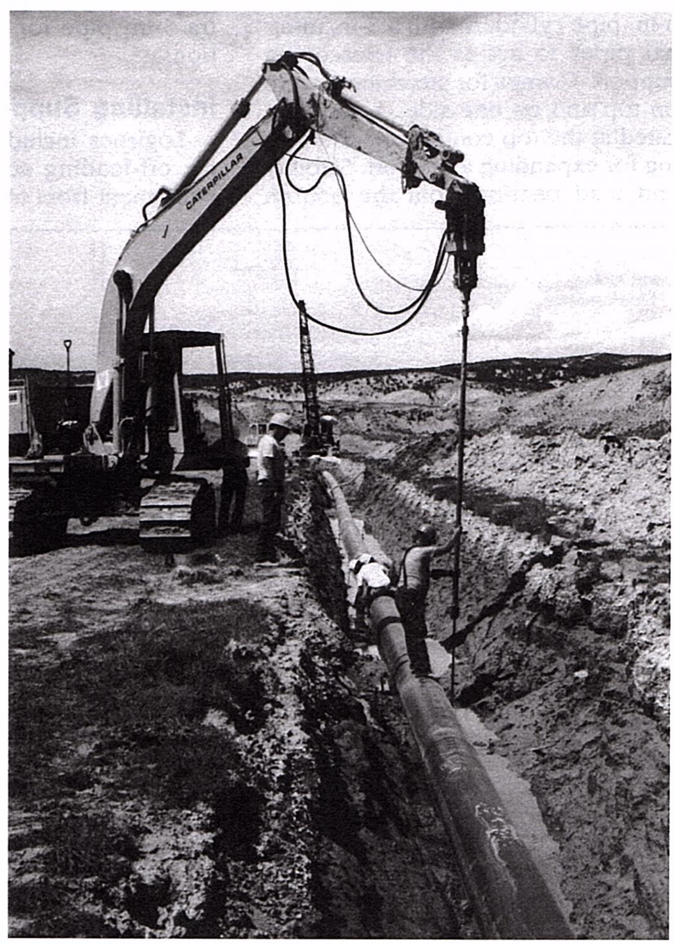
Engineering calculations showed that these spans would require additional support when the water receded and exposed the pipe. Data showed that river bottom conditions and accessibility were almost the same as those associated with the first span project. Redi-mix concrete support pillars initially provided support but began to fail due to multiple floodings.

BKW determined that a dual-leg support was needed due to shallow conditions and perpendicular water flow. Further, it was possible that bottom scour could occur with additional flooding. This meant that pipe support legs would have to penetrate the washout bottom for sufficient support. As a back up and precaution, mud pads were installed after support legs penetrated the bottom to a desired depth.

Further project support was provided by a helicopter which assisted installation and lowering of pipe supports to the river bottom. The same installation barge which was used on the first washout was flown to the job site and connected to the pipeline. Then divers attached a support and extended it until the pipe was brought to its desired elevation.

At the present time, these installed pipe supports are proving to be satisfactory. However, they are monitored and adjusted as needed since this is a temporary solution. Eventually new pipe sections will be installed by directional drilling under the scoured holes. **P&GJ**

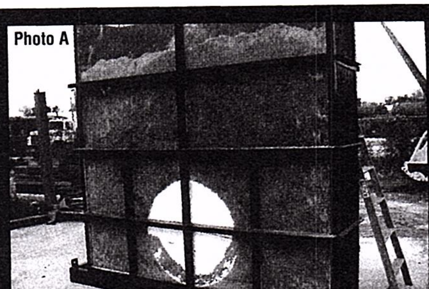


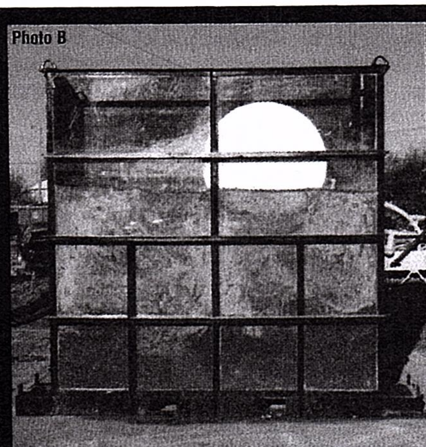


Successful Installation Of Large Diameter Pipelines In Sugar Sand

By **Brian "Butch" Webb,** President, **BKW Inc.,** Tulsa, OK

Large diameter cross-country pipelines know no bounds when it comes to terrain. When going from point 'A' to point 'B,' these pipelines have to cross whatever is in the way and the pipeliner must figure out how to keep them underground once the trench has been backfilled.





