A STUDY OF THE EFFECTS OF LUBRICATING OIL ON ASPHALT

Thesis for the Degree of B. S.

G. C. Sanders

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THESIS

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A THESIS

SUBMITTED TO THE FACULTY OF

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By

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of

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THESIS

A STUDY OF THE EFFECTS
OF LUBRICATING OIL ON ASPHALT.

The purpose of this thesis is to determine and observe the effects of lubricating oil on a sample of asphalt by running a series of tests as outlined by the American Society of Testing Materials with a varying percentage of lubricating oil of a standard grade.

Asphalt is of great importance as a material for road building and road maintenance. The importance is growing with incredible rapidity at present, due to the increase in automotive traffic as well as the change of hauling freight between cities, especially less than car load fright, that was formerly carried by the railroads. The traffic situation is bringing about a need for improved roads - roads that will serve the present era as well as the future, yet being efficient and economical as to first cost and maintenance.

Careful study and consideration has been given the quality and desirability of the materials constituting the ingredients of the roads. Many tests have been performed relative to this subject in an attempt to discover and provide materials which would more nearly reach that of an ideal road.

Some motor vehicles in passing over a road drop oil from the crankcase or other places on the surface of the pavement. This is not so noticeable in the main traveled track because they are in motion, thus only drops strike the surface and are distributed along and other vehicles in passing help spread the oil around. It is quite noticeable, however, near the curbs and parking spaces where vehicles stand for considerable lengths of time.

The question arises as to what effect this oil has on the asphalt and in what way. Nothing has been done to observe or determine the effects as yet. A series of tests has been run, however, relative to the deterioration of asphalt paving mixtures by gasoline, an account of which appears in the January, 1927 issue of Roads and Streets. This does not appear to be as practical or significant a test as that of lubricating oil. It is seldom the case that gasoline is on the surface to any great extent or in any quantity. Gasoline leaks in automobiles and trucks are usually repaired at once as they are dangerous and more costly then oil leaks. Then, too, gasoline evaporates so rapidly that it would have little time to produce any deteriorating effect on the surface.

Lubricating oil, on the other hand, does not evaporate under ordinary atmospheric temperatures and stays on the surface until the traffic removes it or it is washed away or is worked in, thereby, having ample time to produce any deteriorating effects.

It is, then, the purpose of this thesis to observe any effects of the oil on a sample of asphalt. A test of this nature should be of value in comparing the physical characteristics of asphalt mixed with oil and to note any deteriorating effects it might possess.

Only six of the tests for asphalt were used, namely; the flash point, fire point, ductility, adhesion, penetration, and softening point.

A standard grade of asphalt suitable for paving and marketed as such was secured from a well known manufacturer for the experiments. Enough of the sample to complete the six tests was carefully weighed and put in a seamless tin container with a cover. Sixteen such samples were prepared, each carefully weighed and to each was added the lubricating oil starting with zero and going to fifteen percent inclusive.

The oil used was a medium grade of Polarine, as this is one of the brands used most and also is the grade required for the majority of makes of automobiles.

Each sample was heated to a temperature of about 150° F. and thoroughly stirred to insure proper mixing of the oil thruout the sample of asphalt. Covers were put on the tins to lessen possibilities of evaporation by exposure to the room air and dust collecting on the surface.

The flash and fire points were determined by the open cup method with the Cleveland open cup tester. The apparatus consists of a brass cup of specified dimensions seated in a metal plate six inches in diameter and one-fourth inch in thickness. The cup was filled to a depth of one inch with the sample and a standard open cup flash point thermometer, suspended by a wire fastened to the frame, was immersed to a depth of one-fourth inch from the bottom of the cup. A Bunsen burner was used to heat the substance, the temperature being increased at the rate of 10° F. per minute. A test flame of gas about five-thirty-secondths inch in diameter was passed in a straight line across the center of the cup at every five degree mark. The temperature at which there was a visible flash at any point of the surface of the sample was taken as the flash point.

When the flash point has been determined the temperature was increased at the specified rate to the point when the material ignited and continued to burn for a period of at least five seconds. This temperature was the fire point and was recorded as such.

The flash point and fire point were also determined for the oil alone, not mixed with any asphalt. This was for comparison of the curve in the graph.

For the ductility test the samples were prepared in the Dow ductility mold which has a cross-sectional area at the center of one square centimeter. The molds were allowed to cool to room temperature for one hour, then placed in a water bath maintained at a constant temperature of twenty-five degrees centigrade for an hour. At the expiration of this time they were placed in the ductility machine and immersed in water at twenty-five degrees centigrade and pulled apart at the rate of five centimeters per minute. The length at which the samples parted was measured and the mean of the three values taken as the ductility of the sample. In some cases the ductility was more than the machine would register in which case the highest value only was recorded with a plus sign. When taking the average the plus sign was not considered, thus giving a slightly lower value which gave a flatter curve at the beginning of the graph for those percentages whose ductility was greater than 150 centimeters.

The adhesion was determined by means of the Hirschbraun Adhesive tester which consists of a dynamometer with a maximum reading indicator having a ball attached to the lower end. A platform with side clips for holding the container of the sample is attached to a threaded bar, geared to a crank for raising or lowering the sample. Two samples prepared were placed in the cups and stirred to remove any air bubbles and allowed to cool for one hour. After this time they were placed in the water bath for one hour the same as for the ductility test. The samples were next placed in the machine and the wooden ball covered with linen cloth and a 100 gram weight placed on the shaft. This was allowed to settle into the sample for thirty seconds when it was pulled out by turning the crank about 60 revolutions per minute. The highest reading at which the dynamometer registered before the ball suddenly pulled away from the sample was taken as the adhesive force of the sample. Several readings of each sample were taken and an average of the trials recorded.

