



W. H. WARING S-23
HOUSTON REGION
322

Division Headquarters
January 25, 1962
FDA # 56

TO: 322, 322-S, 321, 321-S, 12

SAN ANTONIO'S ATTACK ON THE PROBLEM OF CORROSION

Skyrocketing maintenance and replacement costs due to corrosion of metal pipe in many parts of the country continue to grow in magnitude.

Transite is finding greater and greater acceptance in these areas when it is necessary for a pipe to meet the challenge of aggressive soil and water conditions. Here are the highlights of the accompanying San Antonio story with reference numbers corresponding to the sections marked in the article.

1. By 1953 annual maintenance costs due to corrosion of mains, services, and meters which comprized 95% of the system, had passed the \$400,000. mark.
2. A special division within the Water Board was established to study corrosion. Soil corrosion was established as the major problem.
3. Greatest number of main breaks occurred in soils of resistivity less than 700 ohms/cm³.
4. Cast Iron mains may have a useful life of 10 years in 600 ohm/cm³ soil.
5. Protection of cast iron pipe with sand encasement is at best a stop gap measure.
6. Cast Iron will have to be protected against corrosion in the process of manufacture to be a satisfactory product in "hot" soils.
7. Between 1,250,000 and 1,500,000 linear feet of pipe in the corrosive area should be replaced within the next 10 years at a cost estimated at \$10,000,000.
8. Asbestos-cement pipe for sizes 8 inch through 20 inches are normally used in the corrosive or "hot" areas.

This product stability in "hot" soils can be used as one of our greatest selling tools in these areas where corrosion is a problem.

It is extremely important in our long range selling program to develop data on the performance of both competitive materials and Transite in each territory. Statistics on maintenance and replacement costs, main breaks per mile per year, etc., are valuable information not only in selling locally but in building performance data which can be used on a national scale. Your continued help in seeking out this information so that it can be correlated and used by all, will contribute to increased sales of Transite.

Please include this San Antonio story under the Competitive Materials section of your Pressure Pipe Sales Book.

R. W. SMITH

RWS/bgs

San Antonio's Attack on the Problem of Corrosion



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THE problem of underground corrosion is a problem that confronts almost every water works man charged with the installation and maintenance of a water works system, and in particular the distribution system. The degree of the problem, naturally, varies from place to place and, therefore, may be only of slight concern to a fortunate few readers but of great concern to the majority of us.

This paper will deal with the serious and very real problem of corrosion con-

fronting the City Water Board of San Antonio, and the Board's approach to its solution.

Past History

The first water mains were laid in San Antonio in 1878. Some of these mains are still in use and thus, the present distribution system has mains varying in age from those laid over 80 years ago to those recently installed. Difficulties and losses due to corrosion were experienced and recognized as such 50 years ago by the management of the San Antonio water system. Office records and filed findings reveal

that special methods were long ago used to protect small diameter mains and lines.

Mains and services installed in those early days were either cast-iron or galvanized steel and many of the small mains, particularly the galvanized steel, were embedded in concrete or coated with tar and wrapped with burlap. Nevertheless, no attempt was made to protect the larger steel and cast-iron pipe installed over the years. The rapid deterioration of galvanized service lines however, caused the Board to discontinue their use altogether in

*Read before the Southwest Section, American Water Works Assn. Convention held in Galveston, Texas, October 1960.

