

The Water Supply of the El Paso and Southwestern Railway from Carrizozo to Santa Rosa, N. Mex. eBook

The Water Supply of the El Paso and Southwestern Railway from Carrizozo to Santa Rosa, N. Mex.

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TRANSACTIONS

Paper No. 1170

The water supply of the El Paso and Southwestern railway from Carrizozo to Santa Rosa, N. Mex.[A]

By J.L. Campbell, M. Am. Soc. C.E.

With discussion by Messrs G.E.P. Smith, Kenneth Allan, and J.L. Campbell.

Location.—The El Paso and Southwestern Railway traverses the arid country west of the 100th Meridian in New Mexico, Texas, and Arizona, as shown on the map, Fig. 1. The water supply herein described serves that division of this road lying between Carrizozo and Santa Rosa, a distance of 128 miles.

Rainfall.—The average annual precipitation is 9.84 in. The year 1909 was exceptionally dry, with a rainfall of less than 5 in.

Original Water Supply.—East and west of El Paso, for distances of 270 miles in each direction, the railway crosses no streams, and the supply was obtained from wells ranging from 100 to 1,100 ft. in depth. On the division served by the new supply, this well-water is of very bad quality, as shown in Table 1.

After the most thorough practicable treatment, these waters were still so bad that they caused violent foaming, low steam pressure, hard scaling, rapid destruction of boiler tubes, high coal and water consumption, extraordinary engine failures and repairs, small engine mileage, low train tonnage, excessive overtime, and a demoralized train service.

[Footnote A: Presented at the meeting of May 4th, 1910.]

TABLE 1.

Incrusting solids, in		Non-incrusting solids,	
Station.	grains per gallon.	in grains per gallon.	

Carrizozo	31		7
Ancho	14		14

Gallinas		91		8
Varney		180		14
Duran		127		55
Tony		115		11
Pastura		141		6
Pintado		81		9
Santa Rosa		140		29

New Water Supply.—The writer was directed to find, if possible, a supply of good water, and his efforts proved successful. The pure water now in use has eliminated the adverse conditions before mentioned; has improved the *esprit de corps* of the train service; and, in a short time, the reduction in operating expenses will liquidate the first cost of the new supply.

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This supply is taken from the South Fork of Bonito Creek, which flows down the eastern slope of White Mountain. The latter is 12,000 ft. high, and is 16 miles south of Carrizozo (Fig. 1). The watershed is a granite and porphyry formation, heavily timbered, and the stream is fed by snow and rain. This combination yields an excellent water, carrying on an average 6.05 grains of incrusting and 0.95 grains of non-incrusting solids per gallon. The North Fork of the creek carries 16.60 and 2.40 grains, respectively. Below the junction of these forks, the water contains 10.48 grains of incrusting and 1.57 grains of non-incrusting solids per gallon; and a branch pipe line takes water from the creek during intervals in dry years when the daily flow of the South Fork is less than the consumption.

The Water Plant.—The water is taken to and along the railway in pipe lines. The system includes 116 miles of wood pipe, 19 miles of iron pipe, one 422,000,000-gal. storage reservoir, four 2,500,000-gal. service reservoirs, two pumping plants in duplicate, and accessories of valves, stand-pipes, *etc.*

From a small concrete dam across the creek at an elevation of 7,728 ft., the pipe line drops down the narrow valley eastward, 5-1/2 miles, to an elevation of 6,980 ft, where it turns abruptly north, rising in 1 mile to a table-land, 7,215 ft. above sea level, across which it continues northward 5 miles to the storage reservoir, which is on the north edge of this elevated country. Hereafter, this reservoir will be called the Nogal Reservoir, from the old mining village of Nogal lying 1-1/2 miles to the north and 600 ft. below it. From this reservoir, the line drops abruptly to the Carrizozo plain, and crosses the latter northward to Coyote, at Mile 156, on the railway, at an elevation of 5,810 ft., passing, on the way, 6 miles east of Carrizozo, to which a branch pipe runs, Carrizozo being 5,430 ft. above sea level. There is a 2,500,000-gal. reservoir at Coyote, and a similar one at Carrizozo.

[Illustration: *Fig 1. Map of lines of El Paso & Southwestern system*]

This describes the gravity section of the line which brings the water from the mountain stream to the railway. From Nogal Reservoir to the latter, the capacity of the pipe is equal to the future daily requirements; from the source of supply to the reservoir, the pipe has twice as great a capacity, thereby storing surplus water. This section is 32 miles long, with a 6-mile branch line.

The second, or pumping section, extends eastward along the railway, rising from an elevation of 5,810 ft. at Coyote to 6,750 ft. on the Corona summit, which is the watershed line between the Rio Grande on the west and the Rio Pecos on the east. At Coyote a pumping station lifts the water to Luna Reservoir and the pumps at Mile 171, and the latter lift it to the reservoir on Corona summit at Mile 192-1/2. This section is 36-1/2 miles long.

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The third, or gravity section, extends from the reservoir on the Corona summit to the Rio Pecos at Mile 272, dropping from an elevation of 6,750 to 4,570 ft. in 80 miles. The pipe line extends to Pastura, 58-1/2 miles from Corona, as shown on Plate V.

Where the pipe line passes a water tank on the railway, a 4-in. branch pipe is carried to the bottom of the tank and up to the top, where it is capped by an automatic valve. A gate-valve is placed in the branch pipe at its junction with the pipe line.

There are regulating, relief, check, blow-off, and air-valves, air-chambers, and open stand-pipes on the line, too numerous to mention in detail. They are designed to keep the wood pipe full, regulate flow, prevent accumulation of pressure and water-hammer, and remove sediment.

Water Pipe.—A study of the profile developed a system of hydraulic grades, pipe diameters, and open stand-pipes limiting the pressure to 130 lb. per sq. in., except on 19 miles of the pump main between Coyote and Corona where the estimated maximum pressure is 310 lb.

Investigation justified the assumption that wood pipe under a pressure of 130 lb. would give satisfactory service for 25 years, on which basis it would be less expensive than cast iron, and therefore it was used. Cast iron was considered preferable to steel for pressures not exceeding 310 lb. on account of its greater durability.