In preparing the samples for the penetration test the whole sample was heated and stirred to form a uniform and homogenous mixture and poured into a small tin container and again stirred to remove any free air bubbles. This was allowed to cool for one hour to room temperature then placed in the water bath at 25 degrees centigrade for one hour as in the ductility and adhesion tests. At the end of this time the sample was placed under the needle of the penetration machine in a transfer dish containing water at 25° centigrade to maintain a constant temperature of the sample. A 50 gram weight was used in addition to the weight of the needle which was also 50 grams making a total of 100 grams. The point of the needle was placed exactly at the surface of the sample and released for a period of five seconds. The depth to which the needle penetrated was observed from the dial and recorded. The reading registered the depth in hundredths of centimeters. Several readings were taken at different places on the surface and an average recorded. After each penetration of the needle the water in the transfer dish was changed in order that the temperature be kept exactly at 25° centigrade and not be raised by the room temperature. The needle was also cleaned with a dry cloth after each penetration. This is a very accurate method of testing and by proper manipulation accurate results can be obtained by which to compare samples of asphalt.

The procedure in finding the softening point by the ring and ball method consists in placing the samples in two molds of small rings on an amalgamated brass plate to prevent adhering to the plate. When the samples cooled, a small steel ball of specified size and weight was placed in the center of each ring and the ring placed in a frame such that they were suspended exactly one inch above a plate, the entire frame being in a glass vessel of freshly distilled water cooled to five degrees centigrade. The entire vessel with the samples was then placed in the ice bath and cooled to five degrees for a period of fifteen minutes. After the expiration of the fifteen minutes the vessel was then heated such that the temperature increased five degrees centigrade per minute at the point midway between the samples, where the thermometer bulb was located. The temperature at the instant the samples touched the bottom of the plate was taken as the softening point. The average of the two samples was recorded.

All the data from the above tests was put in tabular form for each successive percentage of oil from 0 to 15 percent inclusive and the data plotted on graph paper.

An examination of the flash point and fire point graphs shows the curve to approximate a straight line. It very likely would be a straight line, but the test flame was passed across the surface only at the five degree marks and the true point might be between the five degree marks. Some results necessarily would be the same in view of this fact, causing a horizontal line in the curve between two percentages. The general curves are, however, approximately a straight line and can be considered as such. This would not be true as the percentages is increased as the fire point and flash point of the pure oil is not in the same proportional decrease.

The graph of the ductility tests is not a straight line altho it is only slightly concave downward. The erratic values near the middle are due to differences in temperature of the room which affected the water bath and also the samples were deformed slightly in removing from the amalgamated plate. The straight horizontal line at the very first of the curve is accounted for by the fact that the ductility machine registered only 150 centimeters and the first three samples exceeded this figure. The curve is steady and uniform in general and the decrease in ductility per percent increase of oil changes uniformly. The oil itself has no measurable ductility and just where the limiting point of measurability is was not determined as samples containing the large amounts could not be used for the other tests owing to limitation of the testing apparatus.

The adhesion curve has a decided double twist in it tho not abrupt. It starts uniformly at the beginning and increases to about 5 percent when the curve starts to invert and decreases from the general trend. It approximates an elongated "S" curve inclined upward to the horizontal. According to the directions the sample was not to be immersed in water to cool but it was completely immersed in the water bath for one hour in this case. Very good results were obtained by this procedure. The sample, however, was carefully wiped dry before placing in the adhesion machine to remove any adhering drops of water which might prevent the adhering of the sample to the linen cloth.

The direction also stated that the rate of turning of the machine was of little importance as the gear ratio compensated for the non-uniformity. It was found in running these tests that the rate of turning does make a decided difference in the results. A variation of 10 to 20 percent was noticed so that a speed of 60 revolutions per minute was adopted to perform the tests. More uniform results were obtained in this way. An error of 10 percent is allowed in these tests by the directions to compensate for rate of turning and changes in temperature while performing the tests.

A slight increase is noted as the curve continues to the right in the penetration curve. It is concave downward in general thruout its entire length. This shows that the penetration increased at an increasing rate per percentage of oil increase. The penetration of asphalt increases indefinitely as the percentage of oil is increased. The limit of the penetration machine was 250 hundredths centimeter and the 15 percent came very close to this limit. The erratic results were due to not stirring the sample thoroughly. It was found in one case that the several trials of the same sample varied by over 10 percent, which when heated over and stirred thoroughly and tested again gave results varying by only 1 percent or less.

The softening point curve is a straight line. The extreme values and several intermediate percentages were determined by test and it was found by interpolation that for each percent increase of oil the softening point decreased 1 degree centigrade. This is a natural conclusion after considering and comparing with the other test which were approximated straight lines also.

From the graphs it is evident that the addition of oil to a sample of asphalt decreases the flash point, fire point, ductility, and softening point and increases the adhesion and penetration.

Only samples from 0 to 15 percent were used as they were within the limits of the testing apparatus and furnished sufficient data with which to note the effects. It was also considered that no amount greater than this would ever be met with in practice.

