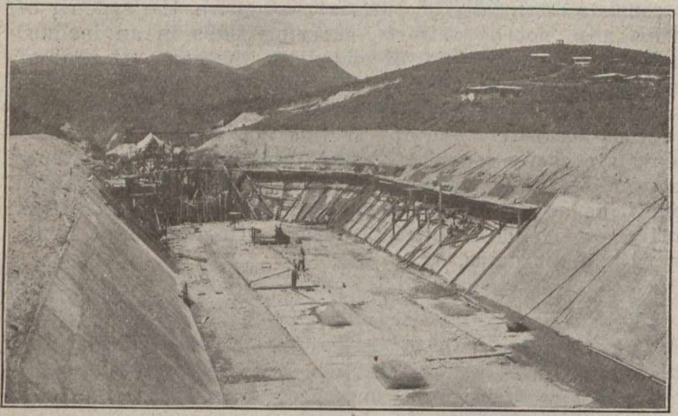
adapted to any type of reservoir whether of vertical or sloping sides. If the reservoir is entirely above ground it will of course be nothing more than a tank, but the usual construction provides that the top of the reservoir be even with or only slightly above the surface of the earth backing.

For slope wall reservoirs the incline is usually from 1½:1 to 2:1. The thickness of concrete lining for slope wall reservoirs is from 4 to 8 ins. and is usually placed in slabs from 10 to 20 ft. square, depending on whether or not the slabs are reinforced. The slabs are usually laid with butt joints, with their ends resting on a sill and the space



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between the ends of the slab filled with some elastic material to form an expansion joint. Expansion joints between slabs have been very successfully made by calking with oakum and overlaying the joints with strips of burlap, well painted with asphalt.

The Green river storage basin, Tacoma, Wash., was built with expansion joints ¼-in. wide at the bottom and ¾-in. wide at the top. The sills had tar paper laid on top of them before taking the slabs. The joints were filled with refined asphaltum, specified to be pliable between freezing and a temperature of 200 degs. Fahrenheit, and not sticky at 100 degrs. Fahrenheit. This joint has proven very satisfactory.

As a general proposition slope wall reservoirs as low as 300,000 gals. capacity may be built more economically than one having vertical walls.

Concrete Pressure Pipe

I have a suspicion that some at the outset are skeptical in regard to the use of concrete for water pressures involving heads of 100 ft. or more, but as a matter of fact concrete pressure pipe has been successfully used with pressures up to 90 lbs. per sq. in., and there is no doubt but that the pressure which may be handled by concrete pressure pipe is limited only by economy in design and construction.

There are certain requirements which pressure pipe must fulfill, among which are the following:—

(a) Ability to resist external and internal pressures; (b) low coefficient of friction; (c) minimum leakage; (d) low maintenance charges; (e) permanency; (f) provision for contraction and expansion; (g) low cost consistent with the above requirements.

Concrete pressure pipe designed to withstand internal pressure will be found to be strong enough to withstand all ordinary external pressures, as from backfill, to which it will be subjected. Reinforcing steel is, of course, placed in the shell of concrete pipe to asist in withstanding the bursting pressure, and some designers use sufficient steel to take the entire bursting pressure. This steel is, of course, not in continuous sheets and therefore requires no complicated and extensive process of manufacture. For long lines of large pipe, the pipe is constructed in place or at a convenient point near the general location of its use. Thus transportation expenses are low and the manufacture of the pipe can be given continuous inspection.

It is not my purpose to discuss the design of concrete pressure pipe, but I do wish to say that regardless of whether or not the strength of the concrete itself in tension is taken into consideration in design, it nevertheless does exist and contributes no small part of the actual strength of the pipe. Where it is not considered in the design, this strength of the pipe affords an extra factor of safety.

Correct methods of manufacture will produce concrete pipe with a low coefficient of friction and negligable leakage. A friction test was conducted on the Sooke lake water supply conduit for the city or Victoria, B.C. The pipe line is of 42-in. diameter, 27½ miles long, and contains 50% of curves with radii varying from 90 to 150 ft. There are in the line seven siphons having a maximum head of 94 ft.

The tests were conducted by Wynne Meridith, San Francisco, manager of Sanderson & Porter, consulting engineers, and the coefficient of friction (*n* of Kutter's formula) was found to be 0.01058 at the inlet end, and 0.0117 at the outlet of the 27½ miles, with the pipe running full at the inlet and six-sevenths full at the outlet. With 20 ins. of water at the inlet, the water level at the outlet was 19½ ins.

Some years ago Marx, Wing & Haskins determined from gaugings on a 6-ft. steel riveted pipe, values of *n* from 0.013 to 0.018.

The reinforced concrete pressure pipe line constructed as a part of the Gunpowder water supply for the city of Baltimore consists of 5,000 ft. of 108-in. diameter pipe and 3,000 ft. of 84-in. diameter pipe. This line carries 120,000,000 gals. daily, and when tested under a head of 85 ft., the leakage in 24 hrs. on the entire line amounted to 13,000 U.S. gals., or less than two-hundredths of one per cent.

Contraction and expansion will occur in pipe of any material, and suitable expansion joints must be provided in concrete pressure conduits if the leakage at joints is to be kept at a minimum. Such joints have been developed for use in precast reinforced concrete pipe and have been successful in practice. As the construction of pipe lines is usually done at temperatures higher than that of the water

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which will flow through the conduit, it necessarily follows that contraction will occur. This will produce cracks at the joints through which leakage of considerable amount will occur if provision has not been made to care for the contraction.

An expansion joint that has been found to take care of expansion and contraction consists of a crimped copper band continuous throughout the circumference of the joint. As the pipe contracts, the crimp opens; and as the pipe expands, the crimp closes. This joint is used in pipes of 36 ins. to 108 ins. in diameter.

It is well to reduce the number of joints by making the units as long as practicable, and each unit should be equipped with an expansion joint. Trench conditions, such as