Wood Pipe.—Machine-made, spirally-wound, wood-stave pipe, made in sections from 8 to 12 ft. long, with the exterior surface covered with a heavy coat of asphalt, was selected in preference to unprotected, continuous, stave pipe. The diameters were not so great as to require the latter.

The first 40 miles of wood pipe was furnished by the Wykoff Wood Pipe Company, of Elmira, N.Y., and the Michigan Pipe Company, of Bay City, Mich., delivered the remaining 76 miles.

The pipe is wound with flat steel bands of from 14 to 18 gauge and from 1 to 2 in. wide. The machine winds at any desired pitch and tension. At each end the spiral wind is doubled two turns, the second lying over the first and developing a frictional resistance similar to that of a double hitch of a rope around a post. The ends of the band are held by screw nails or a forged clip, the latter being the better. It has two or three spikes on the under side which seat into the stave, and two side lugs on top which turn down over the band. The latter passes twice over the seat on the clip, the first turn holding the clip to the stave, while the second turn is held by the lugs which are hammered down over it. The end of the band is then turned back over the clip and held down by a staple.

The staves are double-tongued and grooved and from 1-3/8 to 2 in. thick. The smaller thickness is sufficient. The exterior face of the staves should be turned concentric with

the axis of the pipe and form a circle, so that the band will have perfect contact with the wood.

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The joints are formed by turning a chamber in one end of the pipe and a tenon on the other, or both ends are turned to a true exterior circle and driven into a wood or steel sleeve. The chamber and tenon were used in this work.

Finally, each piece of pipe is covered with as much hot asphalt as it will carry.

Steel Bands.—The specifications required bands of mild steel, of 60,000 lb. strength, with an elastic limit half as great. The winding was spaced to limit the tension to 15,000 lb. per sq. in. If severe water-hammer is present, the ordinary working stress should be materially less than the latter, otherwise the spiral bands will stretch enough to permit the water to spurt out between the staves. This was determined to be true on 4,500 ft. of 12-in. pipe connecting the Carrizozo Reservoir with a water column at the roundhouse there. In pumping tests at the mills, attempts were made, at various times, to burst the pipe, but they never succeeded. Before the elastic limit was exceeded, the water was running out between the staves as fast as the pump forced it in. On the following day, pipe thus tested would carry the pressure for which it was designed without leaking. Except for defects in the band, pipe of this kind will not burst in the service for which it is properly designed. This is true, without exception, of the 100,000 pieces of pipe in this service.

There has been some trouble with a number of the riveted splices on the banding. Such a splice occurs for every spool of banding used. In every case where one of these splices has pulled apart, the break was the result of defective riveting, permitting the rivets to pull out. In no case has a rivet been found sheared off, and even one good rivet appears to be sufficient to prevent rupture. The explanation is found in the high frictional resistance between the band and the pipe, which distributes the weakness of a bad splice over several adjacent turns of the band around the pipe. The band loosens a few turns only on either side of a parted splice, generally not more than three. In no case has any pipe been removed from the trench, repairs being made without interruption to the flow of water.

It is desirable to substitute welding for the riveting of these splices. The trouble is not present with the round band, the wrapped splice of the latter giving practically 100% efficiency.

The flat band was chosen for this work because it is the more effectively buried in and protected by the asphalt, and will not crush the soft wood staves under high pressure. The longevity of either the flat or the round steel band is dependent primarily on effective protection against contact with corrosive elements. Wrought iron should be used for this kind of service, and, for the same reason, for many other purposes. Engineers and consumers should join in some comprehensive and effective plan to bring back the old-time production of high-grade wrought iron.

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Wood Staves.—The staves of this pipe are of Michigan and Canadian white pine. This pine cannot now be had of clear stuff or in long lengths in large quantities; otherwise, it is unexcelled. Douglas fir and yellow pine, coarser and harder woods, have the advantages of clear lumber and long length. Cypress is not as plentiful, and redwood is costly. The mill tests did not determine definitely the minimum degree of seasoning necessary, and press of time compelled the acceptance of some rather green lumber. Service tests do not show that there is any abnormal leakage from pipe made of such lumber, and it could not now be distinguished in the trench by such tests. Undoubtedly, however, thorough air seasoning should be required.

Bored Pipe.—Owing to its small size, a part of the 3-1/2-in. pipe was bored from the log. This was a mistake, for bored pipe has a rough interior and a reduced capacity. The inspection and culling are difficult and unsatisfactory, and imperfections readily apparent in a stave frequently escape detection in bored pipe.

Pipe Joints.—The chamber and tenon of this pipe is an all-wood joint, 4 in. deep. An iron sleeve makes a better and stronger joint. It compensates for any lack of initial tension in the banding over the chamber of the wood joint, and secures full advantage of the swelling of the wood. Cast iron is better than steel; it is more rigid, and its granulated surface breaks up the smoothness of the wood surface swelling against it. One objection to the cast-iron sleeve is that of cost, but it adds 4 in. to the effective length of every section of pipe, as compared with the wood joints. On the Pacific Coast, a banded wood-stave sleeve is used with success.

Coating.—To preserve the banding from corrosion and the wood from exterior decay, the pipe is thoroughly enveloped in refined asphalt having a flow-point adjusted to the prevailing temperature during shipment and laying. One grade can be used through a considerable range of temperature. This coating endured a 2,000-mile shipment successfully. Each piece was carefully inspected along the trench, and any break in the coating was thoroughly painted with hot asphalt. Enough of the latter came in barrels, with the pipe, from the factory.

The first 37 miles of this pipe has been in service for two years. Recent inspections show the coating to be in excellent condition and the steel underneath to be bright and clean. In some cases, where the initial pressure and leaking between the staves of the dry pipe were great, the escaping air and water lifted the coating into bubbles. At some points where this lifting was great enough to rupture the asphalt, and the soil is heavily charged with alkali, some corrosion has begun.

The integrity and impermeability of this asphalt coat are quite as vital as constant saturation. This coating protects the entire pipe from exterior contact with destructive agencies. With such effective exterior protection, a constantly full pipe is not so imperative. In the exterior protection of the wood, this coated pipe has quite an advantage over continuous stave pipe.