Above: View of the test box where a two-foot section of 36-inch diameter pipe was tested to determine how fast it would rise when stimulated by vibration.
Right: Under test the pipe section floated to the top of the test tank within eight minutes.

Sugar sand-type soil can be particularly troublesome. Granular in texture, it is about the same size as sugar with some larger particles and fines that give it color. Sugar sand-type soil is one of the most difficult for a pipeline to cross and it is equally difficult to keep a pipeline in place once it has been installed. If the water table is low, laying pipe is easy. If the water table is high, then laying pipe is a nightmare.

In 1986, a 10-inch pipeline was laid across the Arkansas River near Tulsa. The line floated, was re-laid, and it floated again. As a result, at ASME's 1987 ETCE Conference in Dallas, a paper titled "Vibrating Pipelines in Pure Sand" was presented. The paper described some basic research and illustrated the use of water-saturated sugar sand in a box with a section of 4-inch poly pipe equipped with a vibrator. Since sugar sand has a density of around 2.0, the pipe would float quite easily when vibrated. During the presentation, it became clear that this problem is common.

Recent Installation

Recently, a problem arose on a 36-inch natural gas pipeline project that crossed a large flood plain. The terrain was very flat and the soil consisted primarily of sugar sand. The flood plain had a high water table level and was mostly used for farm land. The area also had a high number of country roads that crisscrossed the area. The bare pipeline had a specific gravity of .54 and the soil had a specific gravity of 1.98. No additional weighting was deemed necessary. The sandy soil was mixed with fines, but the resultant soil had very little shear strength. Following construction, approximately 40 miles of the pipeline floated to some degree and some sections had to be lowered to meet minimum cover requirements. As a result, an investigation was initiated to determine what caused the pipe to float.

In studying the pipeline particulars, the soil depth in the area was found to range from 15 to 20 feet with rock underlying the soil. The water table in the region fluctuates from the surface to around eight feet deep. Rain was found to cause the water table to rise and since rock underlies the soil, the water did not migrate down nor would it migrate horizontally because of the level terrain. The water table falls due to evaporation through crops and other vegetation.

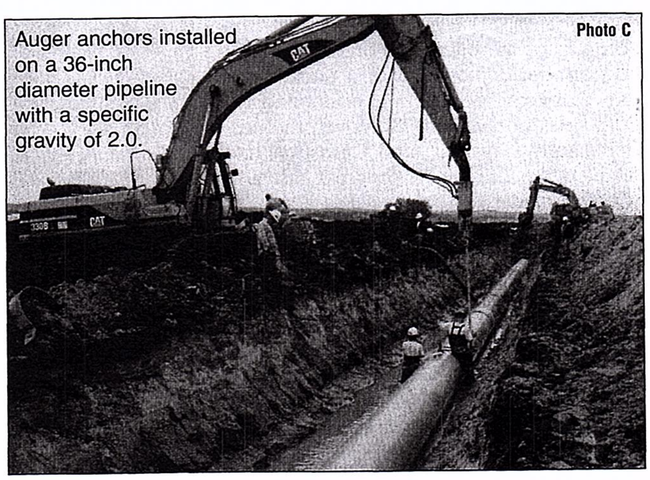
Moreover, when the pipeline was originally laid, the water table was low. However, construction techniques were changed to reduce the effects of the sugar sand soil caving into the ditch. Following construction, rains caused the water table to rise and put buoyancy forces on the pipe, which were only resisted by the low shear strength soil.

Pipeline Test

To locate the raised areas and to measure the magnitude of flotation, a survey was conducted on the pipeline. Upon examining the results, it was found that the flotation was more prevalent near county roads, highways and railroads, (Fig. 1). This pointed to vibration caused by truck and rail traffic as the cause for flotation and, as a result, a test was conducted. The test consisted of building a test box measuring eight feet by eight feet and two-feet deep, with a Plexiglas front.

A section of 36-inch diameter pipe, measuring two feet long with a specific gravity equal to the original pipeline, was installed inside the box, (photo A). The pipe section was marked where the pipe would float in water and in sand. Soil from along the right-of-way was put in the box providing a cover of four feet. Water was injected to saturate the soil.

