EFFECT OF DENSITY ON MARSHALL STABILITY OF HOT-MIX ASPHALTIC CONCRETE

BY JOHN ROLAND
PHYSICAL TESTS ENGINEER

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TESTING PERFORMED IN THE MATERIALS LABORATORY
OF THE
IOWA DEPARTMENT OF TRANSPORTATION

Effect of Density On Marshall Stability Of Hot-Mix Asphaltic Concrete

OBJECTIVE

The Iowa D.O.T. specifications do not require 100 percent of 50 blow Marshall density (generally 94%) for field compaction. However, stabilities are determined in the Laboratory on specimens compacted to 100 percent of Marshall density. The purpose of this study is to determine the stabilities of specimens compacted to various densities which are below 100 percent of the 50 blow Marshall density.

MATERIALS

Ten different asphaltic concrete mixes were tested in this investigation. Four of these were proportioned and mixed in the Laboratory from aggregate and asphalt cement currently in stock. The remaining six mixes were the retained excess materials from field samples. Each mix contained different aggregates and gradations, but all complied with our specified particle size distribution and asphalt content. Different sources and penetrations of asphalt cement were used but the only grade was AC-10

PROCEDURE

By varying the number of blows, five different compactive efforts were made on the specimens. After some exploratory work, it was found that 50, 32, 18, 12 and 7 blows to each side of the specimens would result in the range of densities that was

desired (93 to 100% of Marshall density). The 50 blows resulted, of course, in 100 percent of the Marshall densities, and the densities obtained by each of the lesser compactive efforts were computed as a percent of this figure.

Three specimens were required for each compactive effort resulting in 15 specimens from each mix or a total of 150 specimens molded and tested from the ten mixes. The specimens were all molded at 275°F. Standard Marshall compaction equipment and procedures were used, and also standard density and stability equipment and procedures were employed.

REPORT

The various stabilities that were obtained at the different densities were tabulated (Appendix A). Each is an average of three determinations. The densities were computed as a percentage of the 50 blow Marshall density. The stabilities were computed as a percentage of the stability obtained from the 50 blow Marshall specimens. These percentages of density were plotted against the percentages of stability in the graph.

Appendix B includes the work tickets showing the individual results of each specimen tested as well as the averages. It also includes the flow results of each specimen, the penetration of the asphalt cement used in each mix, and the proportions of aggregates and the asphalt cement contents of the mixes made in the Laboratory. It does not include an aggregate gradation of the individual mixes, but this can readily be obtained by

referring to the test report identified by the Laboratory number.

Appendix C is composed of copies of the actual print-out from the stability apparatus, showing graphically the changes in stabilities and flows corresponding to the changes in densities. The mix numbers and the number of blows for each compactive effort are shown at the top of each sheet.

CONCLUSIONS

The conclusion that can be drawn, and which is readily apparent, from this investigation is that the stability of a hot mix decreases dramatically with a slight decrease in the density. When a density was obtained which was 94 percent of the 50 blow Marshall density (the minimum generally specified in D.O.T. specifications) then the stabilities of all ten mixes tested were below 43 percent of the Marshall stability obtained on specimens compacted to 50 blow Marshall density. Excluding one mix, this percentage drops to less than 35 percent.

The graph of the stabilities versus densities shows the following:

Percent Marshall Density	Percent Marshall Stability
99	all ten mixes < 90
98	" " " < 75
97	" " " < 61
96	" " " < 56, 9 mixes < 51
95	" " " < 50, " " < 42
94	" " " < 43, " " < 35

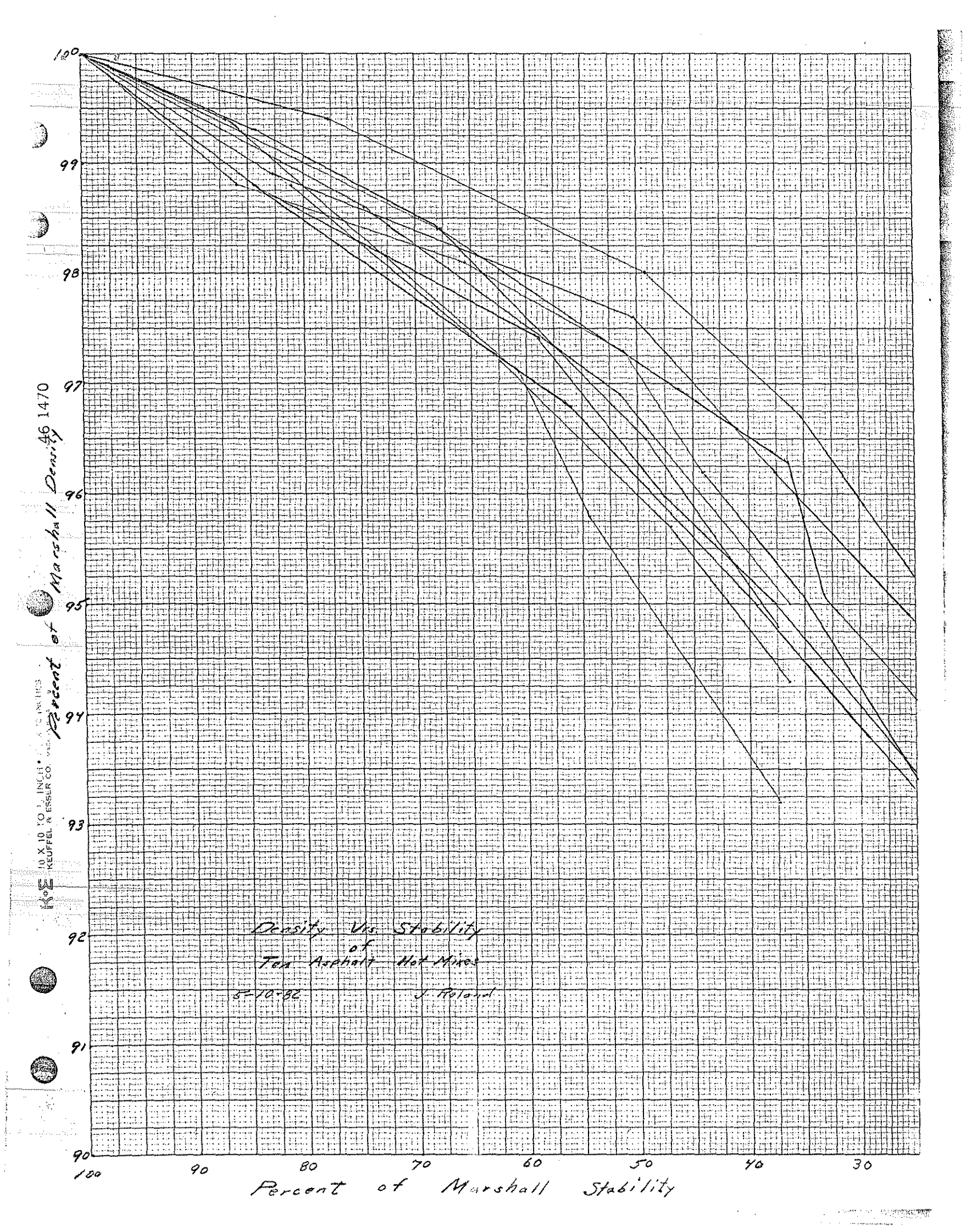
The same graph shows that to obtain 75 percent of 50 blow Marshall stability a density greater than 98 percent was required for all ten mixes. To obtain 50 percent of 50 blow Marshall stability then a density equal to or greater than 96 percent was required for nine of the ten mixes tested.

The mixes tested had a range of 1282 to 3048 pound 50 blow Marshall stabilities, so they were all within the normal testing range of mixes used in construction.

It was also surprising that only seven blows to each side of the specimens resulted in a density average of 94.5 percent of the 50 blow densities for the ten mixes.

Stability testing is normally performed on specimens compacted to 100 percent of Marshall densities and not at the lesser densities obtained by field compaction. When a field mix is compacted to the minimum of 94 percent of Marshall density, most of the stability that was designed into the mix has been lost.

If the stability of a hot mix is important in the functioning of the finished roadway, then it adds emphasis to the necessity of keeping the densities as high as possible.