Even the addition of as great a percentage as 15, which would never be met with in practice of asphalt pavements, the limits were within the specification of the Michigan State Highway for asphalt pavements. There is only about 10 percent of actual bitumen in an ordinary pavement and 15 percent of that figure would be an abnormal case.

The significance of this subject is of vital importance to the engineers today. The oil on the surface is kneaded into the mixture by the action of the wheels passing over it. This may not be a detriment as the asphalt needs a certain amount of this kneading action to keep it alive or pliable. The oil tends to make it softer and more pliable. Asphalt containing a small amount of oil would be beneficial on streets having little traffic to supply this action and near the curbs where cars are parked and do not furnish a path for the wheels.

Cracks or checks are found on asphalt pavements lacking in pliability and pits or depressions are formed by the action of heavy vehicles passing. The problem is confronting the municipalities having bus service, especially where they stop to take on or discharge passengers. The weight of the vehicle while standing still at these places depresses the asphalt.

As little or no data is found on tests of this nature, nothing could be obtained from books or periodicals relative to the method of procedure of the tests or the results that would be obtained. With more consideration and thought other experiments and tests could be devised which would bring out other effects of oil on asphalt. Long time deteriorating effects are another important consideration, but require a considerable longer period to perform than was allotted for these tests.

Conclusions.

1. The flash point of the asphalt was decreased with an addition of lubricating oil at a definite and uniform rate.
2. The fire point was decreased at a definite uniform rate also with the addition of the oil
3. The ductility of the asphalt was decreased at an approximately uniform rate.
4. The adhesion was increased at varying rates with an increase in percentage of oil, but no decided change was noted in all the tests.
5. The penetration was increased at an approximately uniform rate with an increase in percentage of oil.
6. The softening point was decreased at an exactly uniform rate of 1 degree centigrade per percent increase in oil.
7. The samples up to and including 15 percent were within the limits specified by the Michigan State Highway specifications for asphalt pavements.
8. The presence of oil on the surface of a pavement is not a serious objection if in small quantities, but in reality helps to keep the surface pliable and worked in.

0 Percent Sample

Flash Point 550 F

Fire Point 621 F

Softening Point 53.4 C

Ductility	Adhesion	Penetration
150	100	47
150	90	48
150	110	49
3/ 450	110	48
Ave. 150	100	4/ 192
	120	Ave. 49
	3/ 630	
	Ave. 105	

1 Percent Sample

Flash Point 545 F

Fire Point 615 F

Softening Point 52.6 C

Ductility	Adhesion	Penetration
150	110	59
150	100	60
150	110	56
3/ 450	100	58
Ave. 150	130	57
	130	5/ 290
	6/ 660	Ave. 58
	Ave. 110	

2 Percent Sample

Flash Point 540 F

Fire Point 615 F

Softening Point 51.6 C

Ductility	Adhesion	Penetration
150	110	62
150	110	63
150	120	61
3/ 450	115	62
Ave. 150	110	62
	5/ 565	5/ 310
	Ave. 115	62

3 Percent Sample

Flash Point 535 F

Fire Point 610 F

Softening Point 50.6 C

Ductility	Adhesion	Penetration
123	120	76
148	120	77
150	110	76
3/ 451	110	75
Ave. 144	130	76
	120	5/ 380
	6/ 710	Ave. 76
	Ave. 118	

4 Percent Sample

Flash Point	530 F
Fire Point	605 F
Softening Point	49.6 C

	Ductility	Adhesion	Penetration
	128	120	91
	134	140	92
	140	150	91
		150	87
		130	88
			81
	3/ 402	5/ 690	6/ 540
Ave.	134	138	90

5 Percent Sample

Flash Point	535 F
Fire Point	600 F
Softening Point	48.6 C

	Ductility	Adhesion	Penetration
	95	140	100
	110	160	104
	110	150	98
		160	100
		140	98
	3/ 315	5/ 750	5/ 500
Ave.	105	150	100

6 Percent Sample

Flash Point	525 F
Fire Point	600 F
Softening Point	47.6 C

	Ductility	Adhesion	Penetration
	123	170	112
	143	180	111
	140	165	109
		170	108
		170	109
	3/ 416	5/ 855	5/ 549
Ave.	139	171	110

7 Percent Sample

Flash Point	525 F
Fire Point	595 F
Softening Point	46.6 C

	Ductility	Adhesion	Penetration
	104	150	129
	114	200	125
	122	200	120
		210	120
		180	125
		190	120
			120
	3/ 340	6/ 1130	7/ 859
Ave.	113	188	123

8 Percent Sample

		Ductility	Adhesion	Penetration
Flash Point	520 F			
Fire Point	595 F	89	200	127
		102	180	129
Softening Point	45.6 C	120	210	129
		3/ 311	210	125
		Ave. 103	180	128
			5/ 980	5/ 638
			Ave. 196	Ave. 127

9 Percent Sample

		Ductility	Adhesion	Penetration
Flash Point	515 F			
Fire Point	590 F	94	190	138
		96	210	142
Softening Point	44.6 C	99	190	142
		3/ 288	200	141
		Ave. 96	200	144
			5/ 990	5/ 708
			Ave. 198	Ave. 142