A concrete vibrator was inserted in the soil to simulate traffic vibration. Within eight minutes, the pipe section rose from the bottom of the test tank and was floating on the sand, which was a rise equivalent to approximately six feet. The pipe was floating at the calculated depth on the pipe, (photo B). During the experiment, the sand acted as a liquid and could be seen flowing around the pipe. Other



Auger anchors installed on a 36-inch diameter pipeline with a specific gravity of 2.0.

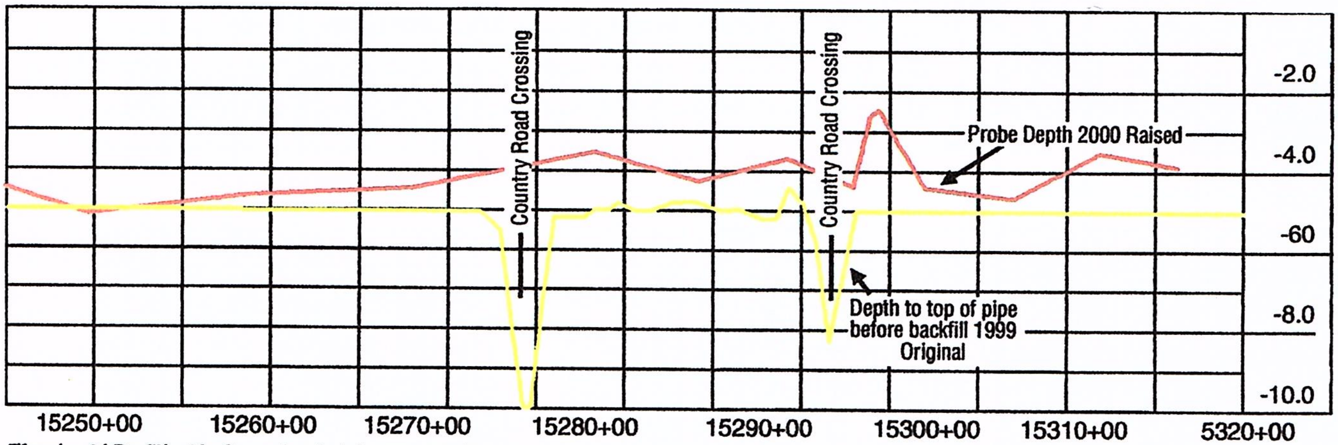


Figure 1: Profile showing raised pipe near roads.

sources of possible vibration on the pipeline were identified as coming from tractors used by the tie-in crews, backfill and clean-up crews. Farm tractors in the 50,000-pound range pulling sub-terrain plows were identified as another source.

This flotation problem was not unique to pipelines in that area. The investigation also revealed that it is normal for area residents to have to use select backfill for sewer and water lines and heavy concrete vaults to hold down burial caskets. Also, in some areas, the houses with basements have to have an external drain system to keep the houses from floating.

Pipe Stabilization

The solution to prevent the pipeline from floating was found to be solved by adding stabilization through the use of concrete weights and mechanical anchors. The most cost-effective use of concrete is installing set-on weights and for mechanical anchors the installation of auger anchors, (photos C and D). Auger anchors were found to offer the most cost effective form of stabilizing pipelines, provided good soil material was located below the pipe to achieve adequate hold down.

On yet another installation, a 36-inch gas pipeline was found to be traversing a sugar sand area. Due to the experience gained on the previous installation, it was decided to add stabilization to prevent it from rising up. In many areas, the contractor had already dug the ditch. So, to add concrete set-on weights after ditching would require widening and deepening the ditch. Therefore, auger anchors were considered and a soil survey was initiated to determine hold down requirements.

The survey was conducted using a Cat 330 backhoe equipped with a BKW anchor installation tool that will pull test each anchor following installation. The Cat 330 can apply a pull test of around 20,000-25,000 lbs., depending on boom out, before the outside track is off the ground. Fortunately, the sugar sand was underlined with yellow sandy clay that would pull the limit of the backhoe when penetrated.

These soil conditions allowed the contractor to dig a normal ditch throughout without planning too far ahead and, if stabilization was necessary, auger anchors were installed without further ditch modification.