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Each piece of pipe goes directly from the winder to the asphalt rolls, then to an adjacent saw-dust table, then back to the rolls, then to the table again, and then to the dry finishing rolls at the opposite end of the table. The coating thus consists of two layers of asphalt and two of saw-dust. When the pipe leaves the finishing rolls, the coat is hard and smooth and about $1 \frac{3}{16}$ in. thick. This describes the coating as done at Bay City, Mich.

At Elmira, N.Y., one application of asphalt and saw-dust only, without a finishing dry roll, completed the work; but the band was run through a bath of hot asphalt as it was wound, thus coating its underside also. This initial treatment of the band on the Wykoff pipe is necessary because the exterior of the stave is neither planed nor turned to a circle. The exterior of the pipe forms a polygon, and the band is in perfect contact only at the angles. The theory in regard to the Michigan pipe is that the perfect contact of the band and the wood on the true exterior circle excludes air from the under surface of the metal, and prevents corrosion. Experience appears to justify this theory.

Cast-iron Pipe.—Beginning at the first pumping plant at Coyote, at Mile 156, and running up to Mile 166, and again commencing at the Luna pumps, at Mile 171, and extending up to Mile 179, the minimum pressure on those portions of the pump main is more than the 130 lb. per sq. in. allowed for wood pipe, and the final estimated maximum pressures run up to 310 lb.

The selection of iron pipe for these pressures was, first, as between steel and cast-iron; and, second, as between the lead joint of the standard bell and spigot pipe and the machined iron joint of the universal joint pipe. Again, the choice was as between lead and leadite for the bell and spigot pipe.

Cast iron was selected because of the certainty of its long life, and the bell and spigot pipe was selected on the basis of comparative costs for pipe laid. The standard lead joint was chosen on the result of tests. This cast-iron pumping main has a diameter of 12 in. throughout.

Pipe Weights.—Makers of standard bell and spigot pipe urged the usual heavy weights selected for municipal service and heavy water-hammer. Three pressures, viz., 217, 260, and 304 lb., were used for the division of pipe weights, on which the standard pipe-makers specified shell thicknesses of 0.82, 0.89, and 0.97 in. Eliminating water-hammer and adopting a working stress of 2,400 lb., the thicknesses are reduced to 0.54, 0.65, and 0.76 in. To make the latter conform to the specifications of the New England Water-Works Association, the pipe was cast to 0.57, 0.65, and 0.77 in. The reduction in cost amounts to \$52,811.

By the provision of air-cushions, hereafter described, the writer's anticipation of no water-hammer on the pumping main has been fully realized.

The pipe was manufactured and inspected under the above-mentioned specifications.

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Pipe Joints.—There was a question about the reliability of the lead joint at 300 lb. The writer had a section of 12-in. pipe, with standard joints containing 22 lb. of lead, laid and tested to 500 lb. without sign of failure or leakage. The joints were caulked down 3/16 in. below the face of the bell. Of 8,700 joints thus made in the field, not one has blown out or failed. A few weeped slightly on top, and they were made permanently tight by additional caulking. The present maximum pressure is 278 lb. These joints are the standard joints specified by the New England Water-Works Association. It should be borne in mind that there is no water-hammer on this line. In 8,700 joints, 198,000 lb. of lead and 3,200 lb. of oakum were used, or 22.76 and 0.37 lb. per joint.

Leadite was tested in competition with lead, but it leaked at 100 lb. and failed under a sustained pressure of 300 lb. It is a friable material, and cannot be caulked successfully. Its principal ingredient appears to be sulphur. The failure was by slow creeping out of the joints. It is melted and poured, but not caulked. It has attractive features for low pressures and for lines not subject to movement or heavy jarring.

Air-Cushions.—To prevent water-hammer on the pumping main, all pumps are provided with large air-chambers. In addition, and as the special feature for absorbing the shock of pumping under high pressure through a pipe 21 miles long, a large air-chamber in the form of a closed steel cylinder, 5 ft. in diameter and 15 ft. long, is mounted on the pumping main outside of the pump-house. This cylinder is set on its side, in concrete collars, directly over the pipe beneath, to which it is connected by a 12-in. tee, in which a 12-in. gate-valve is set. The cylinder is provided with a glass gauge, cocks, etc. It was designed for a working pressure of 300 lb., and, at each pumping plant, it has proved to be entirely air-and water-tight. As indicated by sensitive gauges on the pump main, just beyond these large air-chambers, the latter absorb all the water-hammer which gets beyond the air-chamber on the pumps.

Air-Pumps.—Each pumping plant is provided with four automatic air-charging devices, connecting to all air-chambers of the pumps and to the air-chamber on the pumping main. They are of the Nordberg type, and have proved very efficient. They are operated only a part of the time; otherwise, they accumulate too much air in the chambers.

Air-Valves.—On the entire line there are 144 automatic air-valves made by the United States Metal Manufacturing Company, of Berwick, Pa. They are working satisfactorily.

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Gate-Valves.—In addition to the customary gate-and check-valves at the reservoirs and pumping stations, gate-valves are located at necessary points and elevations in the line to control the flow of water and keep the pipe full, even to the extent of closing all such valves tight and holding the line full without flow. This is for the purpose of delivering through a full pipe any desired quantity of water less than that required to keep the open pipe full. This, of course, is on account of the wood pipe. As the differences of elevations are very great on the gravity sections of the line, and as any one valve might inadvertently become closed tight when other valves above would be open, the bursting of the pipe under such conditions is prevented either by a pressure relief valve attached to and immediately above the gate-valve, or by an open stand-pipe erected on some suitable elevation between the valves. This is more clearly shown on the profile, Plate V, of the ground line and the hydraulic grades of the pipe line. An inspection of this profile will show that these controlling valves are located so that, when closed, the pressure against them does not rise above the maximum pressure on the section above, due to the hydraulic grade of the line when carrying its full capacity.

Safety Valves.—To prevent rupture of the pipe or injury to the pumps, in case the pumping mains should become obstructed, a 6-in. pop safety valve is mounted on the main just beyond the large air-chamber already described. These valves are set to release at the maximum working pressure of the pumps when the regular quantity of water is being pumped, and they are piped to the adjacent reservoir, so that there is no loss from them.