100
99
98
97
96
95
94
93
92
91
90
Percent of Marshall II Density
46 1470
10 X 10 TO 1 INCH
KEUFFEL & ESSER CO.
180
90
80
70
60
50
40
30
Percent of Marshall Stability
Density Vrs. Stability
of
Tex Asphalt Hot Mixes
5-10-62
J. Roland

EFFECT OF DENSITY ON MARSHALL STABILITY

MIX	DENSITY	% OF LAB	STAB.	% OF LAB	BLOWS
ABD1-97	2.291	100	1,617	100	50
"	2.266	98.9	1,338	82.7	32
"	2.236	97.6	813	50.3	18
"	2.204	96.2	608	37.6	12
"	2.175	94.9	413	25.5	7
ABD1-168	2.425	100	2,073	100	50
"	2.385	98.4	1,410	68.0	32
"	2.335	96.3	757	36.5	18
"	2.305	95.1	688	33.2	12
"	2.277	93.9	450	21.7	7
ABC1-444	2.384	100	2,033	100	50
"	2.368	99.3	1,712	84.2	32
"	2.346	98.4	1,375	67.6	18
"	2.301	96.5	1,003	49.3	12
"	2.260	94.8	760	37.4	7
ABD1-152	2.336	100	1,775	100	50
"	2.307	98.8	1,500	84.5	32
"	2.276	97.4	1,042	58.7	18
"	2.242	96.0	848	47.8	12
"	2.219	95.0	667	37.6	7
ABD1-145	2.337	100	2,493	100	50
"	2.305	98.6	1,860	74.6	32
"	2.265	96.9	1,283	51.5	18
"	2.223	95.1	878	35.2	12
"	2.187	93.6	647	26.0	7

EFFECT OF DENSITY ON MARSHALL STABILITY

MIX	DENSITY	% OF LAB	STAB.	% OF LAB	BLOWS
ABCI-403	2.383	100	2783	100	50
"	2.368	994	2422	87.0	32
"	2.315	97.1	1,690	60.7	18
"	2.282	95.8	1,515	54.4	12
"	2.221	93.2	1,042	37.4	7
442	2.319	100	1,282	100	50
"	2.292	98.8	1,103	86.0	32
"	2.276	98.1	840	65.5	18
"	2.258	97.3	657	51.2	12
"	2.231	96.2	565	44.1	7
447	2.390	100	3,048	100	50
"	2.362	98.8	2,473	81.1	32
"	2.323	97.2	1,903	62.4	18
"	2.287	95.7	1,432	47.0	12
"	2.254	94.3	1,110	36.4	7
448	2.302	100	2,575	100	50
"	2.274	98.8	2,172	84.3	32
"	2.228	96.8	1,442	56.0	18
"	2.187	95.0	1,013	39.3	12
"	2.160	93.8	753	29.2	7
449	2.287	100	1,530	100	50
"	2.274	99.4	1,187	77.6	32
"	2.242	98.0	754	49.3	18
"	2.212	96.7	540	35.3	12
"	2.193	95.9	453	29.6	7

APPENDIX B

BITUMINOUS WORK SHEET

Project No. Dept. Info. Lab. Nos. ABCI-403
Project No.
Project No.
County Worth (F.9-6(24)) (ABDI-145)

Effect of density on Marshall Stability

Aggregates

% Aggregate	Agg. Lab. No.	Indivi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight

Batch Wt Agg.			
Pen. Asphalt	AC-10 Pen. 108		
Lab No. Asph.			
% Asphalt			
Batch Wt Asph			
Date Tested	2-22-82		

Specific Gravity Determination

	50 Blow			32 Blow			18 Blow		
Wt. in Air	1212.5	1212.0	1214.0	1187.5	1188.0	1190.0	1163.0	1164.5	1161.0
Wet Weight	1212.5	1212.0	1214.0	1187.5	1188.5	1190.5	1163.0	1165.5	1161.5
Wt. in Water	703.5	703.0	705.5	686.5	687.5	687.0	661.0	662.5	659.5
Difference	509.0	509.0	508.5	501.0	501.0	503.5	502.0	503.0	502.0
Sp. Gravity	2.382	2.381	2.387	2.370	2.371	2.363	2.317	2.315	2.313
Average		2.383			2.368			2.315	
		100 %			99.4 %			97.1 %	

Marshall Stability

Load - Lbs.	2725	2925	2705	2425	2440	2400	1675	1675	1720
Flow 0.01 In.	10	11	11	10	10	10	10	12	12
Average Load	2783		11	2422		10	1690		11
	100 %			87.0 %			60.7 %		

	S.S.D.	Bulk S.S.D.
Sp. Gravity		
Absorption		

Absolute	H.R.B.

Wt. A.C. Start			
Wt. A.C. Reqd.			
Wt. A.C. Left			

BITUMINOUS WORK SHEET

Project No. Dept. Info. Lab. Nos. ABCI-403
Project No.
Project No.
County (Worth - FR-9-6(24)) (ABDI-45)

Effect of density on Marshall Stability

Aggregates

% Aggregate	Agg. Lab. No.	Indivi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight

Batch Wt Agg.			
Pen. Asphalt	AC-10 Pen. 108		
Lab No. Asph.			
% Asphalt			
Batch Wt Asph			
Date Tested	2-22		

12 Blow 7 Blow

Specific Gravity Determination

Wt. in Air	1145.5	1145.5	1141.5	1122.5	1121.0	1121.0		
Wet Weight	1146.0	1146.5	1142.5	1124.5	1123.5	1123.0		
Wt. in Water	643.5	646.0	641.0	618.5	618.5	619.5		
Difference	502.5	500.5	501.5	506.0	505.0	503.5		
Sp. Gravity	2.280	2.289	2.276	2.218	2.220	2.226		
Average		2.282			2.221			
		95.8 %			93.2 %			

Marshall Stability

Load - Lbs.	1475	1570	1500	1080	1025	1100		
Flow 0.01 In.	13	13	13	15	16	16		
Average Load	1515		13	1042		16		
	54.4 %			37.4 %				

25 Blow

	S.S.D.	Bulk S.S.D.
Sp. Gravity		
Absorption		

Absolute	H.R.B.

Wt. A.C. Start			
Wt. A.C. Reqd.			
Wt. A.C. Left			

BITUMINOUS WORK SHEET

Project No. Dept. Info. Lab. Nos. ABCL-442
Project No.
Project No.
County (Polk BGP-000B(6)-74-77) (ABDI-108)

Effect of density on Marshall Stability

Aggregates

% Aggregate	Agg. Lab. No.	Indivi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight

Batch Wt Agg.			
Pen. Asphalt	AC-10	Pen 94	
Lab No. Asph.			
% Asphalt			
Batch Wt Asph			
Date Tested	2-23		

50 BLOW 32 BLOW 18 Blow

Specific Gravity Determination

Wt. in Air	1164.5	1164.5	1165.0	1153.0	1151.5	1153.5	1127.5	1132.0	1138.0
Wet Weight	1164.5	1164.5	1165.0	1153.0	1151.5	1153.5	1127.5	1138.5	1138.0
Wt. in Water	662.5	661.5	663.0	650.0	649.0	[illegible]	630.0	63[illegible]	637.0
Difference	503.0	503.0	502.0	503.0	502.5	503.0	497.5	479.0	492.0
Sp. Gravity	2.320	2.315	2.321	2.292	2.292	2.293	2.266	2.281	2.281
Average		2.319			2.292			2.276	

100 % 98.8 % 98.1 %

Marshall Stability

Load - Lbs.	1345	1240	1260	1100	1060	1150	850	800	830
Flow 0.01 In.	8	8	7	7	8	8	10	9	9
Average Load	1282		8	1103		8	840		

100 % 86.0 % 65.5 % 75 Blow

	S.S.D.	Bulk S.S.D.
Sp. Gravity		
Absorption		

Absolute	H.R.B.

Wt. A.C. Start			
Wt. A.C. Reqd.			
Wt. A.C. Left			

BITUMINOUS WORK SHEET

Project No. Dept. Info. Lab. Nos. ABCI- 442
Project No.
Project No.
County (Polk BGP-000B(6)-74-77) (ABDI- 118)

Effect of density on Marshall Stability

Aggregates

% Aggregate	Agg. Lab. No.	Indivi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight

Batch Wt Agg.	[illegible]		
Pen. Asphalt	AC-10 Pen 94		
Lab No. Asph.			
% Asphalt			
Batch Wt Asph			
Date Tested	2-23		

12 Blow 7 Blow

Specific Gravity Determination

Wt. in Air	1121.5	1123.5	1122.0	1111.0	1109.0	1108.5		
Wet Weight	1122.0	1124.0	1122.5	1112.0	1110.0	1109.0		
Wt. in Water	625.0	627.0	625.0	615.0	612.5	612.0		
Difference	497.0	497.0	497.5	497.0	497.5	497.0		
Sp. Gravity	2.257	2.261	2.255	2.235	2.229	2.230		
Average		2.258			2.231			
		97.3 %			96.2 %			

Marshall Stability

Load - Lbs.	650	650	670	580	590	525		
Flow 0.01 In.	9	10	9	10	12	13		
Average Load	1057		9	565				
	51.2 %			44.1 %				

75-Blow

	S.S.D.	Bulk S.S.D.
Sp. Gravity		
Absorption		

Absolute	H.R.B.

