Concrete structures, if properly constructed, will last for ever; but, assuming depreciation and repairs at 2 per cent., gives a total annual cost of 8 per cent. as compared with 26 per cent. for wooden structures of the first group, and 20 per cent. for wooden structures of the second group. Based on these figures, concrete structures are more economical if their first cost is less than 3¼ times the cost of wooden structures of the first group, and 2½ times the cost of wooden structures of the second group. However, the actual cost of many concrete structures is much less than would be given by such ratios, and is often only a little higher than wooden structures. This is especially true of concrete structures built partly in the ground, for they require only simple forms, and when these forms can be used over many times, as where several structures of the same size are required, the cost is greatly reduced. For illustration, on the Orland project, in California, the average cost of several small drops was $32.82; the estimated cost for a wooden structure of the same size is $27.94, or 15 per cent. less. The average cost of 60 concrete turnouts was $25.50, as compared with $19.80, the estimated cost of wooden turnouts, which was 20 per cent. less. On the University Farm at Davis, California, a concrete check gate cost about 50 per cent. more than wooden ones. The Arkansas Valley Sugar Beet and Irrigated Land Company, of Colorado, have during the last few years constructed some very interesting reinforced concrete structures. The cost of two large reinforced concrete drops was $131 per foot of fall, and the corresponding cost of a series of substantial wooden drops was $120 per foot of fall. The wooden structures were built in 1899, but in 1904 were in such poor condition that the operation of the canal at full supply caused some uneasiness for fear of breaks, and they required complete renewal two years afterwards, making their life about seven years.

In a general way it can be stated that, as a rough approximation, wooden structures built in contact with the ground, such as gates, drops, etc., will cost in place, including excavation and backfilling, from $40 to $50 a thousand. Small reinforced concrete structures of the simplest type will cost $10 to $12 a cubic yard, ordinary reinforced concrete structures $12 to $16, and elaborate structures with thin reinforced walls $15 to $20. Usually a structure 5 to 5 cubic yards of concrete, and the concrete structure requiring 1,000 feet of lumber can be built with about will cost from 25 to 50 per cent. more.

With the structures of the second group, that is, wooden flumes and wooden stave pipes, the comparison is not quite so favorable to concrete as with the other structures. This is because of their longer life as compared with the wooden structures in contact with earth, and to the greater difficulty in constructing them of concrete. The cost per cubic yard of concrete is considerably greater, especially for flumes crossing canyons and deep depressions, because this requires expensive forms to support it during construction and some skilled labor. For that reason the cost of concrete flumes may be as great as three times the cost of a wooden flume, in which case a wooden flume or a steel flume may be more economical, at least until the price of lumber increases. But there are conditions which will favor the use of concrete, for instance, the Modesto and Turlock systems of California have replaced all their old bench flumes, which aggregate several miles, running on the side hills, by concrete channels formed by means of a wall on the down-hill side, a slope lining on the uphill side and a concrete floor in between. This not only did away with the high cost of repairs and renewals, but has paid for itself in the additional security, because a break in their main canal has meant the interruption of delivery of water, and has caused great damage to crops. As a rule, a concrete flume supported on columns should not cost over 2 to 2½ times the cost of a wooden flume.

As regards reinforced concrete pipes compared with wooden stave pipes, several of them have been built by the Reclamation Service, and a few on private projects, and their first cost is generally 1½ times the cost of wooden stave pipes. They are, therefore, more economical, and should be used in preference. They are, however, limited to moderate heads. The maximum head to which they have been submitted successfully is about 100 feet. A large reinforced concrete syphon in Spain, 13 feet in diameter and 7 inches thick, is under a head of 97 feet. On the Umatilla project in Oregon reinforced concrete pipes 4 feet in diameter, 3 inches thick, have been tested successfully for pressures equivalent to 100 feet heads. For even these moderate heads careful work is necessary.

To summarize the above remarks it may be stated that, in a general way, with the exception of some flumes, concrete structures will cost from 1¼ to 1½ times the cost of wooden ones. Since the large annual cost for repairs and renewals of wooden structures makes it economical to spend for concrete structures 2½ to 3¼ times the price paid for wooden structures, in nearly every case a concrete structure is more economical, and will cut the total annual cost of repairs, renewals and interest into one-half.

Another advantage of concrete structures which I have not emphasized is the additional security obtained, which is worth considering.

During the last two years some doubt has been cast upon the durability of concrete, because of its disintegration by the effects of alkali. So far, all that has been published can be reduced to the following facts:—

1st. Out of all the many concrete irrigation structures, including those on the 25 projects of the United States Reclamation Service, constructed in 13 States and territories, there are only two projects, one in Montana and one in Wyoming, where the failures of concrete structures have occurred. The only other recorded instances are some sewers in Montana and some concrete drainstiles in Colorado.

2nd. The disintegration seems to take place where the structures are in contact with strong alkali water of a peculiar composition, and occurs where the water permeates the concrete mass and is evaporated, leaving the salts in the pores of the concrete.

3rd. Black alkali seems to have no harmful effect, and the disintegration is caused probably by only some of the white alkali salts. Wherever disintegration has occurred the alkali salts are sulphates, with magnesium sulphate predominant.

As against these few failures there are hundreds of examples of concrete irrigation structures where alkali has had no effect. Nevertheless, where the sulphates are strong it is good policy to experiment on a small scale in those localities before works involving large amounts of money are built, and to take all known precautions in the construction. At present the best known means to prevent disintegration are:—

1st. To make the concrete as nearly impervious as possible.

2nd. To remove the alkali water where practicable by drainage.

3rd. To use some cement which will be most resistant to alkali.

The Reclamation Service is now experimenting with the use of a special cement, and the Geological Survey is carrying on a series of experiments which it is hoped will help to solve the problem.