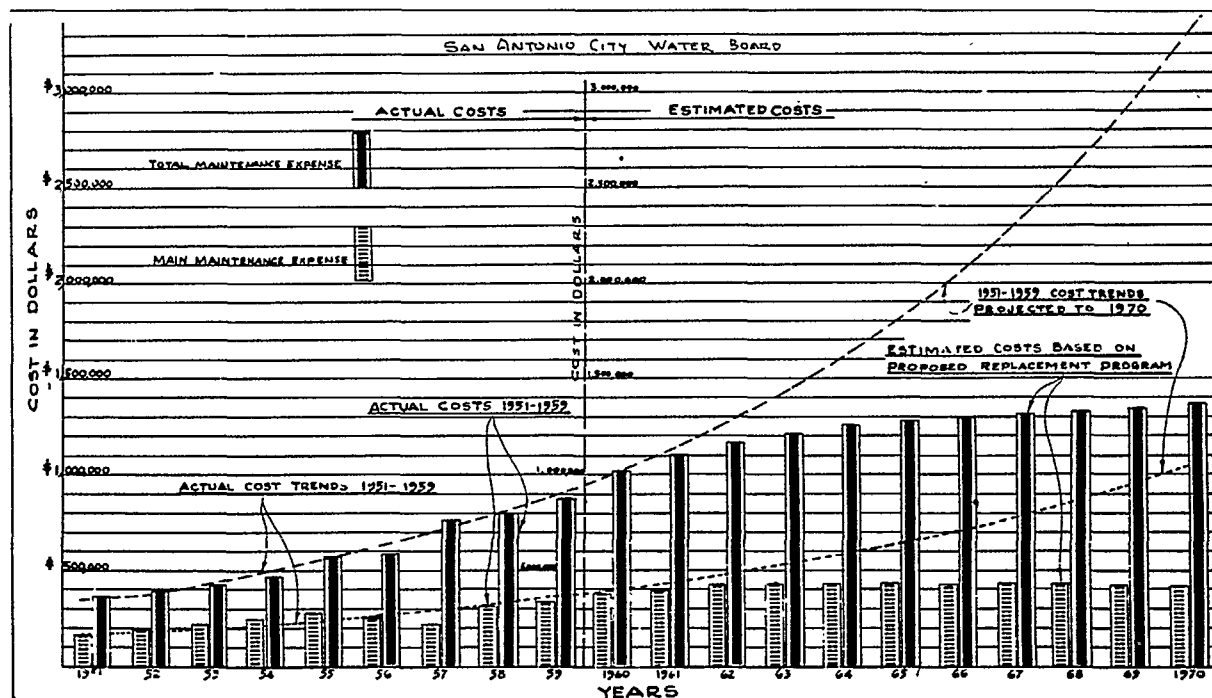
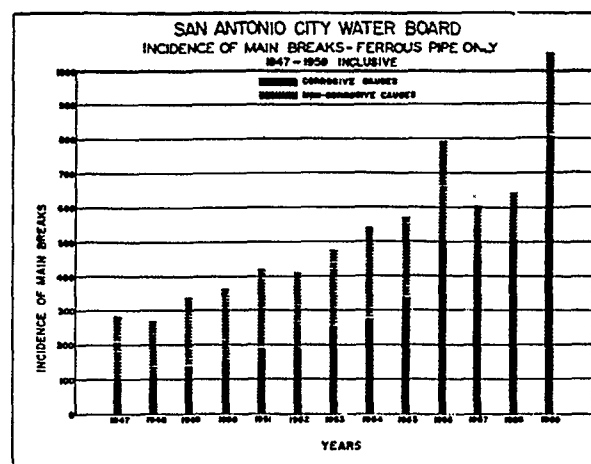


FIG. 1 — Diagram of maintenance expenses from 1951 through 1959; also anticipated expense.

FIG. 2 — Incidence and cause of main breaks in ferrous pipe which, until 1957, comprised approximately 95% of San Antonio's distribution system.



1935, and since then all service lines installed have been of copper.

Scope of the Problem

It wasn't until 1953 that the problem of underground corrosion was given top priority. This was the year that the present General Manager, R. A. Thompson, Jr.*, was appointed to his post. The annual maintenance cost of mains, services and meters had passed the \$400,000 mark by this time and the skyrocketing trend of maintenance costs, based on past experience, was indeed frightening.

Main and service line failures were increasing at an alarming rate and our records and experience indicated that our principal cause of trouble was underground corrosion. Figure 1 diagrams the maintenance expenses from 1951 through 1959 and the trend of such costs to 1970, as well as the anticipated expense following proposed improvements. Figure 2 diagrams the incidence and cause of main breaks in ferrous pipe which, until 1957, comprised approximately 95% of our distribution system. Similar trouble was being experienced with service lines, particularly with those in corrosive areas, many thousands of which were galvanized pipe services installed prior to 1935.