Wt. A.C. Start			
Wt. A.C. Reqd.			
Wt. A.C. Left			

BITUMINOUS WORK SHEET

Project No. Dept. Info. Lab. Nos. ABCI-447
Project No.
Project No.
County (Polk FR-65-4(29)-26-77) (ABD1-42)

Effect of density on Marshall Stability

Aggregates

% Aggregate	Agg. Lab. No.	Indivi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight

Batch Wt Agg.			
Pen. Asphalt	Kook AC-10 Pen 120		
Lab No. Asph.			
% Asphalt			
Batch Wt Asph			
Date Tested	2-24		

50 Blows 32 Blows 18 Blows

Specific Gravity Determination

Wt. in Air	1209.0	1209.0	1206.0	1192.0	1192.5	1193.5	1180.5	1176.5	1179.0
Wet Weight	1209.5	1209.0	1206.5	1192.0	1193.0	1193.5	1181.0	1176.5	1179.5
Wt. in Water	704.0	703.0	702.0	687.5	687.5	688.5	673.5	670.0	671.5
Difference	505.5	506.0	504.5	504.5	505.5	505.0	507.5	506.5	508.0
Sp. Gravity	2.392	2.389	2.390	2.363	2.359	2.363	2.326	2.323	2.321
Average		2.390			2.362			2.323	

100 % 98.8 % 97.2 %

Marshall Stability

Load - Lbs.	3120	3075	2950	2510	2480	2430	2000	1800	1910
Flow 0.01 In.	10	11	10	10	10	10	12	11	13
Average Load	3048		10	2473		10	1903		12

100% 81.1 % 62.4%

	S.S.D.	Bulk S.S.D.
Sp. Gravity		
Absorption		

Absolute	H.R.B.

Wt. A.C. Start			
Wt. A.C. Reqd.			
Wt. A.C. Left			

BITUMINOUS WORK SHEET

Project No. Dept. Info. Lab. Nos. ABC1-447
Project No.
Project No.
County Polk FR-65-4(29)-26-77 (ABD1-42)

Effect of density on Marshall Stability

Aggregates

% Aggregate	Agg. Lab. No.	Indivi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight

Batch Wt Agg.			
Pen. Asphalt	Kook AC-10 Pen 120		
Lab No. Asph.			
% Asphalt			
Batch Wt Asph			
Date Tested	2-24		

12 Blows 7 Blows

Specific Gravity Determination

Wt. in Air	1162.5	1164.5	1163.0	1148.0	1148.5	1145.0		
Wet Weight	1164.0	1165.5	1164.5	1150.5	1151.0	1147.0		
Wt. in Water	656.5	655.5	656.0	641.0	643.0	637.5		
Difference	507.5	510.0	508.5	509.5	508.0	509.5		
Sp. Gravity	2.291	2.283	2.287	2.253	2.261	2.247		
Average		2.287			2.254			

95.7% 94.3%

Marshall Stability

Load - Lbs.	1450	1370	1475	1080	1200	1050		
Flow 0.01 In.	13	14	15	15	16	15		
Average Load	1432		14	1110		15		

47.0% 36.4%

	S.S.D.	Bulk S.S.D.
Sp. Gravity		
Absorption		

Absolute	H.R.B.

Wt. A.C. Start			
Wt. A.C. Reqd.			
Wt. A.C. Left			

BITUMINOUS WORK SHEET

Project No. Dept. Info. Lab. Nos. (ABC1-448)
Project No.
Project No.
County (Adair - SN-6085(9)--51-09) (ABD1-169)

Effect of density on Marshall Stability

Aggregates

% Aggregate	Agg. Lab. No.	Indivi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight

Batch Wt Agg.			
Pen. Asphalt	AC-10 108 Pen.		
Lab No. Asph.			
% Asphalt			
Batch Wt Asph			
Date Tested	2-26		

50 Blows 32 Blows 18 Blows

Specific Gravity Determination

Wt. in Air	1167.0	1167.0	1167.5	1152.5	1154.0	1153.0	1138.0	1137.5	1138.0
Wet Weight	1167.5	1167.0	1167.5	1152.5	1154.0	1153.0	1138.0	1138.0	1138.0
Wt. in Water	661.0	660.0	660.0	646.0	646.5	646.0	626.5	627.5	628.0
Difference	506.5	507.0	507.5	506.5	507.5	507.0	511.5	510.5	510.0
Sp. Gravity	2.304	2.302	2.300	2.275	2.274	2.274	2.225	2.228	2.232
Average		2.302			2.274			2.228	

100 % 98.8 96.8

Marshall Stability

Load - Lbs.	2550	2550	2625	2300	2100	2115	1450	1375	1500
Flow 0.01 In.	10	11	12	11	11	11	12	11	11
Average Load	2575		11	2172		11	1442		11

100 % 84.3 % 56.00 %

	S.S.D.	Bulk S.S.D.
Sp. Gravity		
Absorption		

Absolute	H.R.B.

Wt. A.C. Start			
Wt. A.C. Reqd.			
Wt. A.C. Left			

BITUMINOUS WORK SHEET

Project No. Dept. Info. Lab. Nos. (ABCL-448)
Project No.
Project No.
County (Adair - SN-6085(9)--51-09) (ABDI-169)

Effect of density on Marshall Stability

Aggregates

% Aggregate	Agg. Lab. No.	Indivi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight

Batch Wt Agg.			
Pen. Asphalt	AC-10 108 Pen.		
Lab No. Asph.			
% Asphalt			
Batch Wt Asph			
Date Tested	2-26		

12 Blows 7 Blows

Specific Gravity Determination

Wt. in Air	1119.0	1118.0	1117.0	1107.0	1107.5	1106.0		
Wet Weight	1119.5	1118.5	1117.0	1107.5	1109.0	1107.5		
Wt. in Water	607.0	610.5	604.0	595.0	596.0	595.5		
Difference	512.5	508.0	513.0	512.5	513.0	512.0		
Sp. Gravity	2.183	2.201	2.177	2.160	2.159	2.160		
Average		2.187			2.160			

95.0 % 93.8

Marshall Stability

Load - Lbs.	990	1090	960	760	760	740		
Flow 0.01 In.	11	12	12	13	13	13		
Average Load	1013		12	753		13		

39.3% 29.2%

75 Blow

	S.S.D.	Bulk S.S.D.
Sp. Gravity		
Absorption		

Absolute	H.R.B.

Wt. A.C. Start			
Wt. A.C. Reqd.			
Wt. A.C. Left			

BITUMINOUS WORK SHEET

Project No. Dept. Info. Lab. Nos. ABC1-449
Project No.
Project No.
County (Hardin HES-20-5(23)--2H-42) (ABD1-144)

Effect of density on Marshall Stability

Aggregates

% Aggregate	Agg. Lab. No.	Indivi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight

Batch Wt Agg.			
Pen. Asphalt	9C-10 109 Pen.		
Lab No. Asph.			
% Asphalt			
Batch Wt Asph			
Date Tested	3-2		

50 Blows 32 18

Specific Gravity Determination

Wt. in Air	1171.0	1172.5	1171.0	1158.0	1158.0	1160.0	1144.0	1142.0	1144.5
Wet Weight	1171.0	1172.5	1171.0	1158.0	1158.0	1160.0	1144.0	1142.0	1144.5
Wt. in Water	659.5	659.5	659.0	649.0	648.0	650.0	633.5	631.0	635.5
Difference	511.5	513.0	512.0	509.0	510.0	510.0	510.5	511.0	509.0
Sp. Gravity	2.289	2.286	2.287	2.275	2.271	2.275	2.241	2.235	2.249
Average		2.287			2.274			2.242	

100 % 99.4 % 98.0 %

Marshall Stability 77.6% ← STABILITY → 49.3%

Load - Lbs.	1500	1560	1530	1270	1130	1160	780	720	760
Flow 0.01 In.	8	9	8	7	9	8	9	10	9
Average Load	1530		8	1187		8	754		

100 % 77.6 % 49.3%

	S.S.D.	Bulk S.S.D.
Sp. Gravity		
Absorption		

Absolute	H.R.B.

