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Some problems in the construction of artificial and natural gas pipe lines

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SOME PROBLEMS IN THE CONSTRUCTION OF
ARTIFICIAL AND NATURAL GAS PIPE LINES

by

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A

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INTRODUCTORY

In 900 A. D. the Chinese piped natural gas through bamboo tubes and used it for lighting, and about 1830 artificial gas was carried by three inch wooden pipes in a town in New England. Today there are many thousands of miles of steel pipe bringing gas from Western fields to eastern cities, and many more miles of steel and cast iron pipe for the distribution of artificial and natural gas in the majority of the towns and cities in the United States.

This paper will deal with the construction of acetylene welded steel pipe lines, and some of the problems involved in this type of construction.

The photographs in this article were taken by the author, or under his direction, and the information obtained from personal experience.

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LONG LINES

In the construction of long gas pipe lines the first step, like highways and railroads, is obtaining the right of way. But, unlike highways and railroads, the topography of the country plays a minor part; for pipe lines can be run over hills and under creeks and rivers, without cutting the grade or building bridges.

The construction crew is uasually divided into the following sections, working in the order named:

1. Clearing right of way.
2. Distributing pipe.
3. Firing line or front line welders.
4. Excavation.
5. Bending and final welding.
6. Painting.
7. Laying.
8. Backfilling and cleaning up.

The right of way varies in width from fourteen to fifty feet, depending on the size and number of lines to be laid; and it is the clearing gang that must clear this strip of all obstructions so that the following crews and machinery can move along without interference.

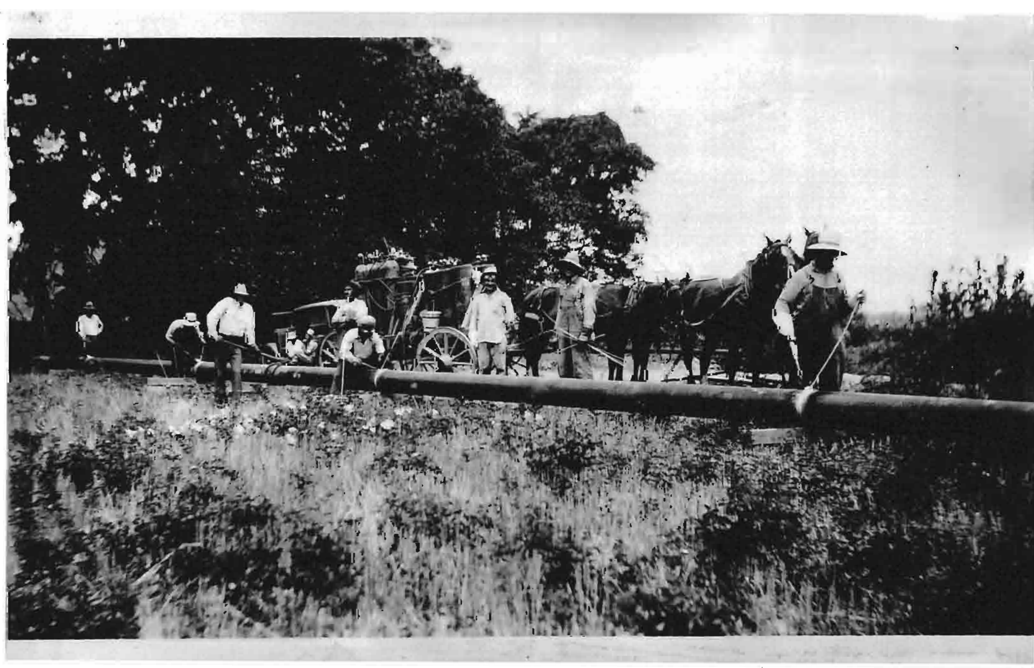
Following the clearing the pipe is distributed along the right of way, the joints being laid end to end wherever possible to avoid unnecessary moving of the pipe later on.

Next is the line-up gang and one welder, known as a tacker. The pipe is lined up on skids (4"x4" or larger timber) in sections of five joints, and these joints tacked together by the welder in order that the pipe will remain in the proper alignment until the front line welders can completely weld each joint. The number of joints of pipe in a section depending on the size of the pipe and the topography.

