In order to manufacture a cement which will pass the autoclave test it is necsssary to grind the raw material very much finer than is customary and to have the clinker well burned. The manufacturer, however, can greatly increase the output of his mill by grinding his raw material coarser and burning his clinker not quite so hard. This produces a cement which contains a very large percentage of dicalcium silicate, which may not be constant in volume, and which would more than likely fail to pass the autoclave boiling test. This cement would probably require seasoning in order to make it pass the regular boiling test.

Future Tests.—Briquettes for tensile strength from the various mills have been made up on most of the samples shown to one year. It is to be expected that the results on cement for longtime tests will be equally as high, if not higher, than on the standard-specification cements. On the long-time tests for expansion very little difference or variation has been noted to date. A number of expansion bars have been kept under observation and measured at frequent intervals. It is believed that some time must elapse before any difference will be noted in these bars.

A large number of cylinders and cubes have been made up for compression tests. The results to date indicate that higher compressive strengths are being obtained, as a rule, on autoclave cement. A large number of 2-in. cubes of the various brands have been made up for compression tests, to be made during a period of from one to five years. The number tested to date is not sufficient to draw any definite conclusions, except as stated above, that in many cases the autoclave cements show higher strength in compression. The results obtained on autoclave cements are more uniform than on other cements.

Discussion of the Paper.—Dr. A. S. Cushman, director of the Institute of Industrial Research, Washington, in presenting his discussion gives some historical data in connection with the autoclave test. It appears that the high-pressure steam test on Portland cement was first recommended in Germany in 1881 by Dr. Erdmenger. His test was fully investigated by some of the leading German authorities on cement and was rejected by them as inadequate and misleading. The International Association of Testing Materials is also mentioned by Dr. Cushman as having reported against the test because it had been found to lead to erratic and inconsistent resource. He likewise refers to a number of researches on the subject, tending to condemn the test as irrational and one not to be used as a method of judging behaviours in construction work of a given brand of Portland cement. He cited tests which go to show that the autoclave process is not able to distinguish between the strength developing qualities of cement up to six months under normal exposure to out-of-door conditions.

In conclusion Dr. Cushman says:—"A careful examination and analysis of all the data obtained in various laboratories and the experience of the Institute of Industrial Research, gained during a systematic investigation of the autoclave test, show that it yields erratic results and is not to be depended upon for determining a quality or condition of any brand of cement either for immediate or future results in service. The conclusion which must be reached as the result of these investigations is that the test is not dependable as a method of distinguishing cement which will give successful results from the cement which may be expected to fail under service conditions."

Table 3—Results of Tests on Cement from Mill 5

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
2....	347	504	45.24	....	0.60	385	466	553	491
3....	310	562	81.29	....	0.60	306	362	457	467
6....	242	388	60.33	....	0.75	251	315	407	425
6 ..	365	392	7.39	....	1.00	345	355	431	452
5....	347	83	....	76.36	4.83	248	287	312	450
18....	233	260	11.50	....	0.91	290	358	416	430
3....	292	472	61.22	....	0.63	312	320	395	396
4....	343	267	....	29.82	2.50	309	380	442	486
4....	275	135	....	60.00	0.40	281	370	407	430
6....	195	410	110.00	....	0.86	328	385	430	446
7....	270	62	....	96.55	2.82	248	355	395	...
4....	268	350	30.70	....	1.20	273	373	472	...
6.. ..	288	80	....	76.60	3.12	305	352	417	...
5....	250	337	53.00	....	0.48	273	346	440	...
7....	193	235	23.68	....	1.50	312	402	483	...
4....	340	435	28.00	....	0.48	339	398	438	...
39....	272	Soft	Soft	....	Soft	352	415	550	...
8....	285	142	....	50.00	1.70	309	372	472	...
1...	370	565	53.00	....	0.23	347	477	...	...
6....	340	Soft	....	Soft	Soft	372	433	504	...
19....	378	Soft	....	Soft	Soft	301	371	532	...
8....	371	Soft	....	Soft	Soft	317	382	509	...
30....	365	25	....	90.41	3.44	328	345	453	...
6....	360	10	....	97.00	4.00	308	363	468	...
16....	275	Soft	....	Soft	Soft	388	438	410	...
6....	352	Soft	....	Soft	Soft	307	435	456	....
6....	385	432	25.90	....	0.52	332	441	524	...
1....	387	532	37.20	....	0.43	355	334	...	...
4....	342	500	46.15	....	0.30	382	424	...	...
6....	372	94	....	80.00	5.40	430	490	430	...
4....	299	70	....	76.60	5.00	413	445	484	...
1....	358	143	....	44.57	3.23	332	390	...	...
2....	261	462	80.00	....	0.52	258	380	...	...
5....	261	374	33.00	....	0.70	233	412	...	...
6....	216	75	....	65.30	No Bar	217	457	...	...
1....	309	494	59.80	....	0.06	...	...	...	...
3....	282	410	45.30	....	0.81	311	395	...	...
2....	387	403	11.10	....	0.68	327	390	...	...
2....	216	440	137.00	....	0.48	361	410	...	...
3....	293	430	47.30	....	0.54	368	466	...	..
1....	308	432	40.26	....	0.36	310	426	...	...
4....	407	325	....	25.23	2.24	370	385	...	...
Av'ge	310	314	49.06	66.80	1.52	320	392	453	447

Mr. Rudolph J. Wig, Assistant Engineer of the United States Bureau of Standards, stated in his discussion that his criticism was based upon tests made by that Bureau over a period of nine months. He drew the following conclusions from these tests:—

1. Of the 48 brands tested, 88 per cent. passed the autoclave requirement upon some tests; 52 per cent. passed upon all tests; and 6 brands failed upon all tests.

2. There is no difference in linear expansion between set cements of types 2 and 3 (unsound and sound, respectively, under autoclave test) which are exposed in the atmosphere for 6 months.

3. Nor is there any difference in linear expansion in these cements when exposed to fresh water for 6 months.

4. The linear expansion of different cements varies from 0.135 to 4.2 per cent. of the original length when exposed to steam at pressures between 180 and 300 lbs. per square inch. The Type 3 cements had an expansion below 0.2 per cent., and the Type 2 cements had an expansion above 2 per cent.