The sugar sand on this job had a specific gravity of 1.98 and the specific gravity of the pipe with auger anchors was selected at 2.0, which provided an adequate safety factor. The specific gravity of the pipe using concrete set-on weights was 1.15. In sugar sand, this low specific gravity could present a problem and the design engineer should be satisfied that the selected specific gravity is sufficient to prevent the pipe from rising, should the soil become liquefied from traffic vibration or earthquakes.

The basic design of set-on weights will utilize the overburden of the backfill to some extent. For instance, because of vibration, the sugar sand has to be considered a very stiff liquid. If you drop a backhoe bucket of water-saturated sugar sand on a section of pipe, most of the sand will flow down the sides of the pipe, leaving a small triangle of sand on top that will match the angle of repose of water-saturated sand. When this sand is placed on a standard flat top 36-inch concrete set-on weight that is 48 inches long by 66 inches wide, the volume of sand is quite large.

This overburden weight, when added to the concrete set-on weight, is the reason the specific gravity of a pipeline using concrete is less than when using auger anchors. However, the engineer should take precaution when laying pipe in sugar sand because the soil's flow characteristics will cause the soil to act as a liquid and require additional hold down, thus a greater specific gravity.

Based on these experiences, the pipeliner should perform a comprehensive soil survey prior to design, if the need for pipe stabilization is suspected. Selected resultant pipe specific gravities should be based on soil types and densities rather than on some rule of thumb.

Soil surveys should include soil shear strengths, densities, thixotropic properties, and a common sense test to see if the soil will make a good mud ball.

The test should also include installing and pull testing auger anchors to determine if auger anchors can be used. If auger anchors cannot be used, then concrete set-ons or some other type of density anchor will have to be considered. A soil survey is a small investment compared to the cost of lowering an unstable pipeline. ***P&GJ***

Flat top set-on weights being installed at construction site.

Photo D

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Description of BKW Slot Weight

BKW announces a new "slot weight" for buoyancy control. The slot weight, which is designed to replace concrete set-on weights and sacks, is made to be placed on the pipe while using the backfill for hold-down. It weighs around 100 pounds and uses nylon straps to form a structure. The slot weight spacing on the pipeline is the same spacing as used by set-on weights or sacks.

Drawings and pictures are presented to describe the system:

- Figure 3 shows the slot weight and the supporting straps located on a pipeline in a ditch.
- Figure 4 shows the ditch after backfilling.
- Figure 5 shows the forces affecting the slot weight and backfill as a result of the buoyancy force of the pipe.
- Picture 1 shows the slot weight setting on a 36" pup that was used to test the strength of the slot weight as a result of the backfill.
- Picture 2 shows the backhoe filling the slot weight.
- Picture 3 shows the slot weight ready for a lift test.
- Picture 4 shows the pipe and slot weight suspended during the test.
- Drawing 2014-13 provides calculations for designing buoyancy control using slot weights.

For more information please contact BKW above.