Wt. A.C. Start			
Wt. A.C. Reqd.			
Wt. A.C. Left			

BITUMINOUS WORK SHEET

Project No. Dept. Info. Lab. Nos. ABC1-449
Project No.
Project No.
County (Hardin HES-20-5(23)--2H.42) (ABD1-144)

Effect of density on Marshall Stability

Aggregates

% Aggregate	Agg. Lab. No.	Indi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight

Batch Wt Agg.			
Pen. Asphalt	AC-10	108 Pen.	
Lab No. Asph.			
% Asphalt			
Batch Wt Asph			
Date Tested	3-2		

12 Blows 7 Blows

Specific Gravity Determination

Wt. in Air	1127.0	1129.0	1128.0	1111.0	1111.0	1111.5		
Wet Weight	1127.5	1129.5	1128.0	1111.0	1111.5	1112.0		
Wt. in Water	619.0	618.5	617.5	606.0	604.5	604.0		
Difference	508.5	511.0	510.5	505.0	507.0	508.0		
Sp. Gravity	2.216	2.209	2.210	2.200	2.191	2.188		
Average		2.212			2.193			

96.7 % 95.9 %

35.3 % ← STABILITY → 29.6 %

Marshall Stability

Load - Lbs.	550	530	540	450	450	460		
Flow 0.01 In.	10	12	10	11	13	13		
Average Load	540		11	453		12		

35.3 % 29.6 %

	S.S.D.	Bulk S.S.D.
Sp. Gravity		
Absorption		

Absolute	H.R.B.

Wt. A.C. Start			
Wt. A.C. Reqd.			
Wt. A.C. Left			

BITUMINOUS WORK SHEET

Project No. Dept. Info. Lab. Nos. (ABD1-97)
Project No.
Project No.
County

Effect of density on Marshall Stability

Aggregates

% Aggregate	Agg. Lab. No.	Indivi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight
50	ABT1-322	#4 (58) 3480	3480	
		-4 (42) 2520	6000	
50	ABT1-323	6000	12,000	

Batch Wt Agg.	12000		
Pen. Asphalt	Pen. 82		
Lab No. Asph.	ABS-290		
% Asphalt	6.0		
Batch Wt Asph	766		
Date Tested	3-11		
	50 Blows	32	18

Specific Gravity Determination

Wt. in Air	1175.0	1176.5	1176.0	1162.5	1159.5	1162.5	1147.0	1146.5	1145.0
Wet Weight	1175.0	1177.0	1176.5	1162.0	1159.5	1162.5	1147.5	1146.5	1145.5
Wt. in Water	662.5	663.0	663.0	649.0	647.5	650.0	635.0	632.5	634.5
Difference	512.5	514.0	513.5	513.0	512.0	512.5	512.5	514.0	511.0
Sp. Gravity	2.293	2.289	2.290	2.265	2.265	2.268	2.238	2.231	2.240
Average		2.291			2.266			2.236	
		100.%			98.9 %			97.6 %	

Marshall Stability

Load - Lbs.	1650	1600	1600	1300	1425	1290	810	740	890
Flow 0.01 In.	8	8	8	8	9	8	8	8	9
Average Load	1617		8	1338		8	813		8
	100 %			82.7%			50.3%		

	S.S.D.	Bulk S.S.D.
Sp. Gravity		
Absorption		

Absolute	H.R.B.

Wt. A.C. Start	1166	1166	
Wt. A.C. Reqd.	766	766	
Wt. A.C. Left	400	400	

BITUMINOUS WORK SHEET

Project No. Dept. Info. Lab. Nos. (8801-97)
Project No.
Project No.
County

Effect of density on Marshall Stability

Aggregates

% Aggregate	Agg. Lab. No.	Indivi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight
50	RAT-322	24 (58) 3480	3480	
		-4 (4½) 2520	6000	
50	RAT-323	6000	12,000	

Batch Wt Agg.	12000		
Pen. Asphalt	Pen. 82		
Lab No. Asph.	P89-290		
% Asphalt	6.0		
Batch Wt Asph	766		
Date Tested	3-11		

12 Blows 7 Blows

Specific Gravity Determination

Wt. in Air	1129.5	1132.5	1133.5	1117.4	1117.5	1117.0		
Wet Weight	1130.0	1133.5	1134.5	1118.5	1119.0	1119.6		
Wt. in Water	617.5	618.5	621.5	605.0	605.0	606.0		
Difference	512.5	515.0	513	513.5	514.0	513.0		
Sp. Gravity	2.204	2.199	2.210	2.175	2.174	2.177		
Average		2.204			2.175			
		96.2%			94.9%			

Marshall Stability

Load - Lbs.	600	600	625	350	420	470		
Flow 0.01 In.	9	10	10	11	11	12		
Average Load	608		10	413		11		
	37.6%			25.5%				

75 Blow

	S.S.D.	Bulk S.S.D.
Sp. Gravity		
Absorption		

Absolute	H.R.B.

Wt. A.C. Start			
Wt. A.C. Reqd.			
Wt. A.C. Left			

BITUMINOUS WORK SHEET

Project No. Dept. Info. Lab. Nos. (ABD1-168)
Project No.
Project No.
County

Effect of density on Marshall Stability

Aggregates

% Aggregate	Agg. Lab. No.	Indivi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight
70	AATI- 656	+4(63) 5292	5292	
		-4(37) 3108	8400	
30	AATI- 655	3600	12,000	

Batch Wt Agg.	12,000		
Pen. Asphalt	AC-10	Pen 82	
Lab No. Asph.	1159-2.90		
% Asphalt	5.0		
Batch Wt Asph	632		
Date Tested	3-15		

50 Blows 32 18

Specific Gravity Determination

Wt. in Air	1211.0	1212.5	1210.0	1197.0	1198.0	1195.5	1187.5	1187.0	1188.0
Wet Weight	1211.5	1212.5	1210.5	1197.5	1198.5	1196.0	1190.5	1189.0	1189.5
Wt. in Water	712.0	712.5	711.5	695.0	696.0	695.5	691.5	679.5	692.0
Difference	499.5	500.0	499.0	502.5	502.5	500.5	509.0	509.5	507.5
Sp. Gravity	2.424	2.425	2.425	2.382	2.384	2.389	2.333	2.330	2.341
Average		2.425			2.385			2.335	
		100 %			98.4 %			96.3 %	

Marshall Stability

Load - Lbs.	2350	1980	1890	1730	1500	1400	725	735	810
Flow 0.01 In.	8	8	8	8	8	9	9	10	10
Average Load	2073		8	1410		8	757		10
	100 %			68.0 %			36.5 %		

75 Blow

	S.S.D.	Bulk S.S.D.
Sp. Gravity		
Absorption		

Absolute	H.R.B.

Wt. A.C. Start	1332	1232	
Wt. A.C. Reqd.	632	632	
Wt. A.C. Left	700	600	

BITUMINOUS WORK SHEET

Project No. Dept. Info. Lab. Nos. (ABDI-168)
Project No.
Project No.
County

Effect of density on Marshall Stability

Aggregates

% Aggregate	Agg. Lab. No.	Indivi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight
70	ABT-656	+4 (63) 5292	5292	
		-4 (37) 3108	8400	
30	ABT-655	3600	12,000	

Batch Wt Agg.	12,000		
Pen. Asphalt	AC-10	Pen 82	
Lab No. Asph.	ABJ-290		
% Asphalt	5.0		
Batch Wt Asph	632		
Date Tested	3-15		

12 Blows 7 Blows

Specific Gravity Determination

Wt. in Air	1178.5	1178.0	1176.5	1169.0	1168.5	1168.0			
Wet Weight	1181.5	1181.5	1179.5	1172.5	1171.5	1172.5			
Wt. in Water	670.5	670.5	669.0	660.0	658.5	658.5			
Difference	511.0	511.0	510.5	512.5	513.0	514.0			
Sp. Gravity	2.306	2.305	2.305	2.281	2.278	2.272			
Average		2.305			2.277				
		95.1%			93.9%				

Marshall Stability

Load - Lbs.	690	700	675	470	480	480			
Flow 0.01 In.	9	9	10	11	11	12			
Average Load	688		9	450		11			
	33.2%			21.7%					

75 Blow

	S.S.D.	Bulk S.S.D.
Sp. Gravity		
Absorption		

Absolute	H.R.B.

