ed and placed in the autoclave. The bar is removed with the briquettes at the end of the two-hour test. The final measurement is made after the bar has remained in the moist closet for one hour.

The tables show the results of all tests on the cements from Mills 1 to 5 respectively. (Two of the tables, showing tests of cements from Mills 1 and 2, are omitted here. All samples, representing 344 cars of cement, passed the autoclave test.) For purposes of comparison, there are shown in Table 4 the averages of the results of all tests from each mill.

Results of Tests.—Each shipment from Mill 2 showed a large increase in tensile strength in the autoclave test and with one or two exceptions the expansions were all very low. The chemical composition of the cement from this mill is about normal. The tensile strengths for the sands on the 7 and 28-day and the 3 and 6-month tests were all excellent.

Mill 1 shows, perhaps, the most uniform results of any of the five mills. This is the first mill in the United States to attempt the manufacture of autoclave cement and is the plant at which many of the early experiments were conducted. From the day that they started to make shipments of autoclave cement up to the present time there has not been one single cause for rejection and this is indeed a most remarkable showing. Mill 1, like Mill 2, shows a continual increase in the tensile strength up to six months.

Mills 4 and 5 also show a wide variation, some of the shipments passing the test, others failing; some showing little expansion, others showing considerable expansion. The results of the 7 and 28-day and the 3 and 6-month tests are lower in this case than in either Mill 1 or 2.

The method of making briquettes used in the laboratory of the Lackawanna Railroad is one of tamping. About 9 per cent. of water is usually used and the briquettes are well tamped in the molds by placing an iron die thereon and striking it several times with a wooden mallet. This gives higher results on the 7 and 28-day tests, but when the briquettes are very firmly packed in with the thumbs there appears to be very little difference in the long-time tests, except possibly that more uniform results are obtained by tamping.

Reasons for Failure Under Autoclave Test.—To all large users of cement the figures from the various mills are certain to be interesting. The question naturally arises as to why a cement which passes the ordinary boiling test in many cases, from some of the mills, shows a decrease in tensile strength or goes entirely to pieces in the autoclave test.

Samples of cement which have failed in the autoclave test, when re-tested again after a period of 30 days, 2 months, 6 months and over a year, in most cases pass the autoclave test. In one or two cases samples which were approximately 15 months old still continued to show no increase in tensile strength; in a few other cases a decrease in tensile strength was shown, while others showed an increase, due to the seasoning process, of over 100 per cent. This points very clearly to the fact that these particular samples were not properly manufactured, for with certain mills any cement which has not passed the autoclave on the first test has in practically every case passed the test after the cement is held for a period of time.

Fine Grinding.—Further investigation as to why some of these cements fail to pass this test after a period of time shows that the raw material was more coarsely ground than in other samples which did pass the test after seasoning. The grinding of the raw material and the proper burning play a most important part in the quality of Portland cement; and the author believes that the failure of cement to pass the autoclave test is due very largely to the coarser granules which do not become hydrated when the cement is set up and that the failure of these granules to become fully hydrated is due to their chemical composition. That is, the granules are composed largely of dicalcium silicate ($2CaO\ SiO_2$), with a smaller proportion of tricalcium silicate ($3CaO\ SiO_2$). Granules of this composition fail to properly hydrate in the period of twenty-four hours and consequently, when brought in contact with the heat and pressure, together with moisture, slaking of the dicalcium silicate is quickly brought about, with the result that a large percentage of expansion occurs, together with a proportionate decrease in tensile strength. On the other hand, if the proportion of tricalcium silicate is largely in excess of the dicalcium silicate, then we may expect a more stable product and one which will show considerably less expansion under the autoclave test and remain constant in volume in after years.

TABLE 2—RESULTS OF TESTS ON CEMENT FROM MILL 4

Number of cars represented	Tensile strength, neat, at 24 hr., lb. per sq. in.	Autoclave test: Tensile strength, lb. per sq. in.	Autoclave test: Change in tensile strength, per cent: Increase	Autoclave test: Change in tensile strength, per cent: Decrease	Autoclave test: Expansion, per cent	Tensile strength of 1:3 briquettes, lb. per sq. in.: 7 days	28 days	3 months	6 months
6.....	275	508	84.72	....	0.20	406	493	535	414
5.....	402	232	....	42.29	2.77	373	461	478	469
4.....	332	297	....	10.54	1.20	401	471	462	482
2.....	435	555	27.58	....	0.50	331	359	475	476
3.....	473	192	....	59.40	1.87	370	418	483	483
9.....	370	146	....	60.53	3.68	342	399	470	428
4.....	410	525	28.05	....	0.31	373	440	408	452
2.....	350	345	....	1.42	0.25	307	412	406	425
3.....	427	367	....	14.00	0.70	328	352	424	...
1.....	420	27	....	93.57	Soft	408	402	...	...
1.....	364	270	....	26.00	1.97	327	435	...	...
1.....	307	475	54.72	....	...	410	505	...	...
2.....	385	602	56.40	....	...	348	452	544	...
9.....	392	9	....	99.24	Soft	413	443	483	...
2.....	369	64	....	80.00	3.10	355	390	454	...
3.....	378	257	....	31.50	1.92	413	461	470	...
1.....	296	459	16.00	....	0.39	390	473	...	...
1.....	237	630	87.00	....	0.20	416	492	...	...
2.....	429	495	15.40	....	0.80	238	433	...	...
3.....	396	447	13.01	....	1.07	390	453	...	...
Av'ge	372	345	42.54	47.13	1.31	367	437	468	453

In order to produce a large excess of tricalcium silicate two things are necessary—the raw material must be more finely ground and the cement must be burned at a higher temperature. Most of the cement in Mill 2, as well as in Mill 1, shows very little expansion and a comparatively low loss on ignition. It is also known that in both Mills 1 and 2 the raw material was very finely ground. In some of the other mills—for example, Nos. 3 and 4—while the burning was good, the raw materials were not so finely ground; in Mill 5 there was not only fairly coarse grinding of the raw material but there was also a much higher loss on ignition. From the report of Mill 5 it is evident that the cement from this mill could not be as constant in volume as that from Mills 1 and 2.