Check-Valves.—Check-valves are placed in the pumping main to prevent the backward flow of water. There is one near the pumps, and one at the upper end and outside of the reservoir into which the main discharges.

Blow-Off Valves.—These valves are located in all material valleys or depressions.

Stand-Pipes.—Between the gate-valves, at certain points where the maximum hydraulic grade is not more than 60 ft. above the surface of the ground, open stand-pipes are erected. If the grade line is too high, relief-valves are used, as stated. Also at two points, where a steep grade ends near the ground surface and is followed by a flatter grade, stand-pipes are erected.

These stand-pipes are of 6-in. iron pipe standing in a special casting in the pipe line and enclosed in a concrete base. They are, of course, open at the top, and vary in height from 15 to 60 ft., depending on the elevation of the hydraulic grade. They have given some checks on the position of this grade during the velocity measurements hereinafter described. Their locations are shown on the profile, Plate V.

Nogal Reservoir.—Nogal Reservoir is the storage unit of the system, and is on the north edge of a table-land, 1,700 ft. above the railway, on the Carrizozo plain, 15 miles away. It is 11-1/2 miles from the head of the pipe on Bonito Creek.

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This reservoir is a natural basin or bowl, 1/2 mile in diameter across the top, 1/4 mile on the bottom, and 36 ft. deep. A level line, 1,500 ft. long, drawn from its bottom, comes out to grade on the north declivity of the table-land. On this level line an open cut was made and the outlet pipe laid. The cut was then closed by a dam.

The supply pipe from Bonito Creek delivers water into the basin over the top of its southern rim, the water, as it leaves the pipe, flowing over a standard weir, without end contractions, into a stone gutter. A by-pass pipe, with suitable valves, passes around the western side of the basin and connects to the outlet pipe.

This comparatively small amount of work equipped a very good natural reservoir with a capacity of 422,000,000 gal., which can be increased to 1,000,000,000 gal. by embankments across low places in the rim.

Service Reservoirs.—At Coyote, an artificial service reservoir, 100 by 200 ft. on the bottom, with slopes of 1-1/2 on 1 and a total depth of 15 ft., serves as an equalizer of the flow to and away from the pumps at that point. The pump-house is built alongside this reservoir. The delivery pipe from the Nogal Reservoir runs directly to the pumps, but has a tee-branch, 50 ft. long, into the Coyote Reservoir. This branch passes through a valve chamber between the pump-house and the reservoir. In this chamber there are controlling valves and an automatic overflow. This overflow is provided against the contingency of a full reservoir and idle pumps. If the pipe line is delivering water faster than the pumps discharge it, the surplus goes into the reservoir. This arrangement is self-acting and controlling. There is a similar arrangement at the Luna pumping plant, also at the Carrizozo service reservoir, and at the regulating reservoir on the Corona summit.

Each of the four service reservoirs is of the same size, and lined with 4 in. of 1:2:4 concrete. At Luna and Corona the concrete is reinforced with 3/8-in. round rods spaced 12 in. from center to center, both ways. This reinforcement should have been used in all the work.

Pumping Plants.—The pumps at Coyote and Luna are Nordberg duplex, cross-compound, condensing, crank-and-fly-wheel machines, with 6-in. plungers, traveling 600 ft. per min. at full normal speed, and designed to work against 300 lb. per sq. in. They have a guaranteed efficiency of 135,000,000 ft-lb. per 1000 lb. of steam at 150 lb. and superheated 75 degrees.

The boilers are 125-h.p., Sterling, water-tube, with Foster superheaters, and 33-in. stacks, 100 ft. high.

Each plant is in complete duplicate pump and boiler units, only one set working at a time.

The pump building is a substantial concrete, brick, and steel structure, 50 by 80 ft. in plan, with a fire-wall, with two steel doors dividing the floor space into an engine-room 50 by 50 ft., and a boiler-room 50 by 30 ft. A concrete coal-bin adjoins the exterior boiler-room door. Coal is delivered directly from the car to the bin.

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The plant is lighted by a small, but very complete, engine and dynamo on one base and run by steam from the Sterling boilers.

The two plants are exactly alike throughout.

Reservoir Leakage.—The Nogal Reservoir basin is covered with from 2 to 5 ft. of good clay, except where it is punctured by a dike, or washed down to the underlying sandstone by a few gullies. These punctures or washes were covered or filled with clay from 1 to 4 ft. deep. During the first season the leakage, above the 6-ft. contour, was at the rate of 2 in. per day.

As the water fell, due to leakage, evaporation, and use, a herd of from 300 to 400 cattle were worked around the shore line. This reduced the leakage to $\frac{3}{8}$ in. below 8 ft., and to nothing below 6 ft., above the outlet. As the flow line rises higher each season, the puddling will be continued to the top. The leakage at 12 ft. above the outlet, or 17 ft. above the bottom, is still approximately 1 in. per day. The total puddling, to date, covering two seasons, is equivalent to 11,150 days' work of one cow, and covers an area of 1,500,000 sq. ft.

The clay packed densely, the final hoof marks being not more than $\frac{1}{4}$ in. deep and remaining distinct under the water around the shore line for one year. Apparently, the reservoir will finally become water-tight at all elevations.

The soil in which the four service reservoirs on the railway are built proved to be about the worst for such work. In its natural state on the prairie, after the excavation for the reservoir was completed, it filtered water at the rate of 3 ft. per day. Tamping and puddling still left a filtration of 12 in. per day, with a tendency to increase. Enough water filtered through the concrete to produce settlement and cracks. Finally, the concrete was water-proofed with two coats of soap, two of alum, and one of asphalt. This has made all the reservoirs water-tight. Elaterite, an asphalt paint made by the Elaterite Paint and Manufacturing Company, of Des Moines, Iowa, was used successfully on the Luna Reservoir. This paint is applied cold, and preliminary tests showed it to be quite efficient.

The analysis of the soil is as follows:

Loss on ignition 3.35
Silica 56.36
Oxide of iron 2.93
Oxide of aluminum 8.97
Calcium oxide 15.95
Magnesium oxide 0.98
Oxides of sodium and potassium 0.47
Carbonic acid 11.35

Sulphuric acid 0.11
Chlorine 0.04
Manganese Traces

100.51

Insoluble matter, 64.50 per cent.