Wt. A.C. Start			
Wt. A.C. Reqd.			
Wt. A.C. Left			

BITUMINOUS WORK SHEET

Project No. Dept. Info. Lab. Nos. ABC1-444
Project No.
Project No.
County (Hardin SN-4689(3)--51-42)

Effect of density on Marshall Stability

Aggregates

% Aggregate	Agg. Lab. No.	Indivi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight

Batch Wt Agg.			
Pen. Asphalt	AC-10 108 Pen		
Lab No. Asph.			
% Asphalt			
Batch Wt Asph			
Date Tested	3-19		

50 Blow 32 Blow 18 Blow

Specific Gravity Determination

Wt. in Air	1197.5	1198.5	1199.5	1185.0	1184.5	1186.5	1162.5	1168.0	1170.5
Wet Weight	1197.5	1198.5	1199.5	1185.0	1185.0	1186.5	1169.5	1168.0	1171.0
Wt. in Water	695.0	696.0	696.5	685.0	685.5	684.5	672.5	669.5	671.0
Difference	502.5	502.5	503.0	500.0	499.5	502.0	497.0	498.5	500.0
Sp. Gravity	2.383	2.385	2.385	2.370	2.371	2.364	2.353	2.343	2.341
Average		2.384			2.368			2.346	
		100 %			99.3 %			98.4 %	

Marshall Stability

Load - Lbs.	2000	2025	2075	1690	1675	1770	1375	1350	1400
Flow 0.01 In.	12	13	12	13	10	11	10	11	11
Average Load	2033		12	1712		11	1375		11
	100 %			84.2 %			67.6 %		

	S.S.D.	Bulk S.S.D.
Sp. Gravity		
Absorption		

Absolute	H.R.B.

Wt. A.C. Start			
Wt. A.C. Reqd.			
Wt. A.C. Left			

BITUMINOUS WORK SHEET

Project No. Dept. Info. Lab. Nos. ABCL-444
Project No.
Project No.
County (Hardin SN-4689(3)--51-42)

Effect of density on Marshall Stability

Aggregates

% Aggregate	Agg. Lab. No.	Indivi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight

Batch Wt Agg.			
Pen. Asphalt	AC-10 108 Pen		
Lab No. Asph.			
% Asphalt			
Batch Wt Asph			
Date Tested	3-19		

12 Blow 7 Blow

Specific Gravity Determination

Wt. in Air	1153.5	1152.5	1153.0	1139.0	1141.5	1138.5		
Wet Weight	1154.5	1152.5	1153.5	1140.5	1142.5	1139.0		
Wt. in Water	653.0	651.0	653.5	636.5	637.5	635.5		
Difference	501.5	501.5	500.0	504.0	505.0	503.5		
Sp. Gravity	2.300	2.298	2.306	2.260	2.260	2.261		
Average		2.301			2.260			
		96.5 %			94.8 %			

Marshall Stability

Load - Lbs.	1000	1050	960	765	765	750			
Flow 0.01 In.	12	12	11	13	15	14			
Average Load	1003		12	760		14			
	49.3 %			37.4 %					

75 Blow

	S.S.D.	Bulk S.S.D.
Sp. Gravity		
Absorption		

Absolute	H.R.B.

Wt. A.C. Start			
Wt. A.C. Reqd.			
Wt. A.C. Left			

BITUMINOUS WORK SHEET

Project No. ~~Dept. Info.~~ Lab. Nos. (ABD1-152)

Project No.

Project No.

County (Linn LA-4889-81)

Effect of density on Marshall Stability

Aggregates

% Aggregate	Agg. Lab. No.	Indivi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight
50	AAT1-611	+4 (36) 2160	2160	
		-4 (64) 3840	6000	
50	AAT1-612	6000	12,000	

Batch Wt Agg.	12,000		
Pen. Asphalt	AC-10	Pen. 110	
Lab No. Asph.	ABD-6		
% Asphalt	6.25		
Batch Wt Asph	800		
Date Tested	3-23		

50 Blow | 32 Blow | 18 Blow

Specific Gravity Determination

Wt. in Air	1173.5	1174.0	1174.5	1154.5	1159.0	1158.0	1147.0	1145.5	1146.0
Wet Weight	1173.5	1174.5	1174.5	1154.5	1159.5	1158.0	1147.5	1146.0	1146.0
Wt. in Water	671.0	671.5	672.0	654.0	657.0	656.5	643.0	643.0	642.5
Difference	502.5	503.0	502.0	500.5	502.5	501.5	504.5	503.0	503.5
Sp. Gravity	2.335	2.334	2.340	2.307	2.306	2.309	2.276	2.277	2.276
Average		2.336			2.307			2.276	
		100%			98.8			97.4	

Marshall Stability

Load - Lbs.	1850	1675	1800	1470	1480	1550	1040	1035	1050
Flow 0.01 In.	7	7	7	7	7	7	8	8	8
Average Load	1775		7	1500		7	1042		8
	100%			84.5%			58.7%		

	S.S.D.	Bulk S.S.D.
Sp. Gravity		
Absorption		

Absoluto	H.R.B.

Wt. A.C. Start	3100	2700	
Wt. A.C. Reqd.	800	800	
Wt. A.C. Left	2300	1400	

BITUMINOUS WORK SHEET

Project No. Dept. Info. Lab. Nos. (ABD1-152)
Project No.
Project No.
County (Linn LA-4889-81)

Effect of density on Marshall Stability

Aggregates

% Aggregate	Agg. Lab. No.	Indivi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight
50	AATI-611	+4 (36) 2160	2160	
		-4 (64) 3840	6000	
50	AATI-612	6000	12,000	

Batch Wt Agg.	12,000		
Pen. Asphalt	AC-10	Pen 110	
Lab No. Asph.	ABD-6		
% Asphalt	6.25		
Batch Wt Asph	800		
Date Tested	3-23		

12 Blow 7 Blow

Specific Gravity Determination

Wt. in Air	1130.5	1129.5	1130.5	1119.5	1118.5	1117.5		
Wet Weight	1131.0	1129.5	1130.5	1120.5	1119.5	1118.5		
Wt. in Water	627.5	626.5	625.0	615.0	616.5	614.5		
Difference	503.5	503.0	505.5	505.5	503.0	504.0		
Sp. Gravity	2.245	2.246	2.236	2.215	2.224	2.217		
Average		2.242			2.219			
		96.0%			95%			

Marshall Stability

Load - Lbs.	875	870	800	650	700	650		
Flow 0.01 In.	10	10	10	11	11	12		
Average Load	848		10	667		11		
	47.8%			37.6%				

75 Blow

	S.S.D.	Bulk S.S.D.
Sp. Gravity		
Absorption		

Absolute	H.R.B.

Wt. A.C. Start			
Wt. A.C. Reqd.			
Wt. A.C. Left			

BITUMINOUS WORK SHEET

Project No. Dept. Info. Lab. Nos. (AB01-145)
Project No.
Project No.
County

Effect of density on Marshall Stability

Aggregates

% Aggregate	Agg. Lab. No.	Indivi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight
55	AATI-576	+8 (43) 2838	2838	
		-8 (57) 3762	6600	
30	AATI-577	+4 (55) 1980	8580	
		-4 (45) 1620	10200	
15	AATI-578	1800	12000	

Batch Wt Agg.	12000		
Pen. Asphalt	AC-10	Pen. 94	
Lab No. Asph.	AB0-82		
% Asphalt	6.0		
Batch Wt Asph	766		
Date Tested	3-24		

Specific Gravity Determination

	50 Blow			32 Blow			18 Blow		
Wt. in Air	1197.5	1196.5	1192.5	1177.0	1182.5	1186.5	1169.0	1168.5	1166.5
Wet Weight	1197.5	1196.5	1198.0	1177.5	1183.0	1186.5	1161.5	1169.0	1167.0
Wt. in Water	686.0	684.5	684.5	666.5	671.0	671.0	655.5	652.5	650.5
Difference	511.5	512.0	513.5	511.0	512.0	515.5	514.0	516.5	516.5
Sp. Gravity	2.341	2.337	2.332	2.303	2.310	2.302	2.214	2.262	2.258
Average		2.337			2305			2.265	
		100 %			98.6 %			96.9 %	

Marshall Stability

Load - Lbs.	2460	2460	2560	1840	1940	1800	1350	1250	1250
Flow 0.01 In.	8	8	8	9	8	8	10	10	10
Average Load	2493		8	1860		8	1283		10
	100 %			74.6 %			51.5 %		

	S.S.D.	Bulk S.S.D.
Sp. Gravity		
Absorption		

Absolute	H.R.B.