Study of the Problem

This skyrocketing trend of maintenance costs, together with the knowledge that approximately 75% of the main and service line failures was due directly to corrosion, prompted the establishment of a special division within the Water Board organization in 1953 for the primary purpose of studying the underground corrosion problem. In preceding years several

*Bob Thompson resigned Dec. 31, 1960

experts had been consulted and their opinion taken into account, but these opinions had been based on a knowledge of corrosion in general and its prevention rather than on actual knowledge of the particular conditions in the city. The program of the division placed emphasis on gathering information on the physical and chemical conditions of the sub-surface environment. This information had to be taken and interpreted in such a manner that it could serve as a basis for conclusions as to:

- Specific cause of corrosion.
- Methods for prevention or at least reduction in the corrosion damage.
- Methods for prediction of the most suitable type of installation.
- Methods of surveillance of the corrosive action.

Much has been learned about the problem, but a great deal remains unknown and the search for answers still goes on.

The types of corrosive action affecting water mains can generally be classified into one of the following categories:

- Stray current corrosion.
- Galvanic corrosion caused by dissimilar metal connections.
- Galvanic corrosion caused by differential electrolytes.

Stray current corrosion during the days of the street cars created severe problems. Today, the most frequent cause of stray current corrosion involve stray currents produced as a result of cathodic protection. Galvanic corrosion caused by dissimilar metals, results from service connections where brass and copper materials are employed in contact with the cast-iron, and in connections of steel and, in particular, galvanized steel pipe to cast-iron.

In the San Antonio area, however, these are minor problems. The greater problem results from soil corrosion or galvanic corrosion caused by differential electrolytes. Prominent among the causes of this type are non-uniform texture of the soil in contact with pipe, differential aeration, difference in moisture content around the pipe and the presence of soluble salts.

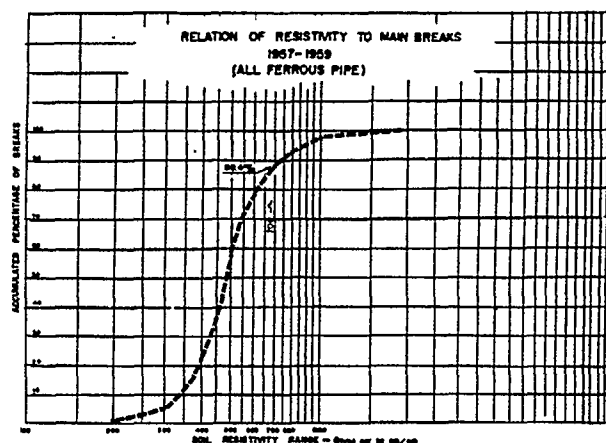
The corrosion of buried pipes is an electro-chemical process which can be illustrated by the action of a wet-cell battery. An elemental battery consists of two pieces of different metals, connected together by a wire and immersed in an electrolyte.

The difference of electrical potential between the two metals causes a flow of current to take place through the circuit thus formed, and a deterioration of one of the metals, called the anode, and the deposition of the particles on the other metal will occur.

When pipe is buried in moist soil it may be pictured as containing a large number of these elemental batteries in each of which there will be a continuous loss of metallic particles from the anodes being deposited on the cathodes.

One of the most significant outgrowths of studies of corrosion by the San Antonio Water Board has been the confirmation of the general relationship between soil resistivity and corrosion.

It is known that a potential difference causing flow of current may occur between two points on the same pipe due to variations in the composition of the pipe or the surrounding soil, and the rate of corrosion will depend on this difference in potential and the rate of flow of the current.



FIGS. 3 and 4, left, show meter and augers used. FIG. 5, above, is diagram of relationship between main breaks and resistivity ranges.

It follows that the current will depend on the kind of metal, the chemical characteristics of the soil and the presence of moisture in the soil. The conclusions can therefore be drawn that soil resistivity should be a good yardstick to measure corrosivity.

This is particularly true if the soil is alkaline. In acid soil the soil resistivity may not necessarily reflect the corrosiveness. However, in San Antonio the native soils are almost all alkaline.