Pipe-Line Leakage.—There is no measurable leakage from the iron pipe. By thorough inspection and measurement at the end of two years, leakage on the wood pipe, between Coyote and Bonito Creek, from the 11-and 12-in. pipe, was found to be as follows:

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On 8.6 miles, 11-in. pipe, 146,600 gal. per day = 17,046 gal. per mile. " 4 " 12 " " 14,829 " " " = 3,702 " " "

The 7-1/2-in. pipe on this section appears to be leaking less than the 12-in. pipe. Inspection and measurement of it are to be made in a short time.

There is no material leakage from the 10-and 16-in. pipe between Bonito Creek and Nogal Reservoir, as determined by velocity and volumetric measurements hereafter described. The greatest probable error in the velocity measurements would not exceed 1/2 per cent. If such error existed, and was all charged to leakage, it would amount to but 17,204 gal. per day, or 1,582 gal. per mile, out of a daily delivery of 3,784,000 gal.; but the measured discharge of the pipe, as determined by the velocity, was 5.84 sec-ft., while the mean maximum volume of this water over the weir at the end of the pipe is recorded by the weir as 5.88 sec-ft.

From Coyote, east along the railway, the wood pipe is remarkably tight. The rate of leakage from it, as determined by 600 observations uniformly distributed, was as follows:

11-in. pipe = 120 gal. per mile per day.
8-1/2 and 7-1/2-in. pipe = 268 " " " " "

The maximum rate on 1 mile was 1,613 gal. The minimum found was zero.

The observations were made by uncovering a joint and measuring the leakage therefrom for 10 min. A graduated glass measuring to drams was used. The rate of leakage varied from 5 drops to 45 oz. in 10 min. Of the joints uncovered 57% was found to be leaking. It is rather remarkable that, in the large leakage of the 11-and 12-in. pipe between Coyote and Bonito, only one out of every eight joints was leaking. This indicates a physical defect in such joints. The largest leak found on one joint was at the rate of 17[,?]280 gal. per day. Leakage between or through the staves is not measurable, as it is not fast enough to come away in drops unless there is some imperfection in the wood.

The insignificant leakage of 120 gal., stated above, is from the 11-in. pipe in the pumping main between Coyote and Corona. The present maximum working pressure on it is 100 lb. per sq. in. All the figures given above include visible and invisible leakage, the latter being such as does not appear on the surface. The visible leakage is but a small part of the total.

Stopping the Leaks.—Generally, any ordinary leak is readily stopped by pine wedges. Sometimes a loose joint requires individual bands bolted around it. Bran or saw-dust is

effective in stopping the small leaks which cannot be reached by the wedges. The good effect of the latter is likely to be destroyed by a rapid emptying of the pipe. If the water is drawn out faster than the air can enter through the air-valves, heavy vacuums are formed down long slopes, and the air forces its way in through the joints and between the staves. The result is that the pipe will frequently leak badly for some time after it is refilled, although it may have been tight previously.

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A full pipe and a steady pressure are highly desirable. This doubtless accounts to some extent for the extreme tightness of the wood pipe in the pumping main.

Grade Lines.—The hydraulic grade lines, shown on Plate V, were laid as best fitting the controlling elevations. The various diameters of pipe were determined by Darcy's general formula, with $C = 0.00033$ for wood and $= 0.00066$ for iron pipe, checking by Kutter's formula, with $n = 0.01$ for wood and $= 0.012$ for iron. These coefficients were taken as conservative and on the safe side, and such they proved to be. It was desired that the line should carry not less than 5 sec-ft. to Nogal and half as much beyond.

Velocities.—The pipe line from Bonito Creek to the Nogal Reservoir affords excellent conditions for velocity and capacity measurements, there being no distribution service from it. Beginning at the creek, it consists of 12,700 ft. of 10-in. wood pipe, with a hydraulic grade of 0.03338, followed by 48,000 ft. of 16-in. wood pipe, with a hydraulic grade of 0.0030625, ending on the south rim of the Nogal Reservoir. There is an open stand-pipe where the two pipes and grades join.

When this section of the line was laid, the last car of 16-in. pipe was late in arriving and, as it was desirable to get water into the reservoir as soon as possible, 500 ft. of 10-in. pipe were laid in the lower part of the 16-in. line, near the reservoir, as indicated on Fig. 2, which shows the hydraulic grades and the pipe diameters of this section of the line.

When the first two velocity measurements, of March 10th and 31st, 1908, described below, were made (after the line had been put into service on February 20th, 1908), the 500 ft. of 10-in. pipe were still in the 16-in. line, and the hydraulic grade was defined by the solid line, *ABCDE*, Fig. 2.

When the third measurement, of May 12th, 1909, also described below, was made, the 10-in. pipe had been replaced by 16-in. pipe, and the hydraulic grade was defined by the solid line, *ABE*.

[Illustration: FIG. 2.]

The dotted line, *AFE*, is the approximate theoretical position which the grade, *ABCDE*, should have assumed when the 500 ft. of 10-in. pipe were taken out of the 16-in. line. On the contrary, it took the position of the grade line, *ABE*.

During the interval between March, 1908, and May, 1909, the water came to overflow from the stand-pipe at *B*, when the line was running under full pressure, indicating an increase of capacity in the 10-in. pipe greater than a corresponding increase in the 16-in. The alignment of the 10-in. line, vertically and horizontally, is more regular and uniform than the 16-in. line. The latter has many abrupt curves and bends, vertically and horizontally. It crosses nine sharp ridges and dips under as many deep arroyos. This introduces a fixed element of frictional resistance which does not decrease with the

increasing smoothness of the interior surface of wood pipe, and probably accounts for the higher resistance of the 16-in. line.



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From Fig. 2 it appears that, while the 10-in. line had an initial coefficient of roughness slightly greater than 0.009 and now equal to it, the 16-in. line had one equal at first but now slightly less than 0.01.

The line from Bonito Creek to Nogal Reservoir was to have a capacity of 5 sec-ft. Referring to the profile, it was determined that for the hydraulic grade of 33-1/3 ft. per 1000 ft., a 10-in. pipe was necessary, and that a 16-in. pipe was required for the grade of 3 ft. per 1000 ft.