10 Percent Sample

		Ductility	Adhesion	Penetration
Flash Point	510 F			
Fire Point	585 F	75	200	152
		92	200	158
Softening Point	43.6 C	110	170	155
		3/ 277	230	152
		Ave. 92	4/ 800	158
			Ave. 200	5/ 775
				Ave. 155

11 Percent Sample

		Ductility	Adhesion	Penetration
Flash Point	510 F			
Fire Point	585 F	83	190	175
		88	200	178
Softening Point	42.6 C	98	200	172
		3/ 269	210	176
		Ave. 89	210	174
			5/1010	5/ 875
			Ave. 202	Ave. 175

12 Percent Sample

Flash Point 505 F

Fire Point 580 F

Softening Pt. 41.6 C

Ductility	Adhesion	Penetration
82	200	195
87	210	196
90	200	195
3/ 259	206	195
Ave. 86	204	194
	5/ 10[illegible]0	5/ 975
	Ave. 206	Ave. 195

13 Percent Sample

Flash Point 500 F

Fire Point 575 F

Softening Pt. 40.6 C

Ductility	Adhesion	Penetration
74	220	209
78	180	209
76	200	209
3/ 228	200	210
Ave. 76	220	4/ 8[illegible]7
	5/ 1050	Ave. 209
	Ave. 205	

14 Percent Sample

Flash Point 495 F

Fire Point 575 F

Softening Pt. 39.6 C

Ductility	Adhesion	Penetration
62	220	243
72	210	238
78	210	236
3/ 212	220	238
Ave. 71	4/ 860	236
	Ave. 215	236
		6/ 1427
		Ave. 238