Soils contain a large number of chemical elements, many of which are present as insoluble compounds which have little chemical influence on corrosion. In general, the more corrosive soils contain considerable amounts of soluble salts.

It is generally accepted that most soil corrosion of pipe is electrical in nature rather than the result of direct chemical reactions. The soluble salts in the soil affect the rate of corrosion because they control the resistance of the path of the corrosion current and the potentials of the corrosion cells.

Using resistivity meters and soil augers, resistivity measurements have been made throughout the area served by the Water Board with readings taken at approximately 2500-foot intervals and at depths varying from ground surface to 4 feet. The resistivity meter used by the Board is a Model 243-A Vibraground meter.

The unit consists of a single probe rod which is inserted into the ground at the desired depth and the resistivity is read directly on the meter.

Figures 3 and 4 show the meter and auger used. The units of resistivity used are ohms per square centimeter

per centimeter, or for convenience ohms/cm².

For the sake of brevity the units of soil resistance will be referred to as ohm-cm in this discussion. These readings were plotted on a map and the resistivity contours sketched in.

The locations of main breaks were superimposed and it was found that the greater part were within those areas in which the soil resistivity was less than 700 ohm-cm.

Figure 5 shows the relationship between main breaks and resistivity ranges.

It can be seen that the great majority of breaks occurred within the 300 to 600 ohm-cm range, and it should be emphasized that all breaks on ferrous pipes from all causes are included.

A map of San Antonio has been prepared showing the areas of dangerously low resistivity. These areas exist within 77 square miles, or 48% of the city's 160 square miles. The total population living within this "hot" soil area is approximately 340,000 people.

With the aid of the resistivity map it is now possible to predict the degree of corrosiveness in any particular area within the city. Consequently, an installation can be planned with the certainty that it will be the best possible and most economical for the conditions at hand.

It should be understood that no area of the city is entirely free of corrosion although in areas of high resistivity, corrosion takes place at a lower rate.

④ For example, indications are that a cast-iron main may have a useful life of 10 years in 600 ohm-cm soil, 25

years in a 1200 ohm-cm area, 45 years in a 4000 ohm-cm environment and perhaps 75 years in a 6000 ohm-cm soil.

Based on judgment, an analysis of costs and other factors, the Water Board has set a soil resistivity of 700 ohm-cm as a limiting value, below which protective measures must be taken.

With the ever mounting cost of replacements and repairs due to corrosion damage, there are grave doubts that this value is high enough.

Figure 6 shows that 88% of the main breaks in ferrous pipe occur in soils having a 700 ohm-cm resistivity or less. This includes those breaks resulting from soil shifts as well as those directly attributable to corrosive causes.

On the basis of evidence gathered to date, the most corrosive soils in San Antonio are the finely divided black and yellow clays. Of them, the yellow clay with a resistivity of 200 to 300 ohm-cm appears to be the most corrosive.

The effect of moisture content and its seasonal or cyclic fluctuations between wet and dry periods has been reviewed.

Most of the soil samples taken for analysis and study have been found to contain about 20-25% moisture at normal pipe depth, even during the dry summer periods, therefore, it is felt that variations of soil moisture at different times will not have any serious affect on the value of the resistivity readings.

This reasoning is based on the fact that research has shown that in the range of 20% to 60% moisture content, the resistivity is fairly constant.

Of interest, and indirectly related to the corrosion problem, is the fact that these corrosive clays are also highly cohesive and subject to extreme variations in volume with changes in moisture content. The resulting enormous soil stresses make the structural strength of the pipe of paramount importance.

Over 60% of all breaks occur in the 30% of 4-inch and smaller pipe present in the distribution system. Figure 7 shows the incidence of main breaks per mile of main according to size grouping.

With a knowledge of the causes of corrosion, the problem of protection in an economic manner arises. Field tests were initiated and evaluated to ascertain the most practical solution to the problem.

Test sections of cast-iron pipe incased in silica sand were installed in the most highly corrosive areas some five to seven years ago. In September, 1959, parts of these sections were uncovered for inspection. They showed no evidence of corrosion pits where the sand is in contact with the pipe.