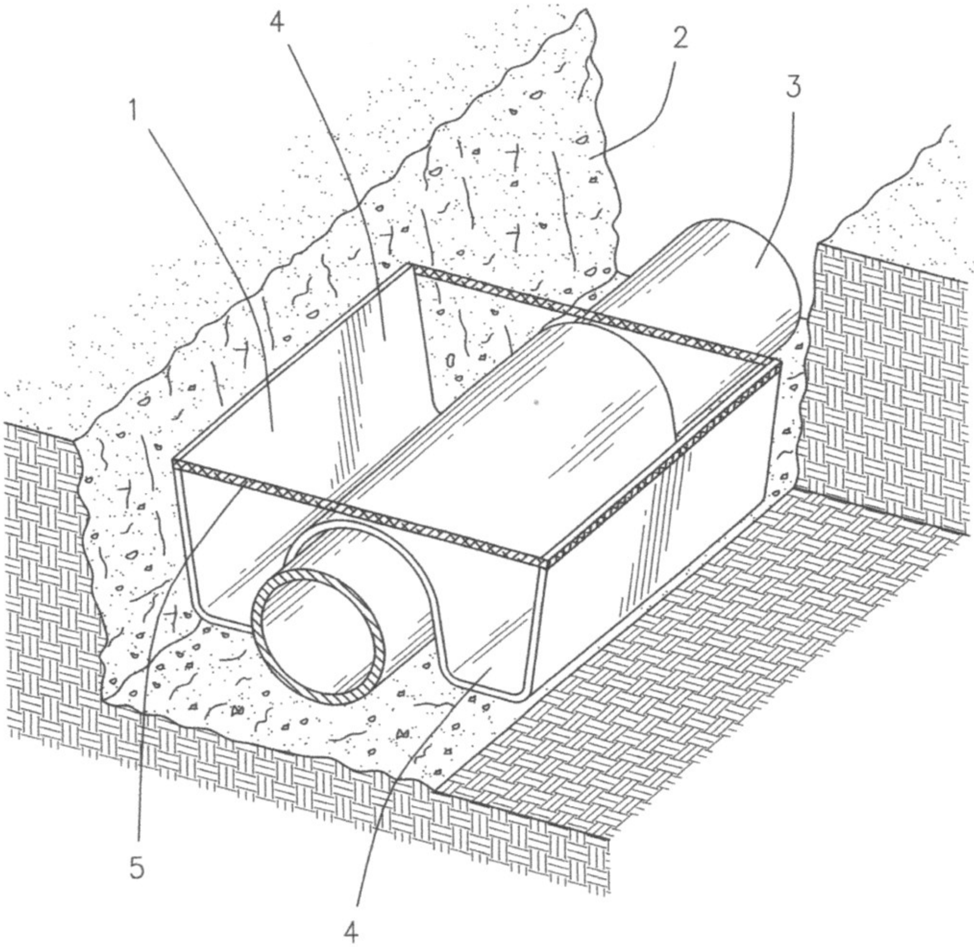


FIG. 3

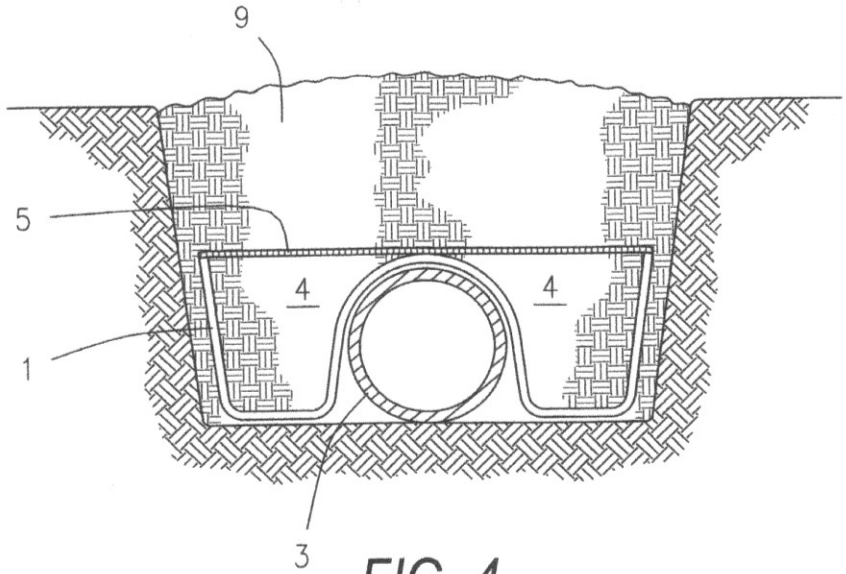


FIG. 4

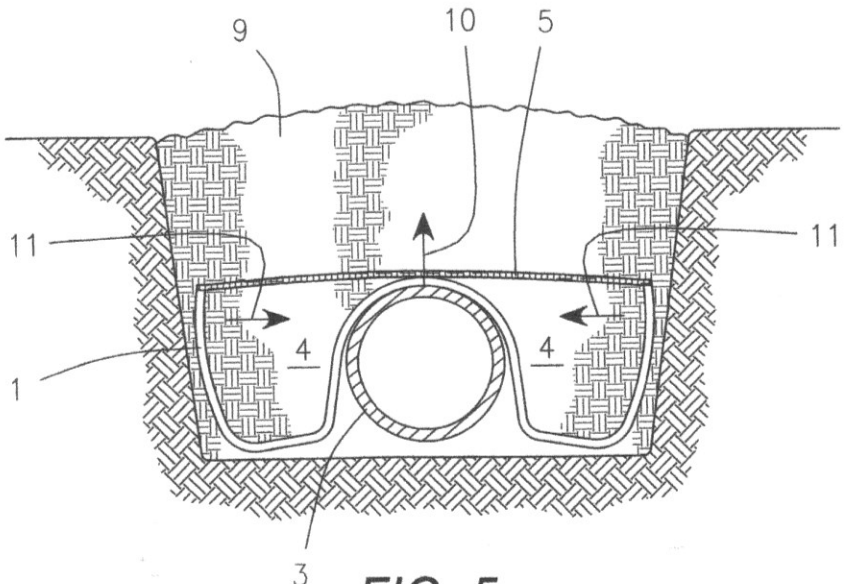


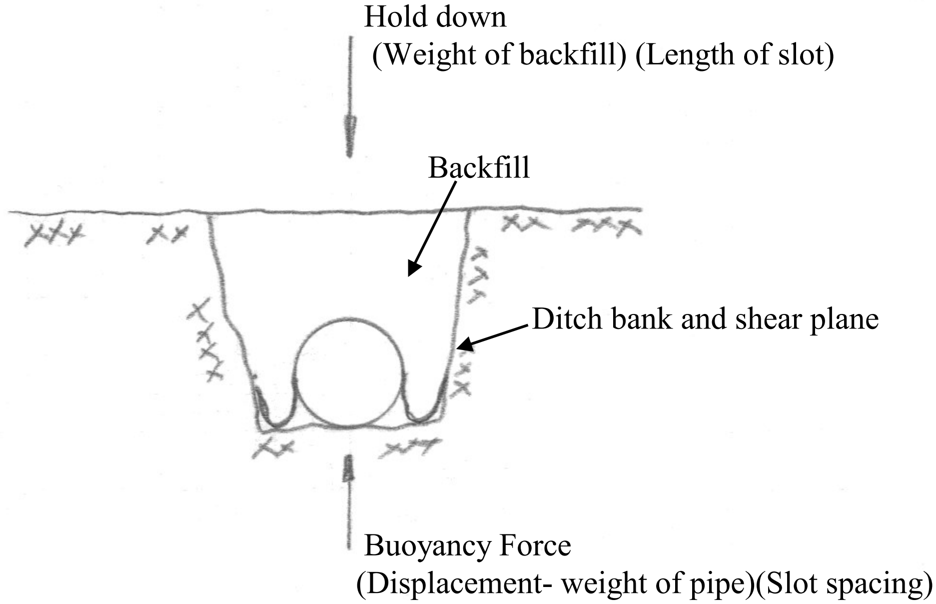