Test No. 1.—On March 10th, 1908, a quantity of bran was poured into the upper end of the 10-in. pipe at A (Fig. 2), and the time of its appearance at the lower end of the 16-in. pipe at E was noted. The time was 3 hours and 50 min.

This gave:

Area of 10-in. pipe = 0.5454 sq. ft.

" " 16 " " = 1.3960 " "

Length " 10 " " = 13,200 ft.

" " 16 " " = 47,500 "

Time, = 13,800 sec.

Let x = velocity of flow in 16-in. pipe, in feet per second, then $2.56x$ = velocity of flow in 10-in. pipe, in feet per second.

From which:

$$\frac{13,200}{2.56x} + \frac{47,500}{x} = 13,800$$

$$x = 3.805$$

$$\text{and } 2.56x = 9.740$$

The discharge is:

For the 16-in. pipe, $1.396 \times 3.805 = 5.31$ cu. ft. per sec.; and, for the 10-in. pipe, $0.5454 \times 9.74 = 5.31$ cu. ft. per sec.

The question arose as to whether or not the particles of bran in the water traveled as fast as the water flowed. It was also desired to check by observation the relative velocities in the two pipes, as above deduced.



Test No. 2.—To determine these points, a second test was made, on March 31st, 1908, twenty days after the first one. In this test, green aniline, red potassium permanganate, and bran were used. An observer was placed at the end of the 10-in. line at *B* (Fig. 2), and, by letting a small quantity of water run from a relief-valve there, he was able to note the time of the appearance of the colors and the bran.

The green was started in the upper end of the 10-in. pipe, at *A* (Fig. 2), at 8.30 A.M. It appeared at *B* in 22 min., and at *E* in 3 hours and 52 min.

The red was started at 8.45 A.M. It reached *B* in 21-1/2 min., but it was so faded that the time of its appearance at *E* could not be noted exactly.

The bran was started at 9.00 A.M. It reached *B* in 22 min., and appeared at *E* in 3 hours and 51 min.

From the average of these figures, the velocities were:

In the 16-in. pipe, 3.792 ft. per sec. " " 10 " " 9.695 " " "

and the discharges were:

In the 10-in. pipe, 5.287 cu. ft. per sec. " " 16 " " 5.293 " " "

The application of the equation for equalized relative velocities, as in the first test, gives:

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Velocity in 16-in. pipe = 9.705

" " 10 " " = 3.791

Discharge of 16 " " = 5.292

" " 10 " " = 5.293

These last figures would check exactly, except for dropping figures in the fourth decimal place.

The results of these two tests, considering that 20 days elapsed between them, are in very close agreement, and establish the fact that bran is an accurate medium of measurement.

Test No 3.—The 500 ft. of 10-in. pipe in the 16-in. line near the reservoir (Fig. 2) were replaced by 16-in. pipe in the summer of 1908.

On May 12th, 1909, green aniline was started through the pipe at *A* at 11.00 A.M., 11.30 A.M., and 12.00 P.M. In each case it appeared at *E* in 3 hours and 31 min. This time is 20 min. less than that observed in the tests of the previous year, and is due to the removal of the 10-in. pipe from the 16-in. line and to the increasing smoothness of the interior surface of the pipe.

The relative velocities and discharges under the third test, using the nomenclature of the first and correcting the lengths of pipe on account of the removal of the 10-in. pipe near the reservoir, are:

$$\frac{48,000}{x} + \frac{12,700}{2.56_x} = 12,660$$

$$x = 4.183$$

$$\text{and } 2.56_x = 10.708$$

and the discharges are:

From the 10-in. pipe = 5.840 cu. ft. per sec.

" " 16 " " = 5.839 " " " "

Coefficients.—On May 12th, 1909, the 10-in. line was working on a grade of 0.03338, and, with $n = 0.009$, C should have been 131. It was actually 138, making $n = 0.00866$. The 16-in. line was working on a grade of 0.0030625, and, with $n = 0.009$, C should have been 145. It was actually 141, making $n = 0.0092$.

Referring to the estimated hydraulic grade between Coyote and Corona (Plate V), the coefficients, 0.01 and 0.012, were used for wood and iron, respectively, on which basis, the maximum pressure at Coyote was expected to be 304 lb. and, at Luna, 310 lb. per sq. in. The actual maximum at Coyote, with pumps at full normal speed, was 270 lb., and, at Luna, 278 lb., indicating that the values of the coefficients taken were too high. This checks with the tests between Bonito and Nogal.

Of course, the iron pipe will increase in roughness, and, in time the pumping pressure will approach the calculated amount. The interior of the iron pipe now has a smooth coat of asphalt.

Pipe Breakage.—The breakage or damage to the wood pipe in shipment occurred on the ends, the tenons being most exposed to injury from shifting in the cars. The damage due to the shipment and handling of the Elmira pipe was 1% and one-half as much for the Bay City pipe. Less than 6 pieces out of 100,000 laid have had to be removed from the trench.

The iron pipe came from Chattanooga, and was badly handled in transit. Much of it was transferred en route, and 6% was broken when received. The breaks were generally cracks of the spigot end. Of this broken pipe, practically all was cut and laid. The average cut was about 16 in. from the spigot end of 533 pieces. This cut pipe has caused no trouble in the trench.

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At least 27 pieces of cracked pipe got past the field inspectors and into the trench. This cracked pipe began blowing out at a pressure of 50 lb., and continued until the full normal pumping pressure was reached, when the breaks suddenly ceased. These pipes were broken out at the rate of 1 or 2 per day, with an occasional day between breaks. A 24-hour work-train service was maintained. The pipe gang soon became skilled, and could put in a new section of pipe in from 4 to 6 hours. Each break generally caused an interruption of about 6 hours to the pumps on the section where it occurred. The best record was 3 hours and 50 min. from the stopping to the starting of the pumps. This strenuous life lasted 30 days. Most of these breaks were in or near the middle of the pipe. Evidently, the field inspectors were not expecting cracks in that locality. An inspection usually indicated that the pipe had been struck by the bell of another one in the vicinity of the break.

All pipes were lifted from the car carefully and laid down at the trench along the track in a single movement by a logging crane, and were not broken in such handling.