Unprotected cast-iron pipe installed in similar areas has been found to be

completely graphitized during the same period of years.

⑤ Although encasement of cast-iron pipe with sand appears at this time to be the best and most practical method at hand for the protection of cast-iron pipe installed in corrosive soils, it is at best a stop-gap measure.

The danger of lumps of corrosive soil being accidentally left against the barrel of the pipe during installation or later during the tapping of the pipe for services is ever present.

Several test sections of cast-iron pipe coated or wrapped with insulating materials were installed two years ago. These test sections were furnished by the manufacturer of the pipe and consisted of several joints of 6-inch pipe, factory-coated with a polyethylene and sand coating.

⑥ Several additional lengths of 6-inch pipe loosely wrapped with a 10 mil polyethylene wrap were also installed. Based on our own experience, we are of the opinion that cast-iron pipe will have to be protected against corrosion in the process of manufacture, in order to be a completely satisfactory product for installation in aggressive or "hot" soils.

Based upon studies and analyses over the past years of all main breaks, we have reached the conclusion that between 1,250,000 and 1,500,000 linear feet of pipe in the corrosive areas should be replaced within the next decade. The cost of replacing these badly corroded mains and appurtenances is estimated at approximately \$10,000,000.

As previously stated, the story of increased maintenance costs due to corrosion is frightening; the number of main breaks and service line failures due to soil corrosion has climbed alarmingly over the past five years. We are keeping mains repaired and operating by sheer frantic effort and at great cost to the system and to the customer.

It is now realized that only a costly replacement program promptly initiated and pursued year after year will change the skyrocketing trend of maintenance costs. Nevertheless, this is the price that must be paid if the system is to survive both economically and physically.

Figure 1 showed how this trend can be changed. The failure to face up to the seriousness of the corrosion problem years earlier than was the case is

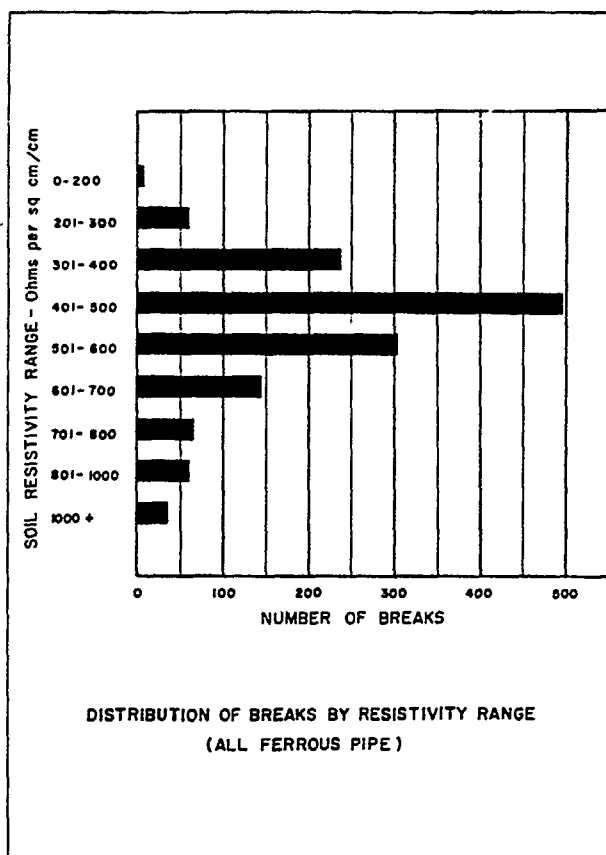
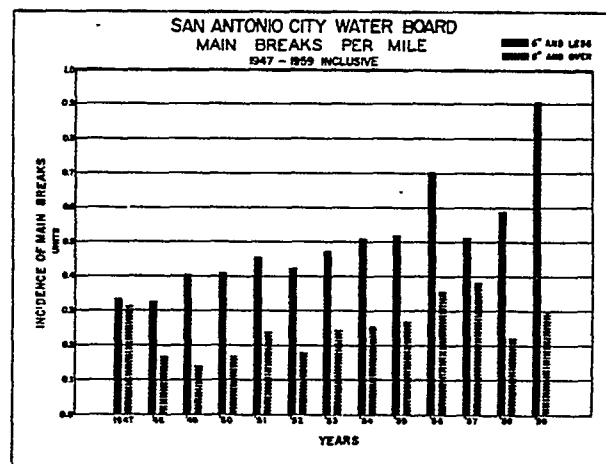