Front Line Welders

The firing line consists of one or more groups of welders, working in four-man sections. Acetylene and oxygen being supplied from a generator and tanks of oxygen mounted on a truck or wagon. Each welder makes one complete weld, the pipe being slowly turned on the skids so that the welder is always welding near the top of the pipe. This is known as a rolling weld.

The excavation follows the firing line and is done, wherever possible, with machinery. Among the various types of machines used the Barber-Greene,



Firing Line Welders on a 10" Natural Gas Line in Kentucky. Note Horse Drawn Generator.

Buckeye, Cleveland, Austin, Parsons and Bay City are the most common. The excavation, as a rule, is kept far enough ahead of the bending and laying crews so that, should the excavator be temporarily stopped, due to breakdowns, the other work will not be retarded. The depth of the trench varies according to the size of the pipe and existing conditions.

Barber-Greene Ditching Machine

Working Along Concrete Highway in New York State.

Following the excavation is the bending crew. This gang places the long sections of pipe on the skids over the trench, makes the necessary bends in order that the line will conform to the trench, and completes the welding by welding the sections into one continuous line.

The bending is done by tractors equipped with a power winch and boom. Pipe of 12" diameter, or less, is usually bent in the field without heating. Larger sized pipe is commonly bent by heating with large portable torches, or shop bends are used instead of bending.

Snaking Pipe Onto Skids Over the Trench With a Caterpillar Tractor Equipped with a Boom.

After the pipe has been bent to conform to the ditch it cannot be turned, as for the firing line welders, so the welders with the bending crew must work around the diameter of the pipe when making the final welds. This is known as an overhead, or position, weld. Overhead welding is much more difficult than any other type and naturally consumes more time. Unless the pipe is of such small diameter that it can be blocked up above the top of the trench a hole, known as a bell-hole, must be dug for the welder to work in. See illustrations on page eight.

Making an Overhead Bend in a 12" Gas Line With a Tractor and Boom.

Working directly behind the bending crew are the painters, and it is their duty to see that no part of the pipe is left unprotected by whatever coating is called for in the specifications. Most pipe coatings are applied hot, and this necessitates the use of portable kettles to keep the enamel at the proper tempature.

The pipe is first cleaned to remove any dirt or oil, and then a coat of priming paint is applied cold with a brush. After the priming coat has dried sufficiently the enamel is applied. This enamel, heated to a tempature of approximately 300°, is applied by pouring along the top of the pipe and using a canvas sling to give an even coat on the sides and bottom. The enamel hardens in from five to fifteen minutes, and if the priming coat has been correctly applied forms a perfect bond with the pipe.

In recent years a mill wrapped pipe has been placed on the market and found to be much more satisfactory than pipe coated in the field. When this pipe is used it is only necessary to coat the joints in the field, for each piece of this wrapped pipe is wrapped at the mill to within eighteen inches of the end. The coating on mill wrapped pipe consists of one coat

Tacking a Joint Preparatory to Making an Overhead Weld. Note Welding Clamp Holding Pipe in Position

Making an Overhead Weld on a 10" Line

of priming paint, one coat of enamel, a wrapping of tar impregnated felt, and an outside coat of enamel. The wrapping of felt is applied by machinery at the same time as the enamel is put on, and as the felt is kept in tension a perfect bond between the pipe, enamel, and wrapping is obtained. Mill wrapped pipe is shipped from the mills in specialy braced cars to insure delivery in an undamaged condition. However, it has been the experience of the author that mill wrapped pipe will stand much rougher handling than pipe coated in the field.

Kerosene Fired Melting Kettle for Heating Enamel

Lowering a 12" Line With Tripods in New Jersey

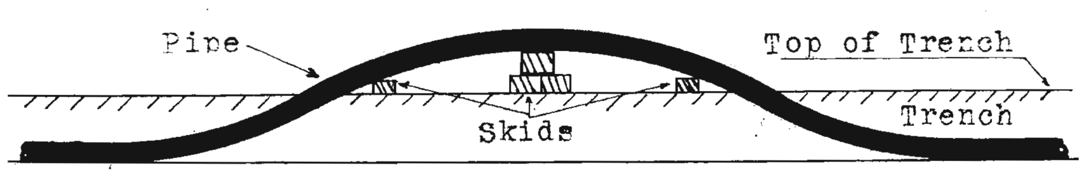
Coating an 8" Line in the Field with Enamel

The lowering of the pipe into the trench is done with portable tripods, equipped with small hand operated winches, or with a tractor equipped with a boom. The pipe is raised high enough above the skids to permit their removal and then lowered into the ditch. If the pipe is of very small diameter it is often welded along side the ditch and lowered by hand without any equipment. However, by using tripods or tractors the work can be done much more rapidly and the danger of knocking dirt into the trench avoided.