Wt. A.C. Start	1466		
Wt. A.C. Reqd.	766		
Wt. A.C. Left	700		

BITUMINOUS WORK SHEET

Project No. Dept. Info. Lab. Nos. (A801-145)
Project No.
Project No.
County

Effect of density on Marshall Stability

Aggregates

% Aggregate	Agg. Lab. No.	Indivi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight
55	AATI-576	+8 (43) 2838	2838	
		-8 (57) 3762	6600	
30	AATI-577	+4 (55) 1980	8580	
		-4 (43) 1620	10200	
15	AATI-578	1800	12000	

Batch Wt Agg.	12000		
Pen. Asphalt	AC-10		
Lab No. Asph.	A80-82		
% Asphalt	6.0		
Batch Wt Asph	766		
Date Tested	3-24		

12 Blow 7 Blow

Specific Gravity Determination

Wt. in Air	1153.0	1143.0	1153.5	1139.0	1138.0	1130.5			
Wet Weight	1154.5	1144.0	1154.5	1140.5	1140.0	1138.0			
Wt. in Water	635.0	631.0	635.0	619.5	619.5	619.0			
Difference	519.5	513.0	519.5	521.0	520.5	519.0			
Sp. Gravity	2.219	2.228	2.220	2.186	2.186	2.190			
Average		2.223			2.187				

95.1% 93.6%

Marshall Stability

Load - Lbs.	925	890	820	640	650	650			
Flow 0.01 In.	11	11	13	13	13	13			
Average Load	878		12	647		13			

35.2% 26.0%

75 Blow

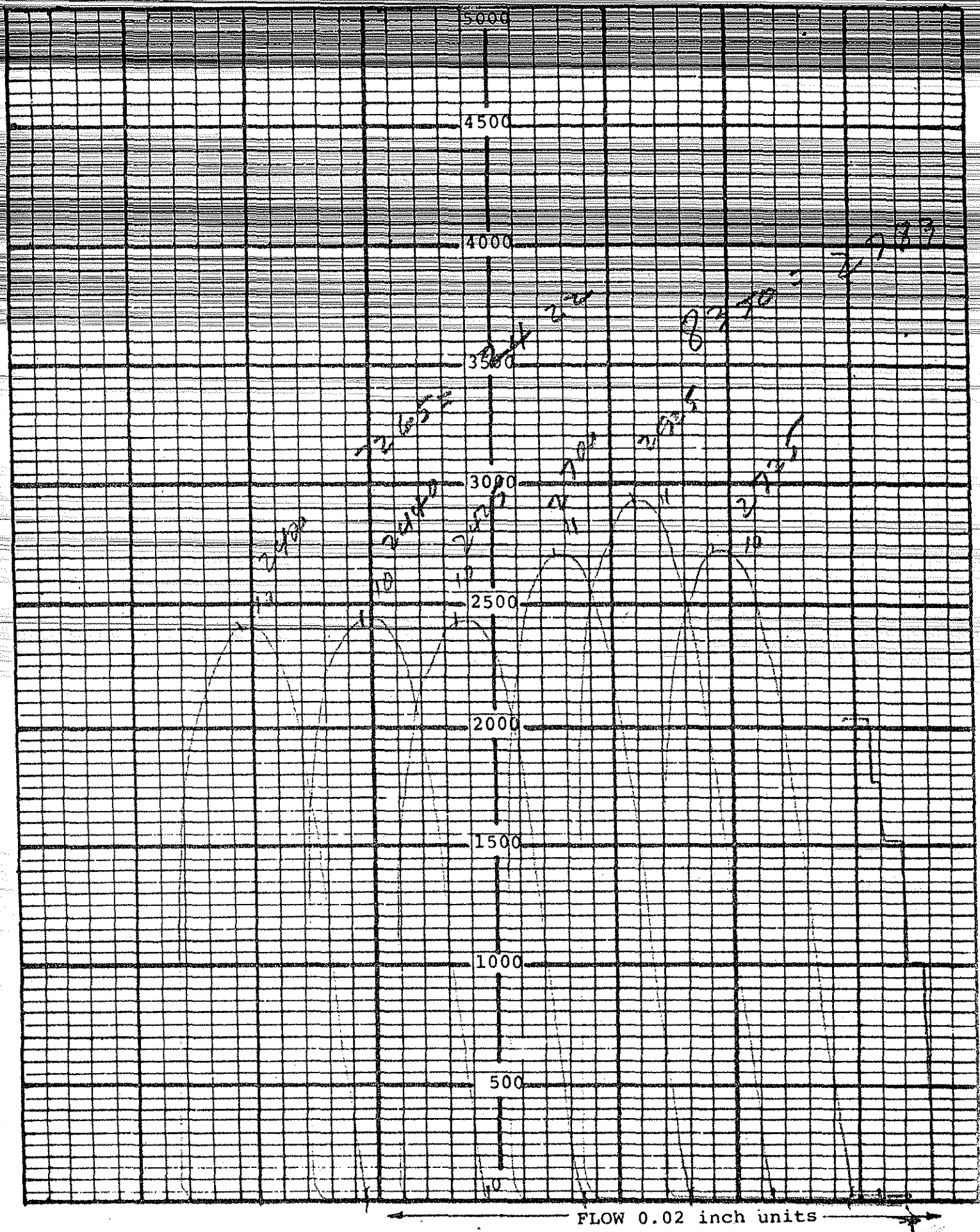
	S.S.D.	Bulk S.S.D.
Sp. Gravity		
Absorption		

Absolute	H.R.B.

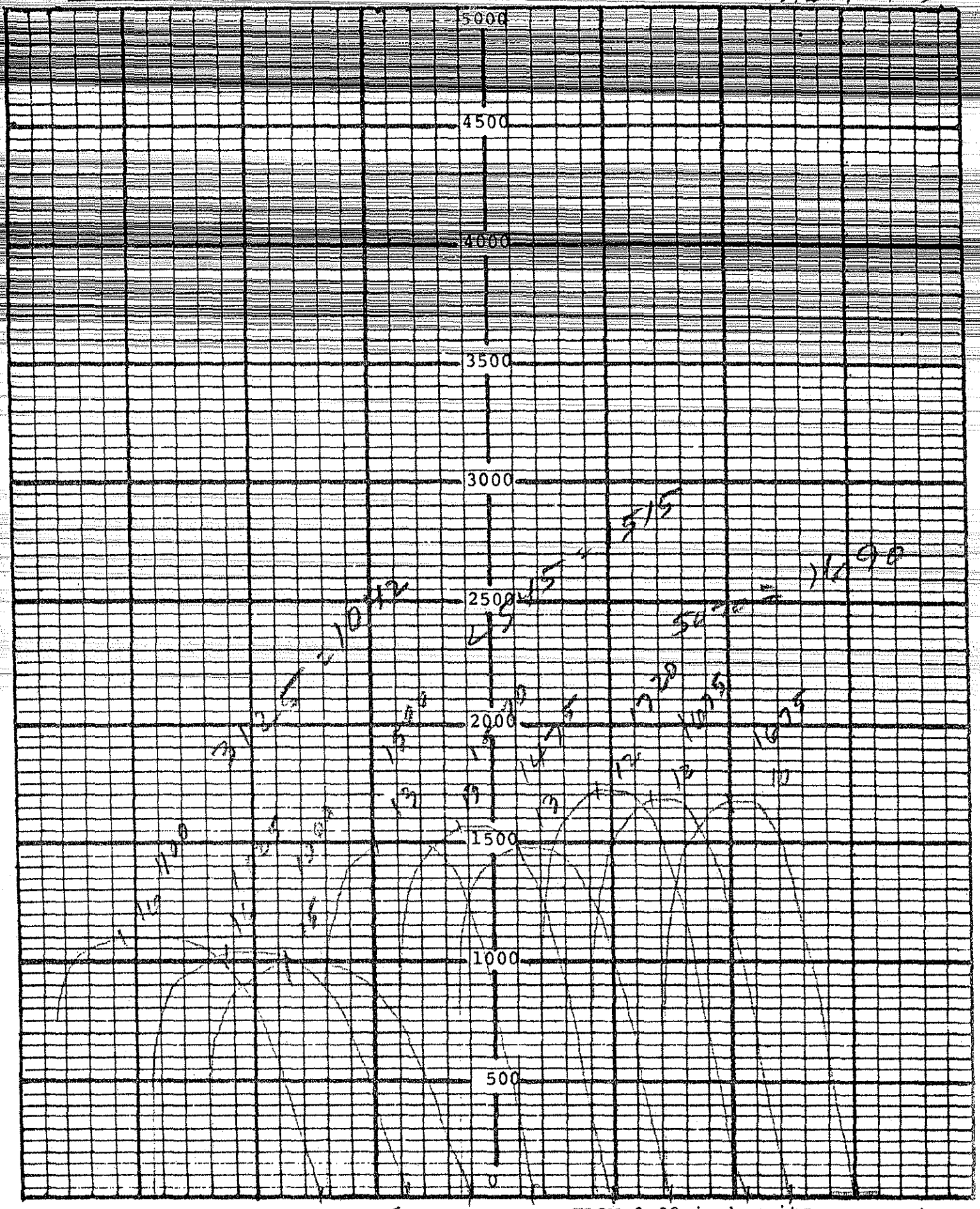
Wt. A.C. Start	1166		
Wt. A.C. Reqd.	766		
Wt. A.C. Left	400		