FIG. 6, left, shows that 88% of main breaks in ferrous pipe occur in soils having 700 ohm-cm resistivity or less. FIG. 7, below, indicates the incidence of main breaks per mile of main according to size grouping.



an unfortunate one, but with the knowledge now at hand and given funds for carrying out the recommended program for the replacement of corroded mains, the picture will have changed for the better by 1970.

Attacking the Problem

To protect our new installations against the ravages of corrosion, protective measures have been included in our specifications covering water works materials and their installation. These protective measures have been in use for the past five years and we have no doubt concerning their effectiveness, although a constant study and effort is being made to improve upon existing procedures and materials.

In general terms the following measures, which have been approved by Management, are in current use:

1. Cast-iron pipe is given preference in San Antonio and is normally used in sizes ranging from 6-inch to 16-inch, inclusive, in all cases where the resistivity is 700 ohm-cm or greater. Six-inch cast-iron pipe is also used in the corrosive areas, in which case it is embedded or encased in silica sand. Specifications for this sand require, among other things, that it contain not less than 98.5% silica, not more than 0.3% organic material and not more than 0.3% alumina (clay). Its electrical resistivity as specified shall not be less than 25,000 ohm-cm at a moisture content of 5% by volume.

⑧ 2. Asbestos-cement pipe for sizes 8-inch through 20-inch is normally used in the corrosive or "hot" areas. Class 200 pipe is specified for the 8-inch asbestos pipe in order to obtain the added beam strength. In larger sizes, Class 150 is considered acceptable. The fact that this pipe is a non-conductor of electricity and relatively inert has resulted in greatly increased usage during the past five years. A test section involving some 5000 feet of 6-inch Class 200 asbestos pipe was installed in a highly corrosive area this year. The performance of this pipe will be closely watched as to whether or not beam failure will occur due to soil induced stresses upon the pipe. In all cases where asbestos cement pipe is used, the fittings, hydrants and valves are encased in silica sand.

3. Pre-stressed concrete-lined steel cylinder pipe is specified for 24-inch through 36-inch sizes. This type pipe is gaining popularity due both to

economy of the pipe plus the benefits of its protection from corrosion. To reduce the opportunity for either the steel cylinder or the reinforcing steel wires from coming into contact with the soil, taps on this type of pipe are not normally made. Parallel local distribution mains of either cast-iron or asbestos-cement are installed in conjunction with the installation of the trunk or feeder main.

4. The use of steel pipe for underground installation is normally limited to the large diameter pipe required in the construction of primary pump stations. All such pipe, ranging in sizes from 24-inch to 54-inch, which has been installed during the past five years in connection with the construction of four new primary stations has been coated and wrapped with insulating material and cathodically protected.

5. Steel and cast-iron pipe used for installation in bored holes made for the purposes of crossing railways, highways and other obstructions is normally primed and then wrapped with a 10-mil polyvinyl tape. Additional measures are required to prevent damage to the protective wrap during installation.

With an idea as to what the economic limits were and a basis on which to proceed established, as far as the distribution system mains were concerned, other components of the system were looked into and corrective measures taken as required. These included steel elevated and ground storage tanks, meters and service lines, including the customer yard piping.

Summary

San Antonio has a serious underground corrosion problem which has resulted in excessively high maintenance costs.

This problem has been given much study and a plan of attack has been developed and put into effect which includes the use of various protective measures for new construction, as well as a long-range replacement program.

It is natural that any long-range project or plan of operation, however well executed, will have faults and deficiencies here and there.

These, however, will be discovered empirically as work progresses and require only a minimum of surveillance and care. The plan as a whole appears sound and it is believed that future installation will eventually reach a high degree of perfection.

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