Bulldozer and Boom Equipped Tractor Lowering Pipe
at Beachaven, New Jersey

Expansion joints are often placed in a line to take care of expansion and contraction due to temp-ature changes; but where these are not used it is customary to put in slack loops. This is done by lowering several hundred feet of pipe into the ditch, then blocking up the pipe on several skids on top of the ditch, and lowering again on the other side of the skids. Early in the morning, while the pipe is cool, the skids are removed and the loop forced into the trench. This gives added slack to the line and is a precaution against breaking at low tempatures.

Backfilling is done wherever possible with mach-inery, or in some sections with horse drawn scrapers. Backfilling and cleaning up are the last steps and speak for themselves.



Showing Method of Supporting Pipe on Skids Laid Over the Top of Trench to Form Slack Loop.

DISTRIBUTION SYSTEMS

The construction of distribution systems is entirely different from the construction of long lines in open country; for it is the distribution systems that deliver the gas to the consumer in towns and cities. Naturally it follows that where there are consumers there are paved streets, traffic conditions, and other pipe lines and underground construction.

Here, also, machinery is used as much as possible, but in many cases hand methods are necessary, especially in excavation. Further, many feet of trench cannot be opened ahead of the actual laying and the pipe must be handled in shorter sections, often in single joints, and more and sharper angles are necessary than in long lines.

In making turns in city work there is little room for bending and angles must be fabricated by cutting the pipe to the desired number of degrees and re-welding. As is often the case, these angles have to be fabricated after the pipe is placed in the ditch and the welds made with the pipe in the position in which it is to remain.

Hence there are many more overhead welds, which take from three to five times as long to complete as the rolling welds.

Street intersections must be kept open to maintain traffic and this necessitates many temporary bridges over the trench. Where the line must go under railroad tracks it is often necessary to tunnel. Many railroad companies forbid tunneling, and where this is the case a casing, larger than the pipe must first be driven, and the gas line run through this.

Welder Tying in 90° Bend with Overhead Weld on

4" Butane Gas Line

In many instances the information on existing water mains, and other underground construction, is very inaccurate and after a casing is partially driven a change may be necessary to avoid some other line, laid years before and on which there is no information.

In using machinery, for excavating in cities, there is always the danger of cutting water mains or underground cables whose exact location cannot be found beforehand. On one project, of which the author was superintendent, an electric company gave the location of a high voltage underground cable at a certain point in the street. As an extra precaution the excavation, being done with a Bay City back-hoe, was started at a point ten feet from the supposed location of the cable. After about six feet of trench had been opened the bucket caught the cable and cut it. Fortunately the machine operator was not grounded at the time, or in all probability he would have been electrocuted.

As a result, with conditions such as these in mind, it easily can be seen why, where four thousand feet or more can be laid in a long line in a day, several hundred feet in city work can be considered a good days run.

Water services, to houses, and sewers, probably constitute the biggest hazards to city work. Here the trench must be carefully dug by hand and the gas line snaked under the water and sewer services. As the grade on existing sewers cannot be changed, over-bends must be made in the line to avoid them. This takes much time and calls for many overhead welds.

Main Line from Compressors Tying in to After Cooler and 24" Line to Gas Holder

Excavating with Machinery Along a County Road in Southern New Jersey. The Machine in the Foreground is a Barber-Greene With the Bucket Line Set to Remove Six Inches of Top Gravel. Following is a Cleveland Cutting the Trench to a Depth of Thirty Inches

RIVER CROSSINGS

Each river crossing presents problems unlike any other, and where one method of construction works to advantage on one crossing it may be totally inadaquate for the next one.

On small rivers, which need not be kept open for navigation, it is common practice to weld the line on shore. As the line is completed it is pushed out in the river, supported by pontoons, and when the entire line is across the pontoons are removed and the line sunk to the bottom.

On a recent crossing in New England the river was only fourteen hundred feet from bank to bank, but the channel could not be closed to navigation for over five hours at a time. In this case an inclined runway, long enough to hold three, forty foot, joints of pipe, was built on the river bank. As the line was welded it was attached to pontoons and pushed upstream, parallel to the shore. When the entire line was welded, and in the river, tugboats were attached at three points and the line swung across the river. When the desired location was reached the pontoons were released and the line sunk to the bottom.