FIG. 5

Picture 1

Picture 2

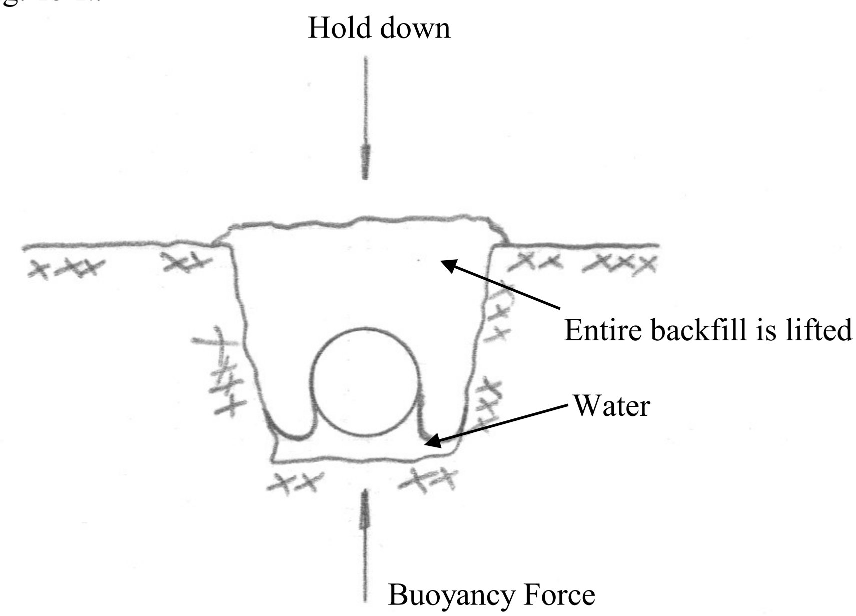
Picture 3

Picture 4



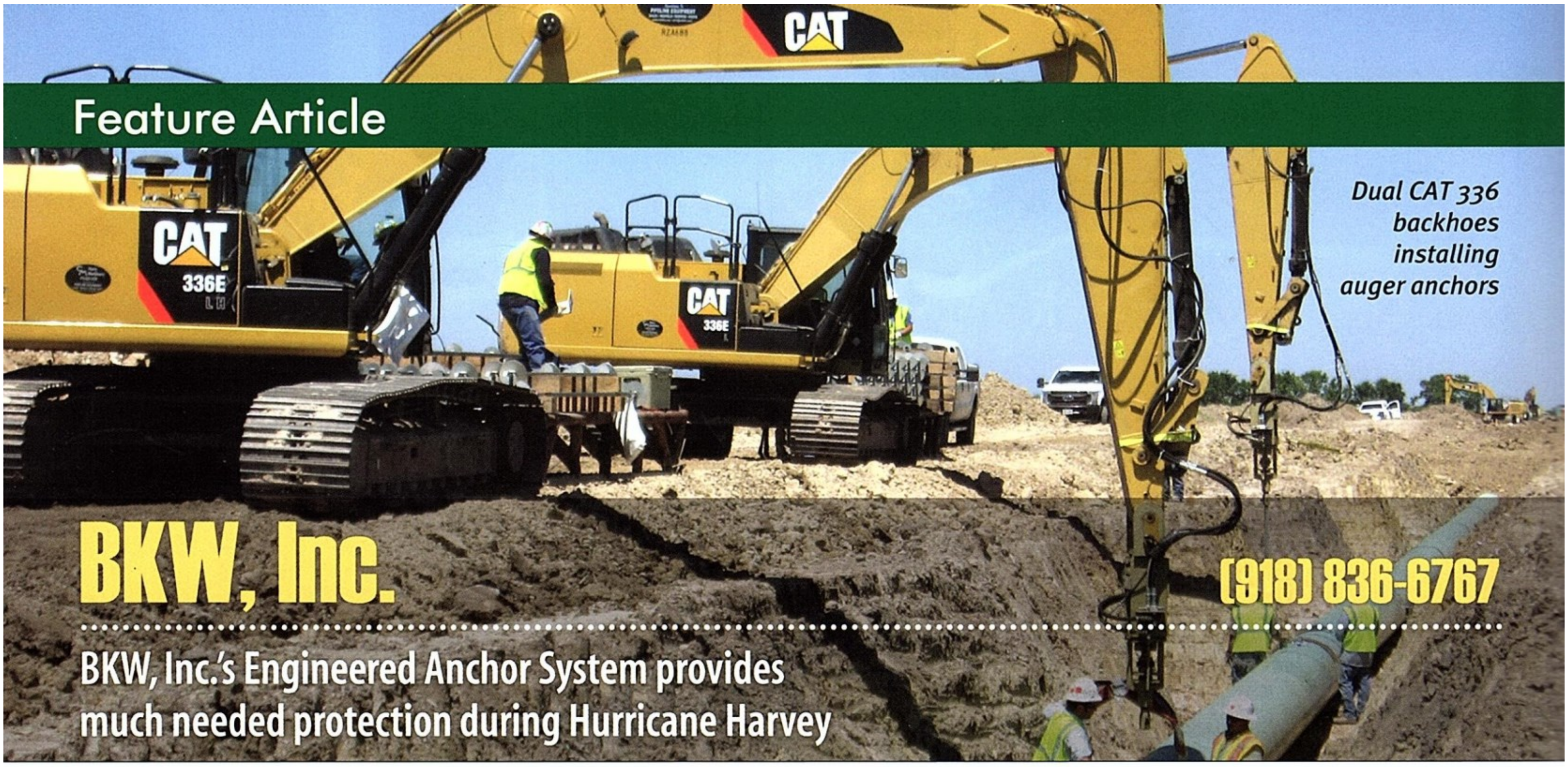
Example:
Pipe: 36"OD x .406" WT API 5LX65
Weight/Foot: 154 Lb/Ft
Displacement: 440 Lb/Ft.
Slot weight:
Length: 5 ft.
Width: 5 ft.
Cover: 3 ft.
Backfill Density: 125 lb/ft³ - 63 lb/ft³ = 62 lb/ft³
Spacing: 15 ft.