APPENDIX C

Date 2-12 Percent AC Stability Flow Lab No. 403

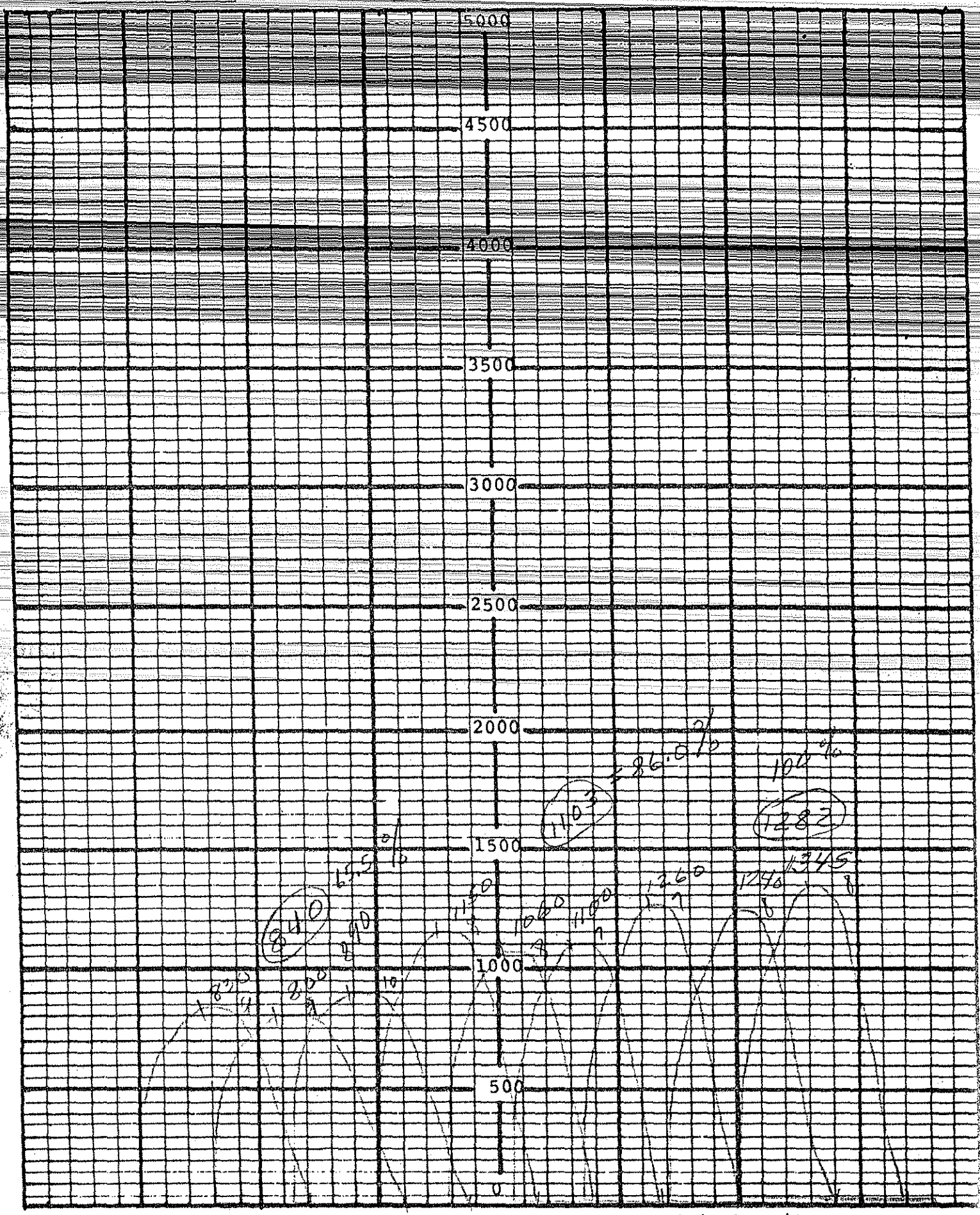


Date 2-22 Percent AC _____ Stability _____ Flow _____ Lab ABCp-403

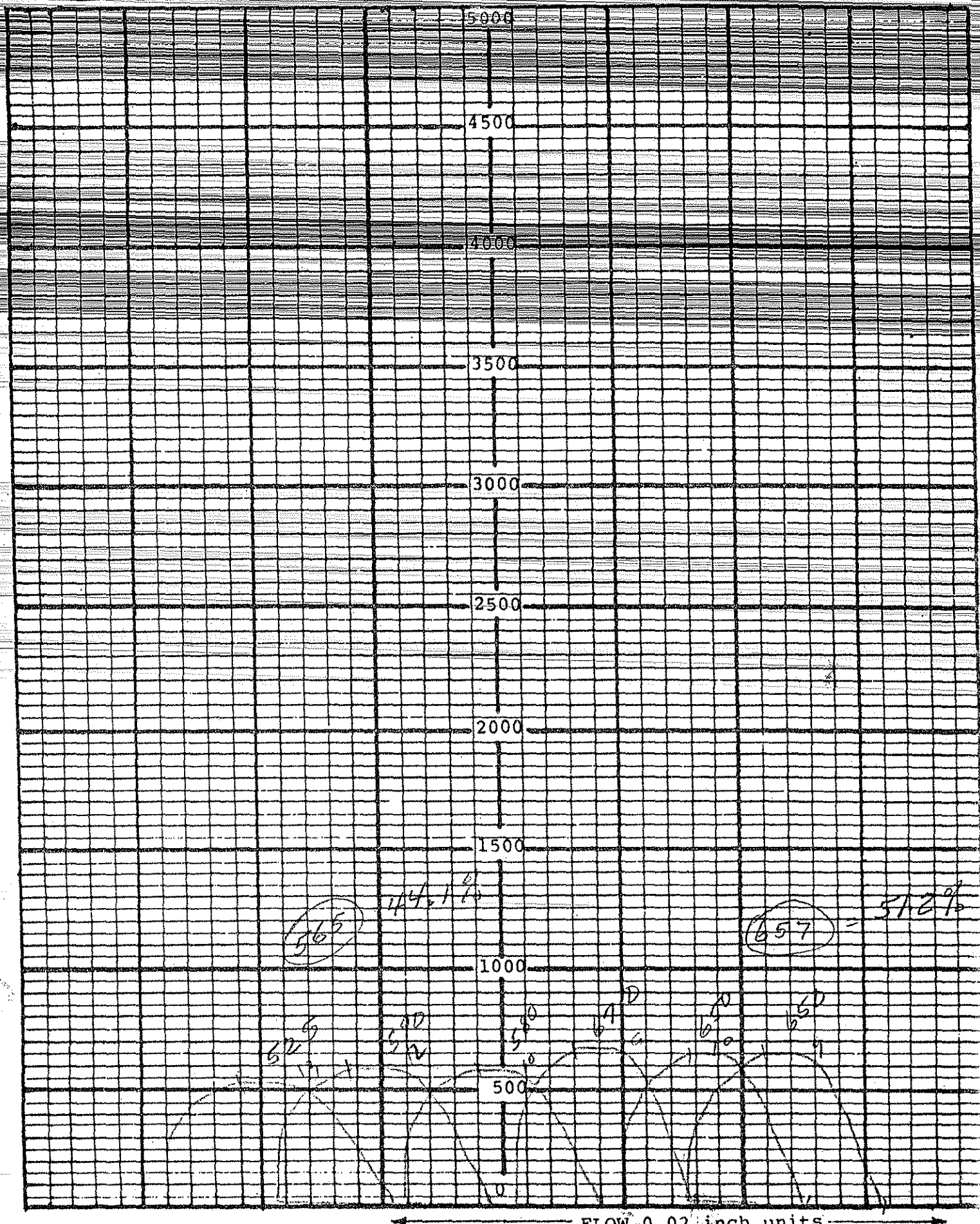