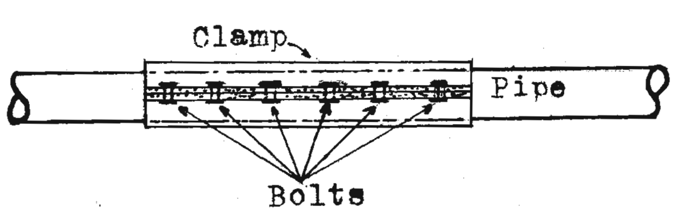
An 8" line crossing a large river in New york State, on which the author was engineer for the contractor, was laid in an entirely different manner. Here the distance from bank to bank was approximately six thousand feet and the channel had to be kept open. The pipe, previously welded into eighty foot sections, was placed on an inclined rack built on the deck of a large barge. Down the center of the deck was built an inclined runway with the lower end at the stern. The pipe was shifted from the rack to the runway, and as each additional eighty foot section was welded the barge was moved ahead eighty feet. Steel pontoons, carrying eighty pounds of compressed air, were attached every eighty feet. These pontoons were not intended to wholly support the pipe, but to allow it to sink in an arc as it came from the barge into the water. Extra heavy pipe was used and without the support of the pontoons there was danger of it sinking too quickly and breaking or kinking. As each additional pontoon was attached, as the pipe came from the barge, the one on the back of the line was released and brought forward to be used again. The barge was moved ahead by two pile drivers, which in turn were moved by lines from the steam winches to anchors previously sunk in the river.

Looking Aft on Pipe Laying Barge on Hudson River Crossing.

Due to the uneveness of the river bottom there was some danger of the pipe being in suspension. In order to remedy this a diver inspected the whole line after it was sunk. At points where the pipe was held up, by small hummocks on the river bed, a water jet was used and the pipe sunk to position. On this particular crossing the construction was continuous day and night and the project completed in eleven days.

On another crossing, of the Green River, the entire line was welded on the bank, at right angle to the river. When the entire line was welded pontoons were attached, and the line shoved across by two tractors pushing from one bank.

Where light weight pipe is used it is often necessary to attach weights to prevent the line from shifting after it has been sunk. The most common type of weights used are river clamps, which consist of a short cast iron sleeve, made in two sections, which is bolted around the pipe.



River Clamp Attached To Pipe

In some cases railroad iron is used in place of river clamps. The rail is cut into short sections which are welded directly to the pipe at the joints. This method, as the use of river clamps, not only adds weight to the line but gives extra stmength at the joints, thus increasing the factor of safety.

The author knows of several cases where gas lines have been supported on concrete or wooden piles. A saddle being bolted to the top of the piling, and the pipe clamped to this saddle by a strap. This method, however, is extreemly expemsive and only used where it is absolutely.necessary.

Where it is allowed by the owners of a bridge the pipe line is often carried across on the bridge itself. This method is more advantageous than putting the line under water, for it allows for frequent inspection and lessens the cost of any repairs which may be necessary in later years. Unfortunately, most states forbid pipe line crossings attached to the bridge.

WELDING

Of the two types of welding, acetylene and electric, the former is most commonly used. A unit for welding consists of the acetylene and oxygen tanks, with their respective gauges, fifty or more feet of hose, and the welding and cutting torch.

On long lines an acetylene generator is used for the firing line and is mounted, with the accompanying oxygen tanks, on a wagon, truck, or trailer. By using the generator the handling of individual tanks is reduced to a minimum and much time is saved. On the generator wagon is mounted a rack to hold the oxygen tanks, and extra cans of carbide are also carried to avoid delay in recharging the generator.

The welding equipment for the welders, who work individually with the bending crew, is carried in a wagon, or in rough country on a wooden sled drawn by a horse or mule. Here the acetylene tanks are used instead of a generator.

In city work, or where the line is along a road, the equipment for the individual welder is carried on a two wheeled metal cart.

As mentioned before, there are two types of weld used in pipe line work; the rolling weld and the position, or overhead, weld. In the rolling weld the welder works on the top part of the pipe at all times, the pipe being slowly rotated as the weld is completed. This is the fastest weld and is made whenever possible.