Net hold down force
Buoyancy force up
(440-154)(15) = 4,290 lb.
Hold down
(5'x5'x3')+2(3'+1')(62)= 5,022 lb.
Net = 5,022 –4,290
=732 lb. or 732/15= 49 lb/ft.



BKW, INC. TULSA, OKLAHOMA	Slot Weight Design		
	Webb	9-3-14	2014-13

Feature Article



Dual CAT 336 backhoes installing auger anchors

BKW, Inc.

(918) 836-6767

BKW, Inc.'s Engineered Anchor System provides much needed protection during Hurricane Harvey

A new 36-inch natural gas pipeline was constructed south of Houston, Texas and extended to the shore of the Gulf of Mexico. The route of the pipeline traversed the Gulf Plain and low-lying terrain. As a result, the pipeline required several miles of buoyancy control for stabilization to prevent flotation. The engineers located the areas requiring buoyancy control and two types were specified. The first included the use of 9,000-pound sack weights located on 8-foot centers, and the second was BKW auger anchor sets located on 49-foot centers. Thus, one anchor set replaced six 9,000-pound sack weights.

The auger anchor design required a 1.35 specific gravity to be compatible with the backfill and soil conditions. The 1.35 specific gravity required the pipe to have a 571 pound per foot hold down. Each anchor installed was pull tested to verify the 571 pound per foot requirement. The auger anchor sets selected for the 36" pipe consisted of dual 10-foot long anchors with one anchor on each side of the pipe and a strap over the pipe connected to each anchor. The strap was padded with rubber to protect the pipe coating.

The auger anchors were installed using the patented BKW anchor installation tool mounted on a CAT 336 backhoe capable of lifting 18,000 pounds when boomed out. The tool was mounted in place of the backhoe bucket and powered by the backhoe hydraulic system. The installation tool is equipped with a 25,000-pound Martin Decker load cell that measures the pull on every anchor following installation to insure reliability. When carefully engineered the auger anchors have the reliability of sacks or set-on weights.

On this job, BKW proposed an engineered anchor system that required 14,000-pound pull on each anchor thus 28,000 pounds per set. During installation the inspector recorded the location, pull test and remarks concerning type of anchor used. This information became a part of the engineering history.

During kickoff, the soil was conducive to auger anchors and the pull test on 6-inch diameter auger anchor flukes exceeded the capability of the backhoe. However, as the pipeline construction moved further south the soil conditions deteriorated and to obtain the 14,000-pound pull test the use of auger anchors with dual 12-inch diameter flukes was required.

During Hurricane Harvey the pipeline was inundated with flood waters and even when the soft backfill was saturated with water the pipeline was stable. Thus, the buoyancy control was well engineered. This confirms that operating companies can reduce costs by using auger anchors in place of sacks or weights.

CAT 336 backhoe with track off the ground during anchor pull test

BKW's Engineered Anchor System

BKW's Engineered Anchor System


330B L
CAT

NEW INNOVATIONS AND SERVICES PROVIDED BY BKW

1. Engineering: Includes studies and recommendations for pipeline hold down for swamps, rivers and offshore areas using concrete and mechanical anchors.
2. Soil surveys: Includes a full size anchor to multiple soil depths and data is taken from actual pull tests for engineering recommendations.
3. Anchors: Customized for the particular application using mechanical and concrete anchors to provide the most efficient hold down.
4. Bevel anchor: Developed for rocky soils for easier penetrations.
5. Hook Anchor: Developed for use on small diameter pipelines and for offshore areas.
6. Probe: Developed to reduce the cost of mechanical anchors.
7. Mud Anchor: Developed for areas with very low shear strength soils.
8. Installation Tool: A special patented tool for installing anchors that applies a pull test on each anchor to ensure adequate hold down.
9. Inspection and Documentation: This service is provided to satisfy the pipeline owner that the pipeline has adequate hold down.
10. Installation: Provide labor and equipment to install anchors offshore and onshore.
11. Sub Sea Installation Tool: Skid mounted tool for installing anchors on marine pipelines up to 42-inch diameter. Provides pull test to 30,000 lbs. on each anchor set.

BKW will provide technicians on anchor installation jobs to instruct the installation crew to the proper installation technique and testing of the anchors. In addition the location and pull test on each anchor is recorded and documented to provide the pipeline owner with a permanent record.

BKW is the leader in pipeline anchoring. Design information, engineering, and specifications are available upon request.

We invite you to visit our website for additional information.

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