15 Percent Sample

Flash Point 495 F

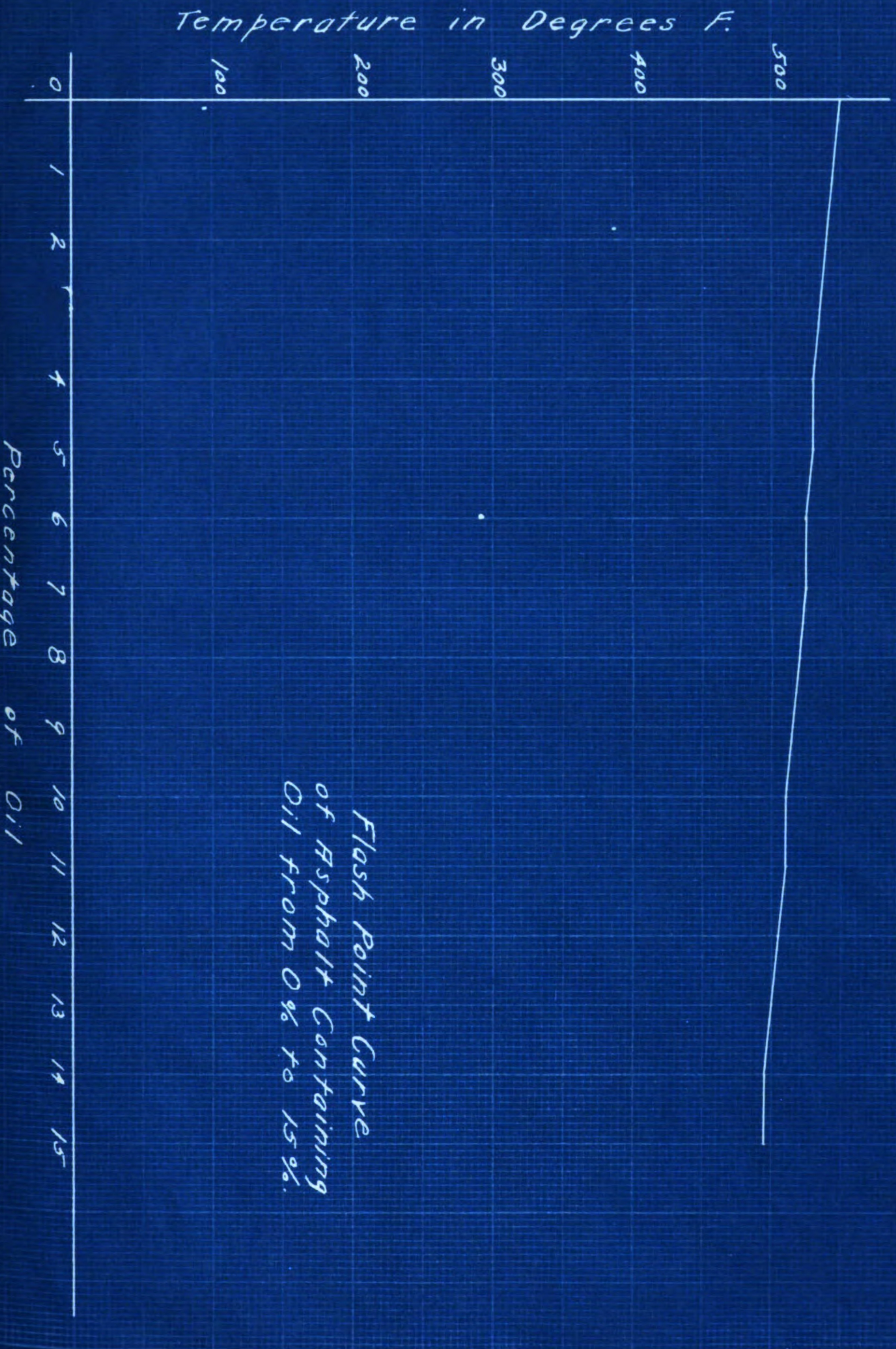
Fire Point 570 F

Softening Pt. 38.6 C

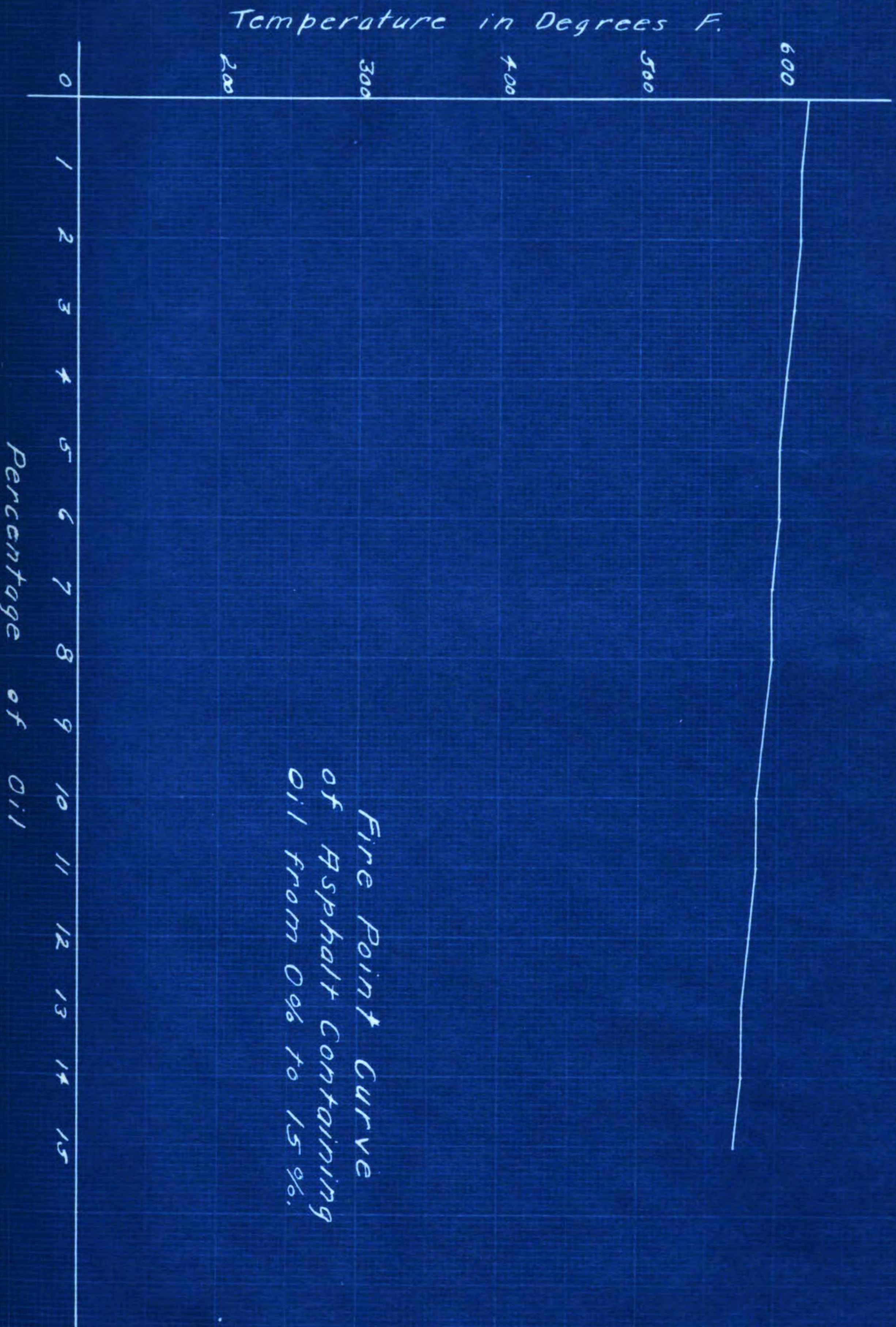
Ductility	Adhesion	Penetration
58	240	244
66	220	240
71	200	248
3/ 195	3/ 660	3/ 7[illegible]2
Ave. 65	Ave. 220	Ave. 244

Results of Tests.