The overhead weld is made when the pipe cannot be rotated, and in this case the welder must work around the diameter of the pipe. Where it is necessary to make an overhead, after the pipe has been lowered into the ditch, it is necessary to dig a hole around, and under the pipe, for the welder to work in.

In exhaustive tests made on welded joints the strength of the weld has been found to be very high, and a properly made oxy-acetylene welded joint is as strong as the pipe itself and one hundred percent efficient.

The single vee butt joint is the most efficient and is recommended for pipe welding. Due regard must be given to the penetration and shape of the joint, particularly the reinforcement of the weld. Butt welds should be reinforced at least 25% and should be built up so as to present a gradual increase in the reinforcement from the pipe wall to the center of the weld.

Some results from tensile tests of acetylene welded joints are given in a table on page 24. The cross-sectional area of the pipe was computed from the measured weight and length of the specimens by the following formula:

$$A = \frac{W}{.2833 \times L}$$

where A = Cross-sectional area of pipe in square inches

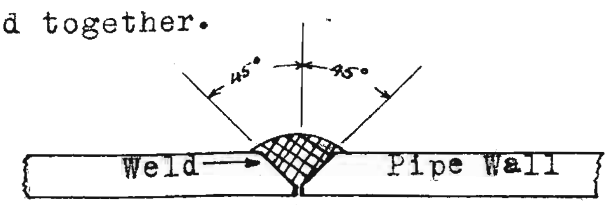
W = Weight of pipe specimen in pounds

L = Length of pipe specimen in inches

.2833 = Weight in pounds of 1 Cu. In. of steel

In the table are also shown the location of all fractures in relation to the weld.

The results shown in the table are from tests made with a 600-ton hydraulic testing machine. The specimens consisted of two pieces of pipe, each 6' long, welded together.



Single Vee Butt Weld

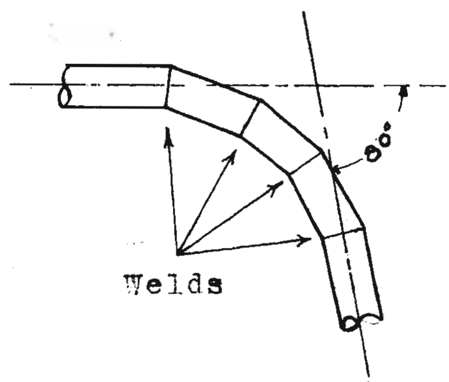
Specimen No.	Weight In Lbs.	Area Sq. Ins.	Yield Point Lbs. Sq. In.	Ultimate Strength Lbs. Sq. In.	Failure
			8" O. D. Pipe. Wall Thickness .186		
1	211	5.17	31800	51900	Outside Weld 6"
2	203	4.98	35400	55000	Outside Weld 5"
3	196	4.80	36700	54200	Outside Weld 6"
4	207	5.07	36700	58000	Part in Weld
			12" O. D. Pipe. Wall Thickness .250		
1	391	9.6	37100	57500	Outside Weld 1'
2	416	10.2	35300	53600	Outside Weld 1'
3	427	10.46	36300	55000	Outside Weld 16"
4	444	10.88	33100	54000	Outside Weld 2'
5	428	10.49	35400	55400	Outside Weld 1'

There are many types of welding rod on the market today. The type of rod used depending on the pressure the line is to carry and, to some extent, on the pipe itself, but that most universally used is a rod of medium-low carbon content.

Lately a device has been placed on the market for speeding up the making of rolling welds by automatically feeding the rod ahead of the flame. This new designed torch eliminates puddling to a great extent and allows the welder more freedom of movement, as it only requires one hand to operate. However, this new torch is only practical for pipe of 6" or larger diameter.

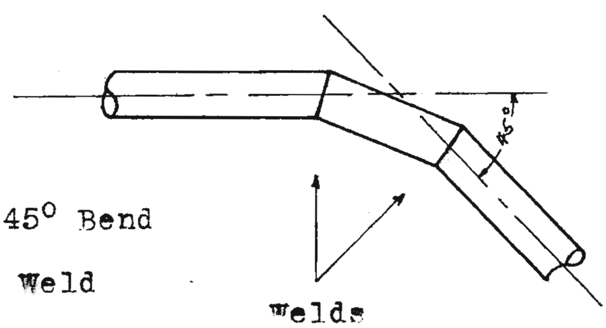
A welding clamp is often used to hold the pipe in alignment while it is being tacked. This assures the welder of a true joint and prevents the pipe from getting out of line before it has been sufficiently welded to hold.

