the daily variation in the temperature of the air is about 50 deg.

4. In the case of concrete 3½ ft. from an exposed face, no daily variation in temperature is apparent when the daily variation in the temperature of the air is about 50 deg.

5. The seasonal variation in the temperature of concrete 3⅝ ft. from an exposed face is about 32 deg. when the seasonal variation in the mean daily temperature of the air is about 75 deg.

6. The experiments have not yet been carried far enough to show the seasonal variation at other distances from exposed faces, but it is probable that they become very much less as the distance from the face increases.

BRASS IN WATERWORKS CONSTRUCTION.*

FOR many years hydraulic engineers and manufacturers of equipment and materials to be exposed to water and atmospheric moisture have sought a strong, uncorrodible, moderate-priced metal or a method of rendering iron and steel greatly resistant to corrosion. For about forty years several kinds of forgable copper alloys have been produced having high tensile strengths, for which very broad fields of usefulness seemed open in engineering construction. These alloys have been commonly known as bronzes or brasses.

Claims of brass or bronze makers backed up by tests and experience led the engineers of the Catskill aqueduct, after careful investigation, to adopt some of these copper-zinc alloys for extensive use where their non-corrodibility and other good qualities claimed for them made them especially suitable. It is safe to say that on no other single engineering enterprise have such large quantities ever been used, the total being nearly three million pounds. More than two million pounds of this was in the form of castings ranging from a fraction of a pound to 22,000 pounds each. Forgings constituted a large proportion of the remainder, varied from small bolts to sluice gate stems about 6 inches in diameter and 31 feet long, weighing 3,200 pounds each. The balance was made up of plates, rods and shapes. Manganese bronze constitutes a very large proportion of the total, "naval brass," including Tobin bronze, was used in large amounts and various common brasses and special compositions made up the relatively small remaining quantity. As an illustration of some of the larger castings may be mentioned the shaft caps.

It was not in these large castings, however, that trouble was experienced, but in the smaller objects, such as bolts, ladder rungs and pipes. These numerous and various brass articles had been made by a number of manufacturers scattered through New England, New York, Pennsylvania and New Jersey. The experience of the Catskill aqueduct with these brass articles may be summarized as follows: Large numbers of brass bolts have been found cracked and broken in their packing boxes after storage through a winter, but having never been stressed; others never exposed to low temperatures and never stressed have been found in similar condition. These bolts ranged from ½ inch to 2¼ inches in diameter. Similarly, flat bars, rolled plates and long rods supporting only their own weight have been found cracked or severed after a lapse of a few or many months. Flanged ¼-inch plates riveted together, after careful inspection being in apparently good condition, were found some months later to have incipient and well developed cracks, with many rivets cracked or yielding to relatively light blows from a hand hammer. Many upset rivet heads have come off. Hundreds of bolts have broken under tension after short or long intervals. The failures have been so numerous and important as to have caused the gravest apprehension and led to the substituting of steel for brass in many cases, in spite of the recognized disadvantage of steel as to corrosion which the engineers had sought earnestly to avoid.

No brand or make of brass or bronze has wholly escaped. Manganese bronze, naval bronze (including a well-known bronze, and its imitation), and Muntz metal, from all the manufacturers who have furnished any considerable quantity, all have failed. Hitherto castings and large forgings have been exempt, or at least failures in them have not been discovered, except in a few cast bolts and nuts.

When studying the extent and cost of these failures, it was found that other users also have had trouble of one kind or another, knowledge of which has come to hand within relatively recent time. At just what date or when in the state of development of brass manufacture these troubles began, or how extensive they have been, has not yet been learned. Possibly they might have been considered occasional or accidental but for the large use of these alloys on the Catskill aqueduct under supervision which led to a detection of these defects.

The discovery of these failures in the fall of 1913 was all the more disappointing because the specifications had been drawn carefully in the light of information which is in hand and practically all the metal accepted had been subjected to careful inspection, including the standard physical tests and chemical analyses. Much of the metal accepted had shown physical qualities in generous excess of the specified requirements, and it is quite unthinkable that the manufacturers were not honestly endeavoring to fulfil the specifications and furnish satisfactory materials.

Among the physical characteristics required were that manganese bronze should have a tensile strength of not less than 65,000 pounds per square inch, an elastic limit of not less than 45 per cent. of the ultimate tensile strength and an elongation of not less than 25 per cent. That rods for brass rivets should have a tensile strength of not less than 55,000 pounds per square inch, an elastic limit of not less than 30,000 pounds, and an elongation not less than 20 per cent. It is known that in brasses the elastic limit or yield point is not well defined and, judging from some experiments recently performed, must under prolonged stress be regarded as the ultimate strength. It was known that apparently sound brass pipes and some kinds of brass wire would occasionally crack without evident reason; but leading manufacturers of brass pipe have discovered how to modify the details of manufacture so as to overcome these troubles in a large measure, and little trouble has been experienced with pipes furnished by reputable manufacturers in recent years. There is, therefore, small excuse for supplying other than dependable brass pipe nowadays.

Experiments carried on by Inspector Jonson of the Catskill aqueduct laboratory demonstrated that improperly cold-worked rods were in a state of initial stress, and that these stresses were frequently of important magnitude, so

*Abstract of an article before the Municipal Engineers of the City of New York by Alfred D. Flinn, deputy chief engineer, Board of Water Supply of New York City.