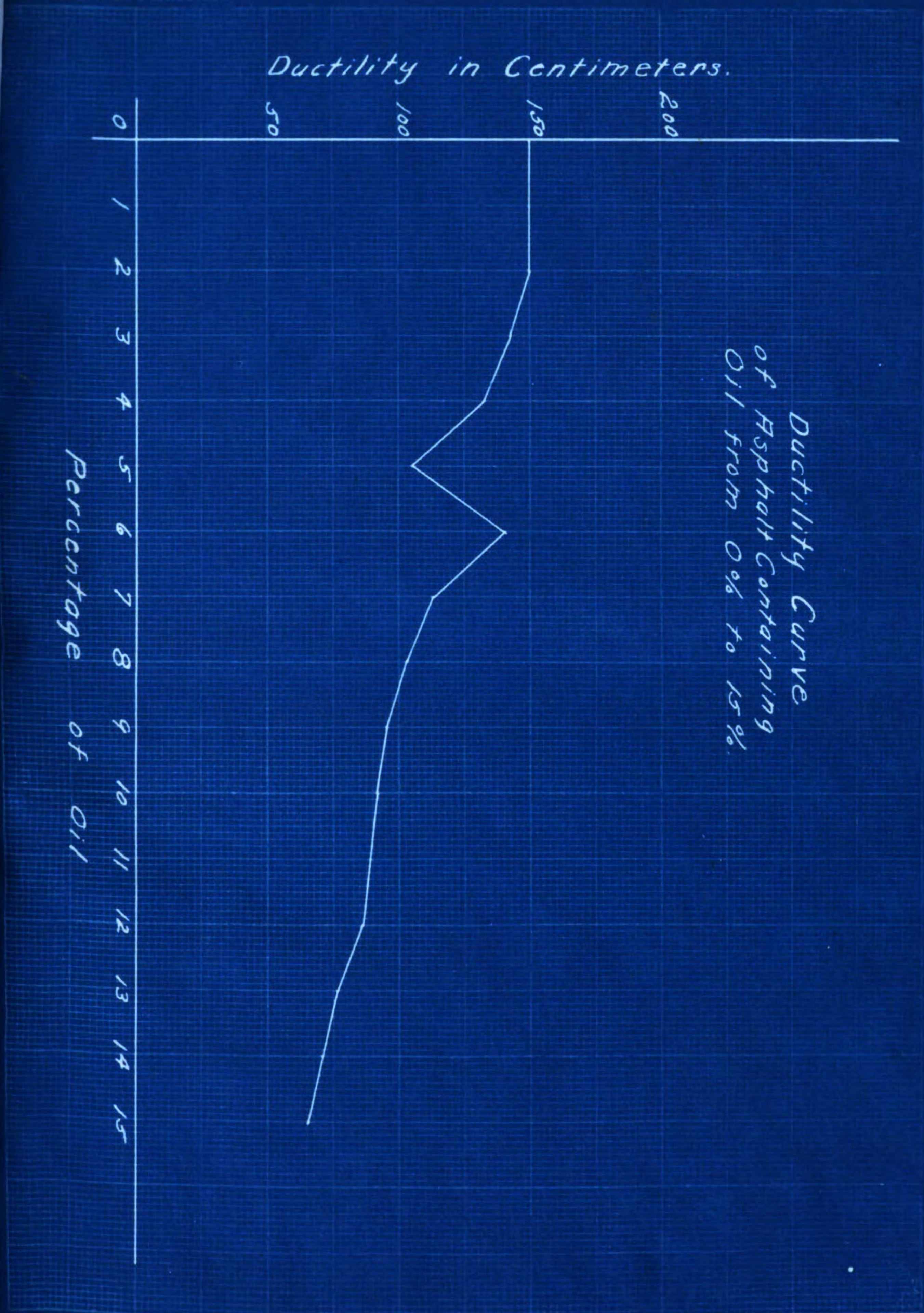
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	100
Flash Pt.	550	545	540	535	530	530	525	525	520	515	510	510	505	500	495	495	420
Fire Pt.	620	615	615	610	605	600	600	595	595	590	585	585	580	575	575	570	470
Ductility	150	150	150	144	134	105	139	113	103	96	92	89	86	76	71	65	
Adhesion	105	110	113	118	138	150	171	188	196	198	200	202	206	210	215	220	
Penetration	48	58	62	76	90	100	110	123	127	142	155	175	195	209	238	244	
Soften'g Pt.	53.4	52.6				48.6					43.6					38.6	