Angles are almost entirely fabricated in the field. The sketches on page 26 show the number of welds necessary in fabricating angles of different degrees.



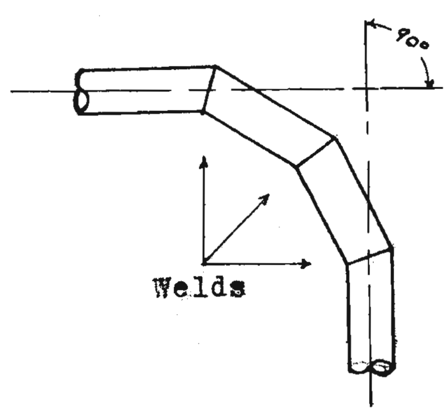
Five Piece 80° Bend

20° at Each Weld



Three Piece 45° Bend

22½° at Each Weld



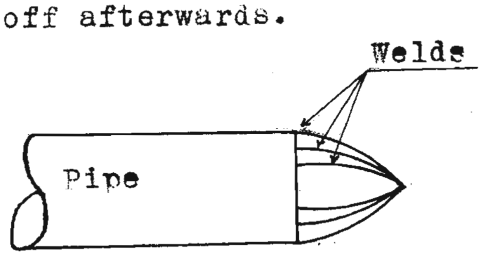
Four Piece 90° Bend

30° at Each Weld

TESTING

Long lines are usually, and distribution lines are always, tested before being lowered into the ditch. After a section of the line has been welded, and before the joints are painted, a cap is placed over each end of the section and compressed air pumped in until the desired pressure is reached. A soultion of soap suds are then applied to each weld and any leaks detected. After the testing is completed the air is released and the joints painted.

The ends of the section to be tested are closed by either a welded bull-nose or a removable cap, of which there are many different kinds on the market. Some contractors prefer to make their own caps, and there are mahy different designs in use today. The caps are by far the most popular, as their use eliminates welding the bull-nose on before the test and cutting it off afterwards.