Three breaks only have been reported as due to defective metal or casting. No break of a sound shell of full thickness has been found.

Trenching.—Deep frosts are unknown in this section. The pipe was laid so that the top was about 1 ft. below the surface of the ground. The trenching was a simple matter. Part of the work between Bonito and the railway on the Carrizozo plain was done by Buckeye ditchers. All other ditching was done by a railroad plow followed by pick and shovel, or by the two latter tools only. The ditcher could open 2,000 ft. of trench per day, but averaged about 500. The plow and 35 men could open 3,500 ft. A chain about 6 ft. long separated the end of the plow beam and the double tree. In this way the trench was plowed to the bottom. Two mules, two men, and a scraper could back-fill 3,500 ft. per day.

Pipe Laying.—Between Bonito and the railway, one gang of ten men could lay 4,000 ft. of 12-in. pipe per day. The average was much less, owing to a variety of causes. At the end, the railway company added to the contractor's force, and laid the last 10 miles of pipe in 7 days, there being a half dozen separate gangs at work.

Along the railway, the day's record on wood pipe was 4,000 ft. of 11-in., 6,200 ft. of 7-1/2-in. and 8345 ft. of 3-1/2-in. pipe laid by a gang of eight men after the pipe was distributed along the trench. These eight men, of whom five were Americans, laid 76 miles of pipe, and became expert. Their operation was like the working of a clock.

On the 12-in. iron pipe, the regular day's work was 96 joints, or 1,152 ft. of pipe laid and caulked. The record was 1,644 ft. Two gangs laid 101,300 lin. ft. in 60 days. Such a gang consisted of 1 foreman, 1 inspector, 8 caulkers, 4 yarners, 1 melter, 1 pourer, 1 helper, and 10 men putting pipe into the trench.

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Cost Data.—The pipe from Bonito to the railway was laid by contract. The price was 18 cents per lin. ft. laid and back-filled from the railway to the Nogal Reservoir, and 28 cents from Nogal to Bonito. In addition, 50 cents per ton per mile was paid for hauling pipe, and extra compensation for setting valves. From Coyote, east along the railway, the work was done by the railway company under the writer's direction.

The total cost of laying 384,300 ft. of wood pipe, from 11 to 3-1/2 in. in diameter, was \$18,156.77, or 4.72 cents per ft., divided as follows:

Ditching	\$0.0249
Laying	0.0113
Back-filling	0.0110

Total	\$0.0472

This includes unloading from the cars. Train service cost 1/3 cent per ft. additional.

The pipe gang, including back-filling, consisted of 1 foreman, at \$100 per month, one assistant foreman at \$75, and about 30 Mexicans at \$1 per day. The rates were the same in the ditching gang. The plow team cost \$6 per day.

Including all general expense, the cost does not exceed 6 cents per lin. ft.

The cost of laying 101,300 ft. of 12-in. cast-iron pipe was \$23826.67, or 23.5 cents per ft., divided as follows:

Ditching	\$0.0249
Laying	0.1180
Back-filling	0.0110
Lead	0.0790
Oakum	0.0014

Total	\$0.2343

This includes train service and unloading pipe, but nothing for tools. The foreman and inspector received \$100 per month, the caulkers, \$3; pourer, \$3; melter, \$2.50; 2 pipe-men, \$2, and laborers, \$1 per day. Professional caulkers wanted \$5 per day. Carpenters, blacksmiths, and boiler-makers made good caulkers; their work is standing perfectly under a 275-lb. service.

The cost of the pumping plants complete per horse-power is as follows:

Pumps	\$79.00
Boilers	18.70
Building	41.70

Total \$139.40 per h.p.

The approximate cost per million gallons of storage capacity is as follows:

Nogal Storage Reservoir \$103.00
Carrizozo Service " 3,040.00
Coyote " " 2,880.00
Luna " " 3,480.00
Corona " " 2,720.00

To cover general expense, 3% should be added to all the costs above given. The costs per foot of pipe-laying include the setting of all specials, valves, and stand-pipes. The difference of cost in laying 11-in. and 3-1/2-in. wood pipe is not nearly as great as the difference in diameter or the total quantity laid on record days. While the record is 4,000 ft. and 8,345 ft., the 76 miles of pipe of all diameters were laid in a total time, including all delays, of 223 days, or an average of only 1723 ft. per day. The cost of the 11-in. pipe is covered by 7 cents per ft. The pipe was laid by a single gang as fast as it was received from the factory.

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The reduction from 7 to 3-1/2 in. at Mile 230 (Plate V) is on account of delivering water to the Santa Fe's new transcontinental low-grade line which crosses the El Paso and Southwestern Railway at Vaughn, and has a division point there. On its adjacent divisions, the Santa Fe had the same trouble with local waters which compelled the El Paso and Southwestern to find a better supply. The Bonito water is conducted to and used at points 160 miles from its origin on Bonito Creek.

DISCUSSION

G.E.P. SMITH, ASSOC. M. AM. SOC. C.E. (by letter).—The author has done great service to the West in demonstrating the practicability of transporting small water supplies to great distances.

Close association with the desert is required to appreciate fully its waterless condition. For most of the year there are no living waters on the surface. As a rule, ground-waters are concentrated beneath very limited areas of valley land. The great masses of valley fill in some places are underdrained to great depths and in other places are so compacted and cemented as to be impervious. Wells sometimes are driven from 1,000 to 2,000 ft., without securing any supply at all. Moreover, desert ground-waters are often exceedingly hard or alkaline, and, therefore, are unfit for many uses.

In going to the high mountains for a supply, the author has struck a principle of wide application. In many of the mountains of the Southwest there are springs and small streams of excellent water. Often, as in the case discussed, very little storage is required. These streams, however, are absorbed or disappear before reaching even the mouths of the canons, and the problem has been to convey the water to distant cities and mining camps at reasonable cost. There are several cities in Arizona now possessing pumped water supplies, which have possible gravity supplies of superior quality. The writer believes that ultimately the gravity supplies will replace the pumping plants.

In the Bonita pipe line, wood-stave pipe was used for the gravity sections. In other localities, where the grade of the line is very uniform, as would be the case down a typical clinoplain, cement pipe is deserving of consideration. It would cost no more than wood stave, would be more durable, and, furthermore, it need have no greater leakage. Its cost, however, increases rapidly when built to withstand high pressures.