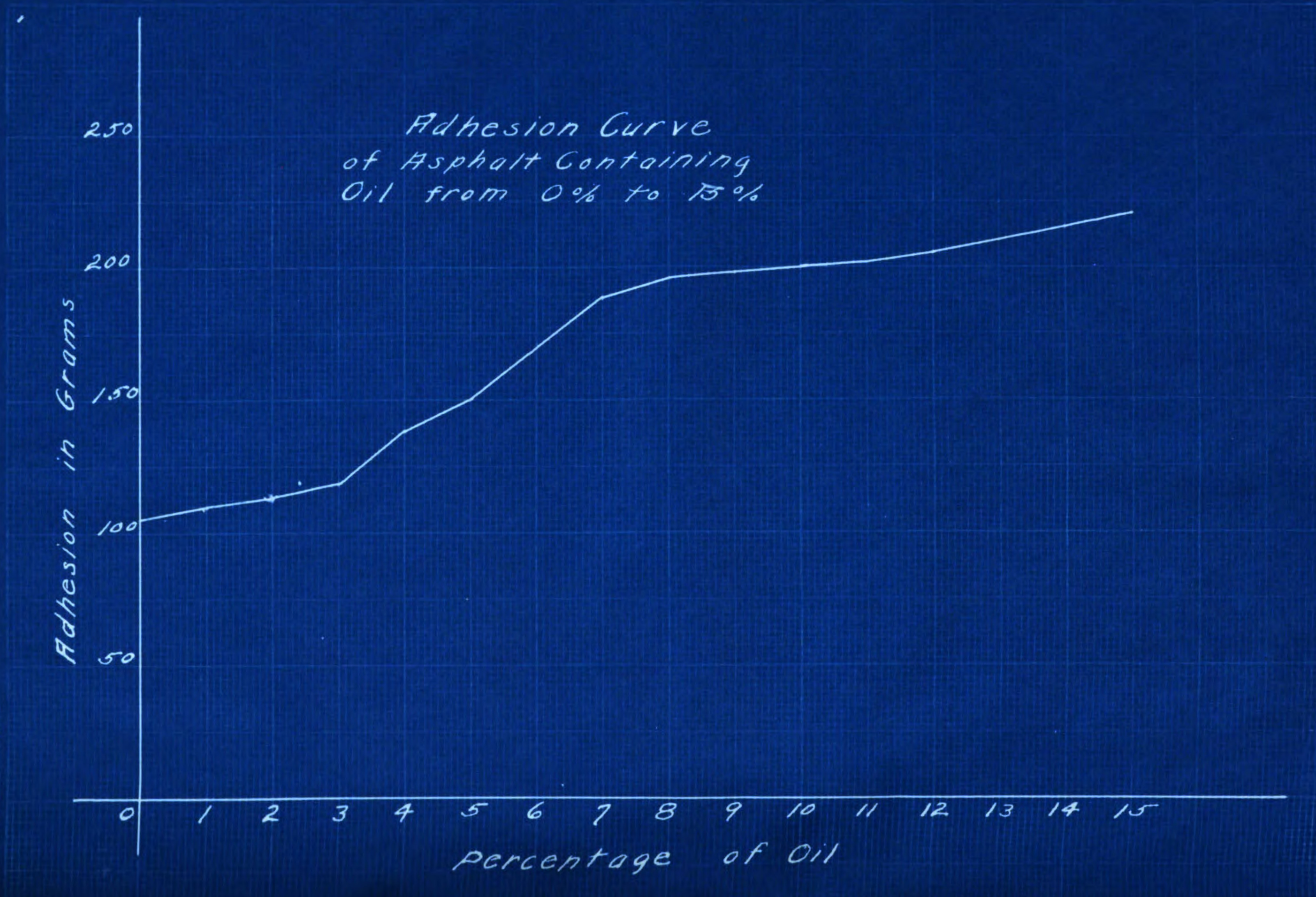


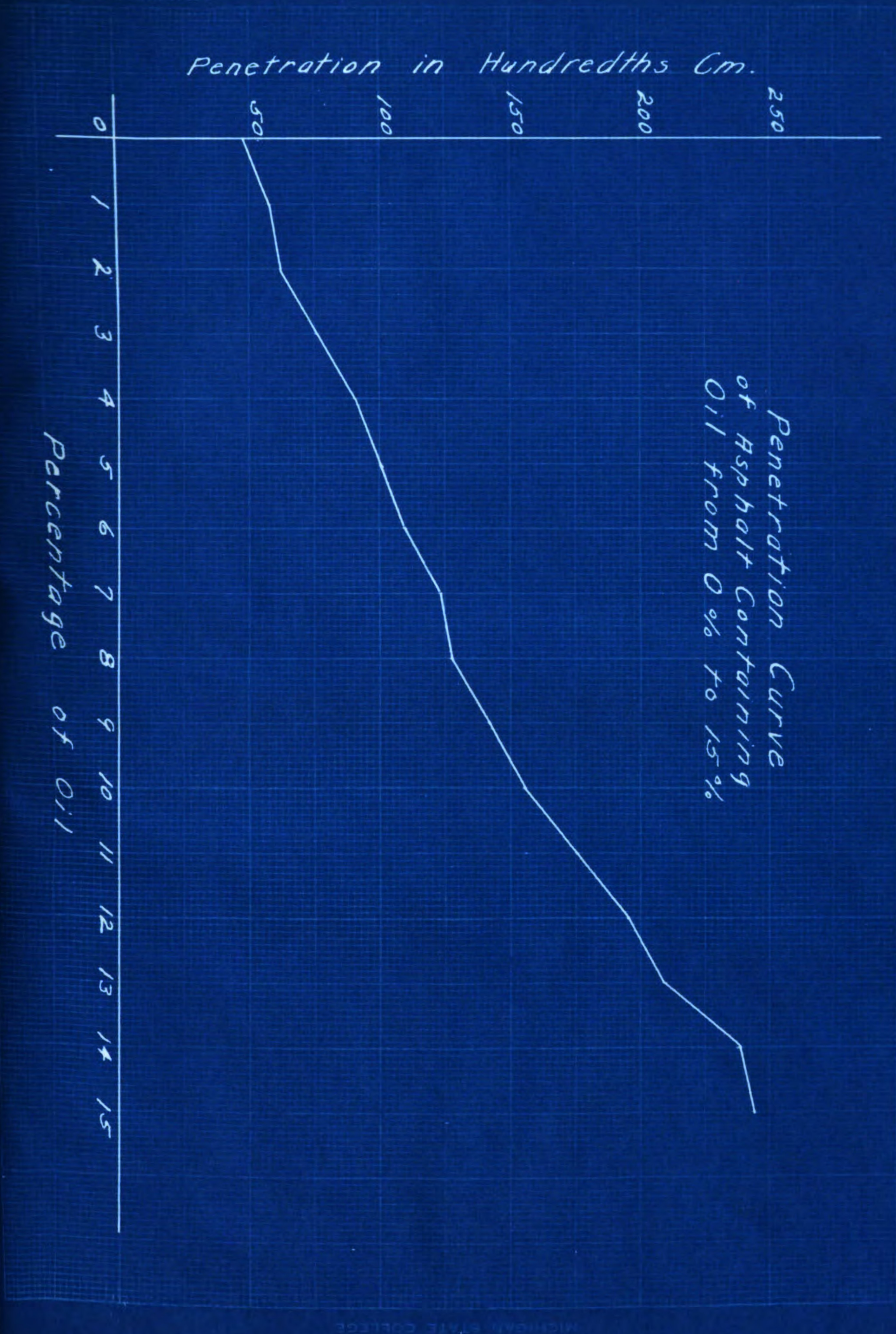
Temperature in Degrees F.
0
100
200
300
400
500
Percentage of Oil
1
2
4
5
6
7
8
9
10
11
12
13
14
15
Flash Point Curve of Asphalt Containing Oil from 0% to 15%.