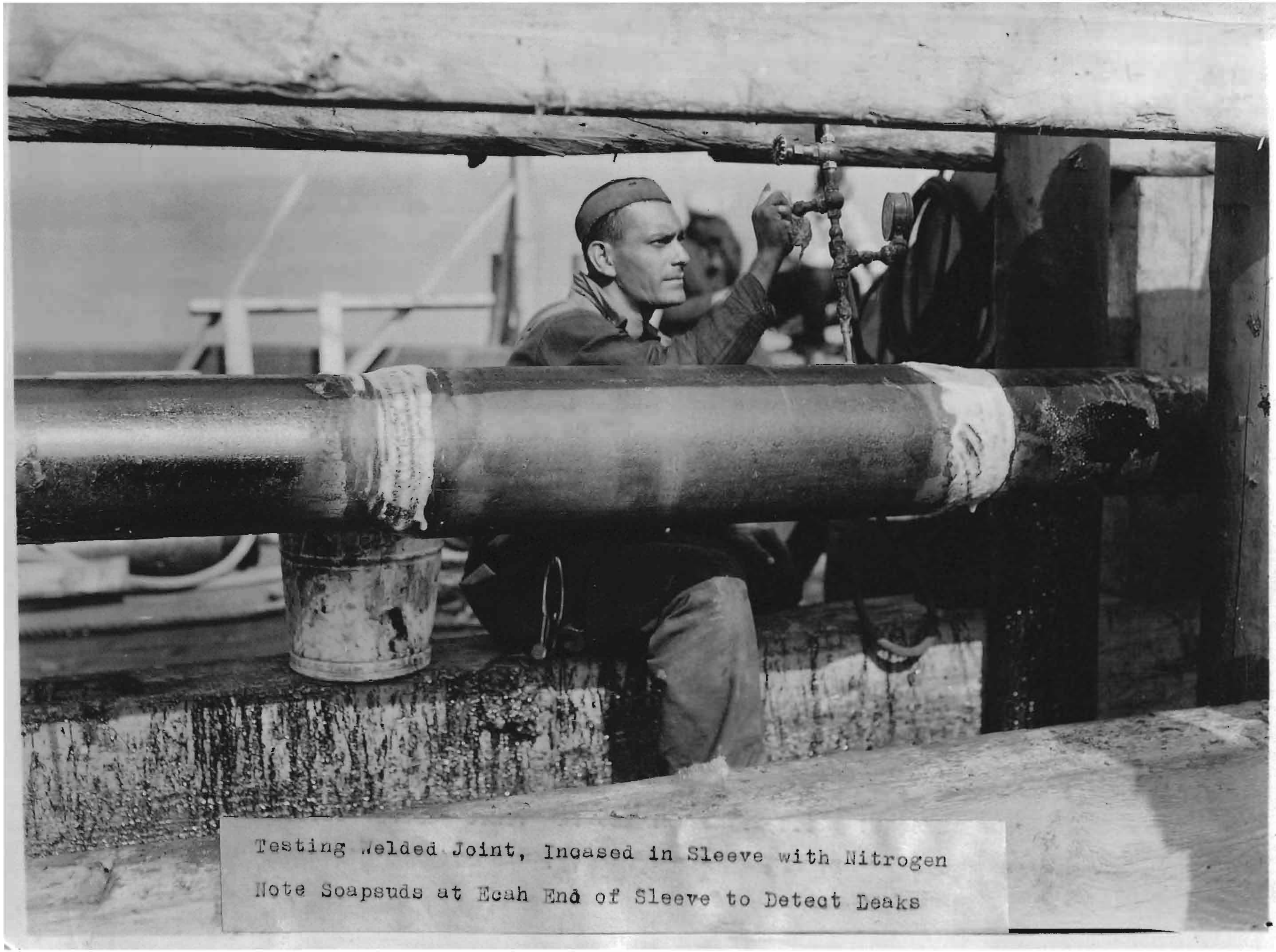


Welded Bull Nose

After the line is backfilled it is customary to test it under pressure for twenty-four hours. The line is pumped up as in the preliminary test and a recording gauge is connected. From the pressure reading on the chart and drop in pressure can thus be noted.

In some cases no testing is done until the entire line is completed and backfilled. The line is then filled with gas and by drawing a large torch, at the end of a long rope, over the surface of the backfill any escaping gas is ignited and the leak located. This method, however, is only used on lines in open country where there are no buildings or traffic; and is extreemly dangerous if a large leak is encountered.

Although compressed air is most commonly used for testing, the author was engineer on one project where nitrogen was used. On a river crossing the specifications called for a three hundred and fifty pound test per square inch. There was no compressor available that would deliver this pressure so cylinders of nitrogen were used. A sleeve, slightly larger than the pipe itself, was welded over each joint and the nitrogen forced between this sleeve and the weld to be tested. Oxygen could not be used due to the danger of an explosion should there be any oil on the pipe. The illustration on the page following shows the method of testing welds with the sleeve.



Testing Welded Joint, Incased in Sleeve with Nitrogen
Note Soapsuds at Ecah End of Sleeve to Detect Leaks

CONCLUSION

It is the opinion of the author that, although much progress has been made in recent years, there remains much room for improvement and research in this field of construction. Not only in determining better methods but in improving the type of machinery now being used for this work. Any such developments will necessarily be derived from the cooperation between the civil engineers and metallurgists in this field.

Additional Conclusions From the Authors Personal Experience.

1. Oxy-acetylene welding is by far the most practical for pipe line construction.

2. It is essential, from an economical standpoint, as well as for efficiency, that only experienced welders be employed.

3. In coating with hot enamel it is of the utmost importance that the enamel be heated to, and under no circumstances above, the proper tempature.

4. Removing all dirt and scale from the pipe before coating is as important as the coating itself.

5. That only the most reliable men handle the testing, and that every leak, no matter how small, be reported and repaired.

6. Where bends are made in the line they should be of such radius that no part of the pipe will be under any strain after backfillong.

BIBLIOGRAPHY

To the authors knowledge there are no text books or references available on this subject. However, the following papers have been presented, and can be obtained from their respective authors.

Pipe Line Welding, By R. S. Fuller, Pacific Gas and Electric Co. San Francisco, Cal.

New Developmnnts and Procedure Specification for Oxy-Acetylene Welding of Steel Pipe, by T. W. Greene, Linde Air Products Co. New York, N. Y.

Report of the Subcommittee on Pipe Joints, American Gas Association, New York, N. Y.