The use of bran for determining velocities is of interest. The results are in close accord with those obtained from the weir measurements. In the measurement of ground-water velocities by means of salts in solution, it is found that the velocities of different filaments of waters are extremely variable, and a quart of salt solution, after moving forward a few feet, is widely dispersed. It would be of value to know to what extent the bran was distributed during its 4-hour journey through the pipe line, and during how

many minutes it was being discharged at the lower end of the line. Was the first appearance, or the average time of appearance, accepted for computing the velocity of flow?

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KENNETH ALLEN, M. AM. SOC. C.E. (by letter).—From its lightness, toughness, flexibility, and the facility with which it can be laid, wood pipe has manifest advantages for use in inaccessible places and where handling is difficult; loss in transportation is almost negligible, it will stand much unequal settlement without cracking, and ordinary leaks are easily repaired.

The coating of the bands is of such great importance that it should be inspected very thoroughly, in order to remedy defects before the back-filling is done. The writer has found Durable Metal Coating an excellent preservative. Bands coated with this preparation were buried in a salt marsh, and, after a year, the metal was found intact and the coating fresh and elastic. This coating, however, does not adhere very firmly to a smooth metal surface, so that, with careless handling, patches may become rubbed or torn off.

There is no advantage in coating the surface of the pipe. To prevent decay, such pipe should carry water under pressure or be laid in a saturated soil, so that the wood of which it is made will always be saturated, and coating the wood may interfere with this. Under these conditions the life of such pipe is not known, but it is evidently very great. Large quantities of wood pipe have been removed from trenches in Boston, New York City, Philadelphia, Baltimore, and elsewhere, usually in perfectly sound condition. It was commonly made of logs of spruce, yellow pine, or oak, from 12 to 18 ft. long, 12 to 24 in. in diameter, and with a bore from 3 to 6 in. in diameter. Some 6-in. pipe taken up in Philadelphia had an external diameter of 30 in. The ends were usually bound with wrought-iron collars, and adjacent lengths were connected by an iron thimble driven into the end of each piece.

A few years ago the writer took up more than 2000 ft. of wood pipe of this kind, which had been laid in saturated soil about a century earlier. It was of Southern pine logs, about 16 in. in diameter, 14-1/2 ft. long, and had a 5-in. bore. Joints were made with tapering cast-iron ferrules 9 in. long, and connections to smaller service pipes were made with similar but smaller ferrules of cast brass. The wood was apparently as sound as when it was first laid.

The use of flat iron for wrapping or banding pipe is believed to be wrong in principle. Round iron furnishes the requisite strength with the least exposure to corrosion, and ensures a more perfect contact with the wood.

In a 42-in. stave pipe laid by the writer for the Water Department of Atlantic City, N.J., the lumber used was Washington fir, cypress having been found difficult to procure in sufficient quantity, and redwood being more costly and no better. In this, his experience coincided with that of the author. Cedar was considered, but could not be obtained in sufficient lengths or quantity, and long-leaf pine which would have passed the somewhat rigid specifications would have been difficult to secure. It is believed, however, that

there is a field at least for long-leaf pine for such construction. Washington fir was found admirable in every respect, and was moderate in cost at that time.

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The bands were bent in the field, and, after heating in an oven for about 3 min., were dipped in bunches of five into a kettle of melted mineral rubber at a temperature of about 400 deg. Fahr., and then hung up for the coating to harden. This took place rapidly, as the work was done in winter. If the band were wound spirally, the coating would have to be done in the shop, but field coating is preferable, as it avoids injury to the coating during transportation.

An advantage of wood pipe for conveying water is its low coefficient of friction. The results obtained by the author ($n = 0.00866$ to 0.0092) appear to be very low as compared with determinations made for wood-stave pipe. Kutter's coefficient for the latter varies from 0.0096 in the case of the 30-in. pipe at Denver,[B] to from 0.012 to 0.015 as determined by Messrs. Marx, Wing, and Hoskins for the 72-in. pipe of the Pioneer Power Plant of Ogden.[C] Probably 0.011 would be a fairly safe figure to use in designing new work.

[Illustration: FIG. 3. DETAILS OF OLD WOOD PIPE.]

J.L. CAMPBELL, M. AM. SOC. C.E. (by letter).—Referring to Mr. Smith's question about the velocity measurements by bran, the first appearance of the bran and the colors was taken because the intervals of time given thereby were in close accord among themselves and with the weir measurements. The time from the first trace of bran or color until final disappearance varied between 15 and 20 min. Bran in abundance or pronounced color showed in 2 min. after the first appearance, while the disappearance or fading was noticeable after a period of from 7 to 10 min. It required 2-1/2 min. to get the bran or colors into the intake at the head of the line and leave the water clear.

[Footnote B: *Transactions*, Am. Soc. C.E., Vol. XXXVI, p. 26.]

[Footnote C: *Journal*, New England Water Works Assoc., Vol. XXII, p. 279.]

Mr. Allen refers to the bored wood pipe laid many years ago in Eastern cities. The writer's experience indicates that a bored pipe will not deliver as much water as a planed stave pipe, on account of the greater interior roughness of the former.

Referring to the profile, the 8-1/2-in. pipe between Corona and Duran had a theoretical capacity of 744,000 gal. per day. A recent test showed it to be delivering water at the rate of 759,000 gal. per day.

The 3-1/2-in. pipe between Vaughn and Pastura had a theoretical capacity of 84 000 gal. per day. It delivers only 65,000 gal. per day. There are 5 miles of bored pipe on the upper end of this section. Pressure gaugings show a hydraulic gradient in excess of the theoretical on the bored pipe, whereas the stave pipe on the lower end carries the 65,000 gal. on a flatter gradient than the theoretical one.

Experience on this pipe line indicates that $n = 0.009$, in Kutter's formula, closely approximates the capacity of planed wood stave pipes of 8 to 16 in. in diameter. The writer favors the use of 0.01 as conservative and economical.

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With equal exposure to corrosion, the round band is undoubtedly the better, but the flat band has the advantage of being completely buried in the protective coat of the particular kind of wood pipe under consideration.