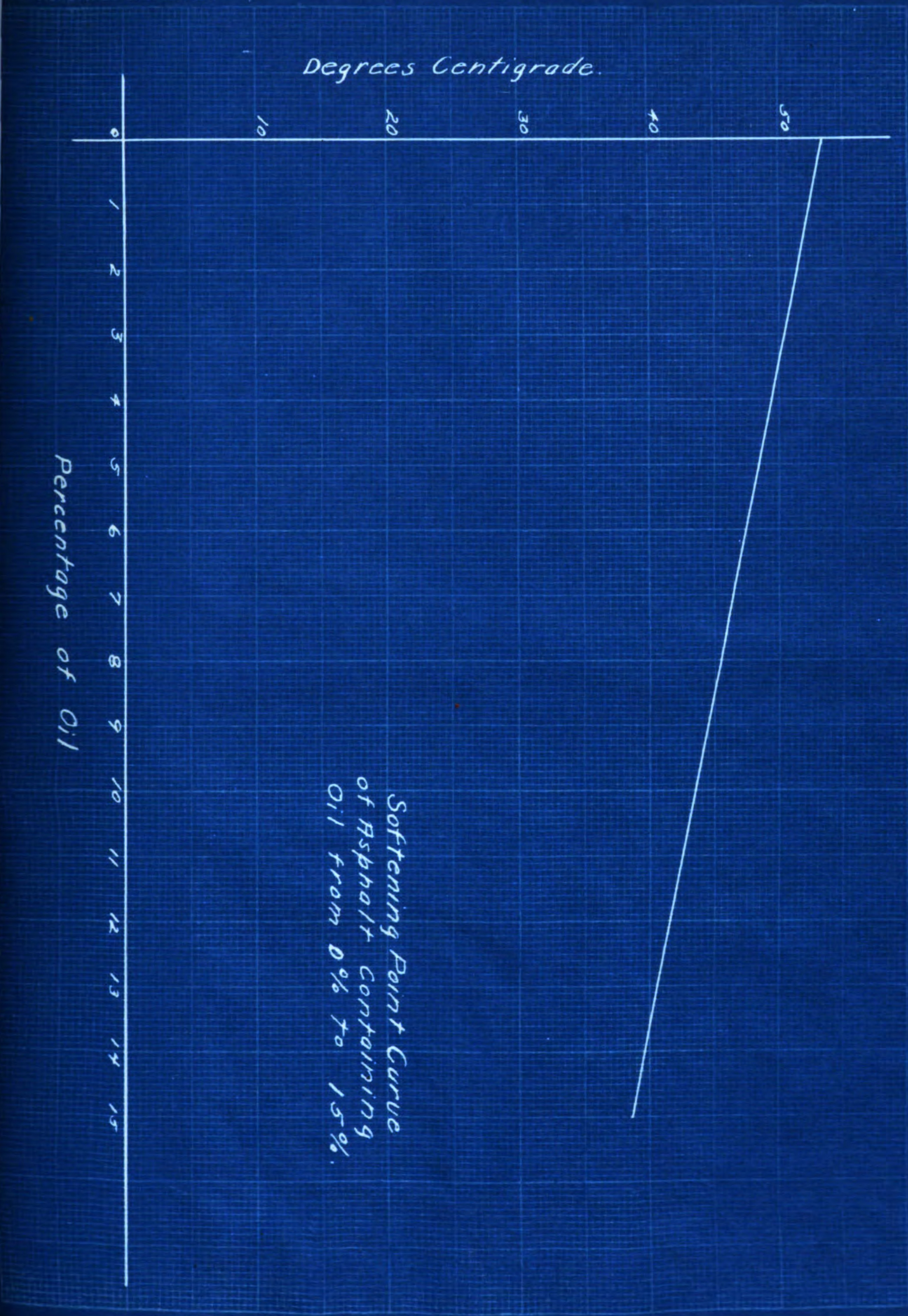


Temperature in Degrees F.
0
200
300
400
500
600
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Percentage of Oil
Fire Point Curve
of Asphalt Containing
Oil from 0% to 15%.


Ductility in Centimeters.
0
50
100
150
200
Ductility Curve
of Asphalt Containing
Oil from 0% to 15%.
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Percentage of Oil


Adhesion Curve
of Asphalt Containing
Oil from 0% to 15%
Adhesion in Grams
250
200
150
100
50
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Percentage of Oil


Penetration Curve
of Asphalt Containing
Oil from 0% to 15%
Penetration in Hundredths Cm.
0
50
100
150
200
250
Percentage of Oil
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15


Degrees Centigrade.
0
10
20
30
40
50
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Percentage of Oil
Softening Point Curve
of Asphalt Containing
Oil from 0% to 15%.