In Providence, R.I., the infiltration has been estimated at 47 gals. per capita per day.

In Waterbury the infiltration to a concrete sewer about 4 ft. 5 ins. square laid under a head of from 4 to 12 ft. amounted to one gallon per second for every 400,000 sq. ft. of interior surface, or 0.218 gal. per sq. ft. per day.

The infiltration of 140 miles of sewers in Massachusetts towns has been estimated at 40,000 gals. per mile daily. Taking the larger systems of the state it has been estimated at 70,000 gals per mile.

In the metropolitan system near Boston it has averaged 40,000 gals. per mile before making connections.

In their report on a system of sewerage for the city of Baltimore in 1897, Messrs. Hering and Gray recommended an allowance of 750,000 gals. per sq. mile in the low-lying districts near the harbor, and 100,000 gals. per sq. mile per day in other parts of the city. In 1906 Mr. F. P. Stearns proposed an allowance of from 30,000 to 80,000 gals. per mile of sewer daily. In later estimates 12 gals. per capita have been assumed.

Mr. C. E. Grunsky estimated for the sewerage of San Francisco a daily volume of 55,300 gals. per sq. mile for pipe sewers and 166,000 gals. per sq. mile for brick sewers.

In Peoria, Ill., the infiltration was estimated at from 50,000 to 100,000 gals. per mile for sewers in wet ground. In the case of brick sewers it was estimated at 15 gals. per sq. ft.

The above figures show the variation in the amount of ground water infiltration and indicate how serious the problem may become in some cases. Mr. Hammond considered it likely that his list could be extended to include nearly every sewer system installed in this country previous to 1900, and many since installed.

Methods of Waterproofing Sewers.—As Mr. Hering points out, waterproofing may be applied in three general ways. One way is to have the material of the structure and the joints impervious. This will prevent leakage in either direction. Another way is to coat the outside of the sewers if the object is to prevent infiltration of ground water into the sewer. The third way is to coat the inside of the sewer if a leakage of the sewage into the ground is to be prevented.

Mr. Hammond submits the following classification of the causes of failures and leaks in pipe sewers: 1. Pipe of improper material for sewers. 2. Defective or broken pipe. 3. Defective joints. 4 Defective house connections. 5. Improper foundations. 6. Careless or improper backfilling of trenches. 7. Improperly constructed brickwork and concrete. 8. Disintegration of pipe or masonry, caused by chemicals or impurities in solution in the sewage or in the ground matter, and from steam admitted to the sewers. 9. Failures from other causes not classified, as unexpected contraction and expansion, impact, etc.

Mr. Hammond discusses waterproofing methods as follows:—

"The waterproofing of sewers is perfectly practicable. The extent to which it should be employed, and the best method adaptable to a given case, are the problems to be met, as well as the probable length of time during which the waterproofing employed will continue effective, and the best should be selected for each special case.

"There are various methods here for producing the effect, as elsewhere. Coatings of bituminous materials may be applied to the external surface of the sewer, and gaskets dipped in tar or maltha or hot asphalt may be employed in the joints; or the whole interior of the sewer may, in the case of large masonry structures, be treated with a plaster. Again, the sewers may be designed to be built of concrete pipe rendered impervious by exterior coatings of asphalt paint or maltha; or by having an antihydrous waterproofing compound mixed with the cement used in the concrete. Recent experiments seem to show that even the admixture with the concrete of clay, or various other substances, will produce a dense and waterproofing material. Concrete rendered impervious by one of these methods may be used in forming the larger sewers in place, and in making the manholes and other appurtenances. Also, in the construction of pump wells and disposal works; and in various instances this method may be supplemented by the use of bituminous exterior coatings.

"In Baltimore, where the most elaborate and extensive system of sewers now under way in this country is being constructed, and no detail is being lost sight of or expense spared which could render the system more perfect, the intercepting sewers are being treated with a complete waterproof coating."

In addition to the data given by him on the amount of ground water infiltration, previously quoted in this abstract, Mr. Allen discussed the methods and cost of waterproofing sewers. We quote, as follows:

"In the case of vitrified pipe sewers, if these are sound and of good quality, it only remains to secure an impervious joint. This is not practicable with natural cement. With Portland cement mortar following a gasket saturated with grout and carefully calked there will be very little leakage. The difficulty lies in ensuring perfect work, especially in a wet trench, and the possibility of cracking the joint by settlement in a soft soil. To overcome these objections various substitutes for the cement mortar joint have been used with more or less success.

"With a firm bed or foundation a mixture of 1 part of fine sand with 1 part of flour of sulphur heated to about 230° F. poured in the joint over a well calked gasket is said to give a water-tight joint costing for an 8 in. pipe 12 cts., for a 15 in. pipe 19 cts. and a 30 in. pipe 30 cts. Possibly leadite, which is somewhat similar in character and which the writer has used successfully for cast iron pipe joints would answer equally well. Either of these materials will provide a strong and unyielding joint, so that in case of settlement an undue strain is brought to bear on the bell.

"For yielding soils the writer believes some form of bitumen may eventually be found that will be both elastic and impervious. For a number of years Mr. J. H. Decker has used a paste made by kneading cement and pine tar pitch by hand until of the consistency of dough in the sewers of Atlantic City with success, the material being pressed into the joint by hand. The writer employed this method in laying about ¼ mile of conduit of 8 in. to 20 in. vitrified pipe conveying water from a series of artesian wells to a reservoir. Testing under a head of 3 or 4 ft. after completion, the line was found to be almost absolutely water-tight. This joint, although setting quite hard, remains sufficiently pliable to conform to ordinary settlement without injury.

"In Baltimore, Mr. E. B. Whitman experimented with a joint which proved so satisfactory that a considerable amount of vitrified pipe has been laid in wet trenches in the sewerage of that city with bitumen joints. The specifications provide that the inside of the bell and at least 4 ins. of the spigot end shall first be painted with a thin paint consisting of a solution of bitumen and gasoline or turpentine. Two or three pipe lengths are usually joined together before lowering to the trench by first centreing and packing with a thin gasket of hemp or jute well calked and then filling the joint full of hot bitumen, heated sufficiently to expel bubbles but not so as to render it brittle. The bitumen may be the refined natural or artificial material or a mixture of both, but must not have a melting point lower than 170° F. or be brittle when cooled to 30° F. It must also be of such a consistency that a fragment will not materially alter in shape when kept in