18 32 HBC1-442 50

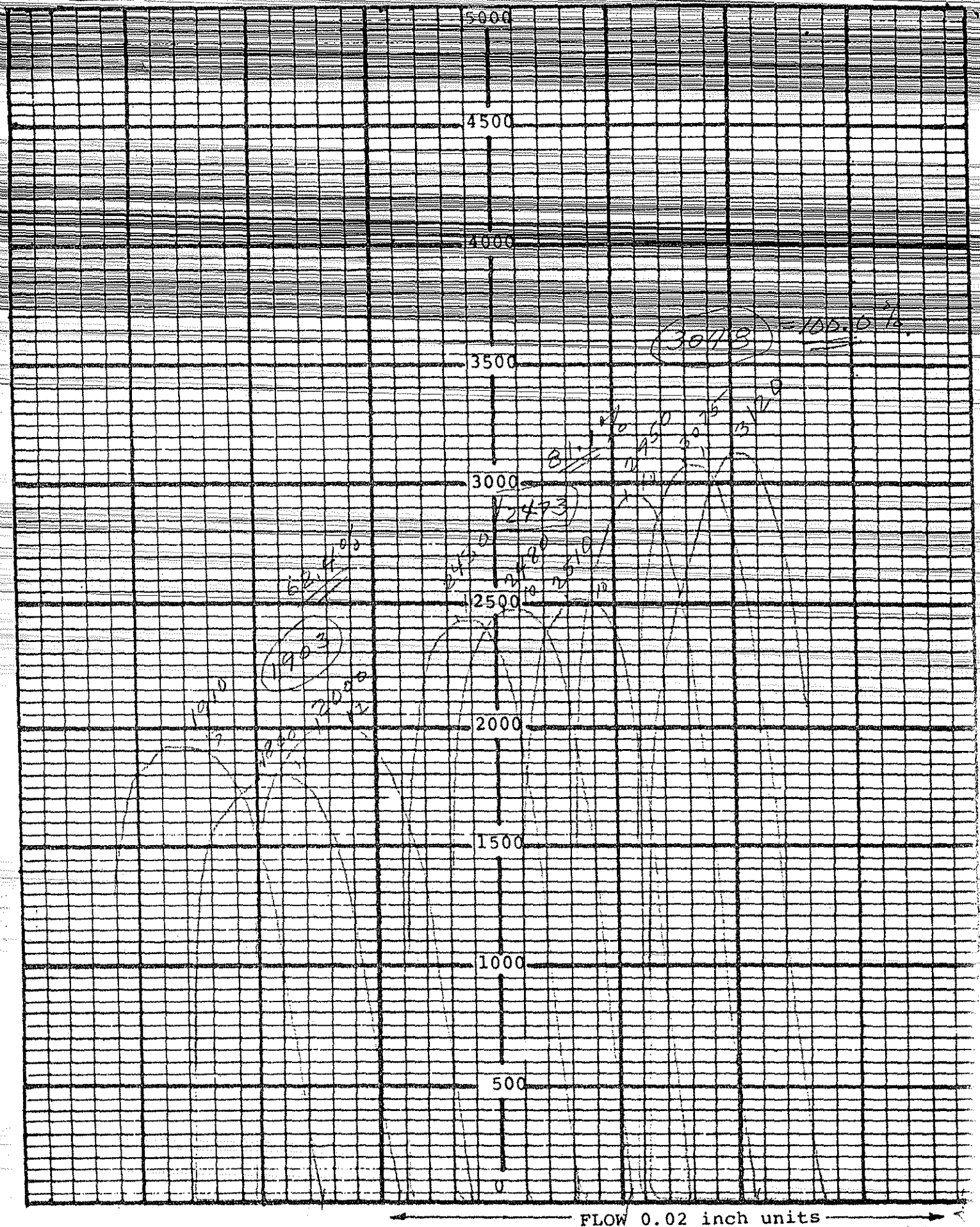
Date 2-23 Percent AC Stability Flow Lab No. 441



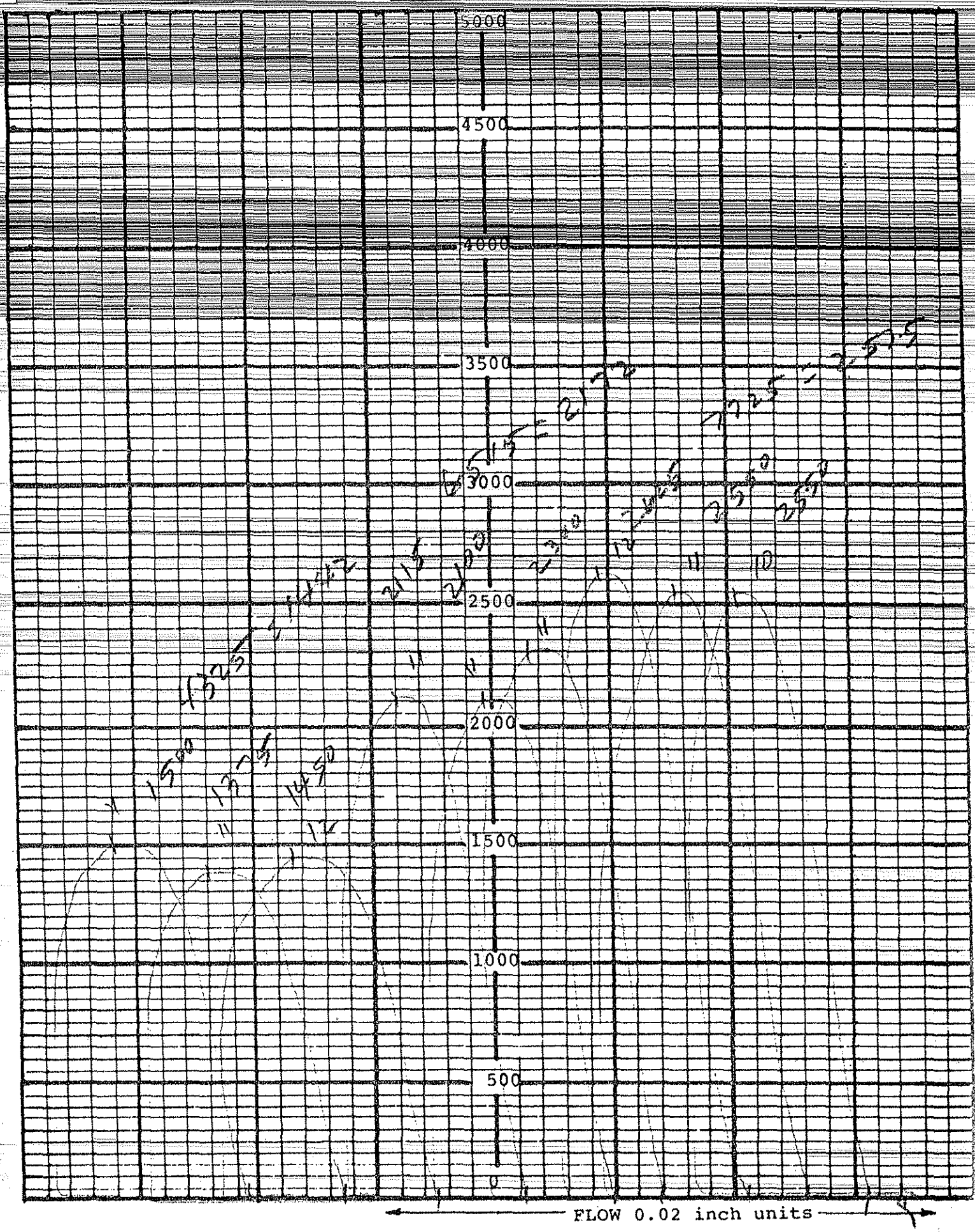
Date 7-13 Percent AC Stability Flow 12 Lab No. 442



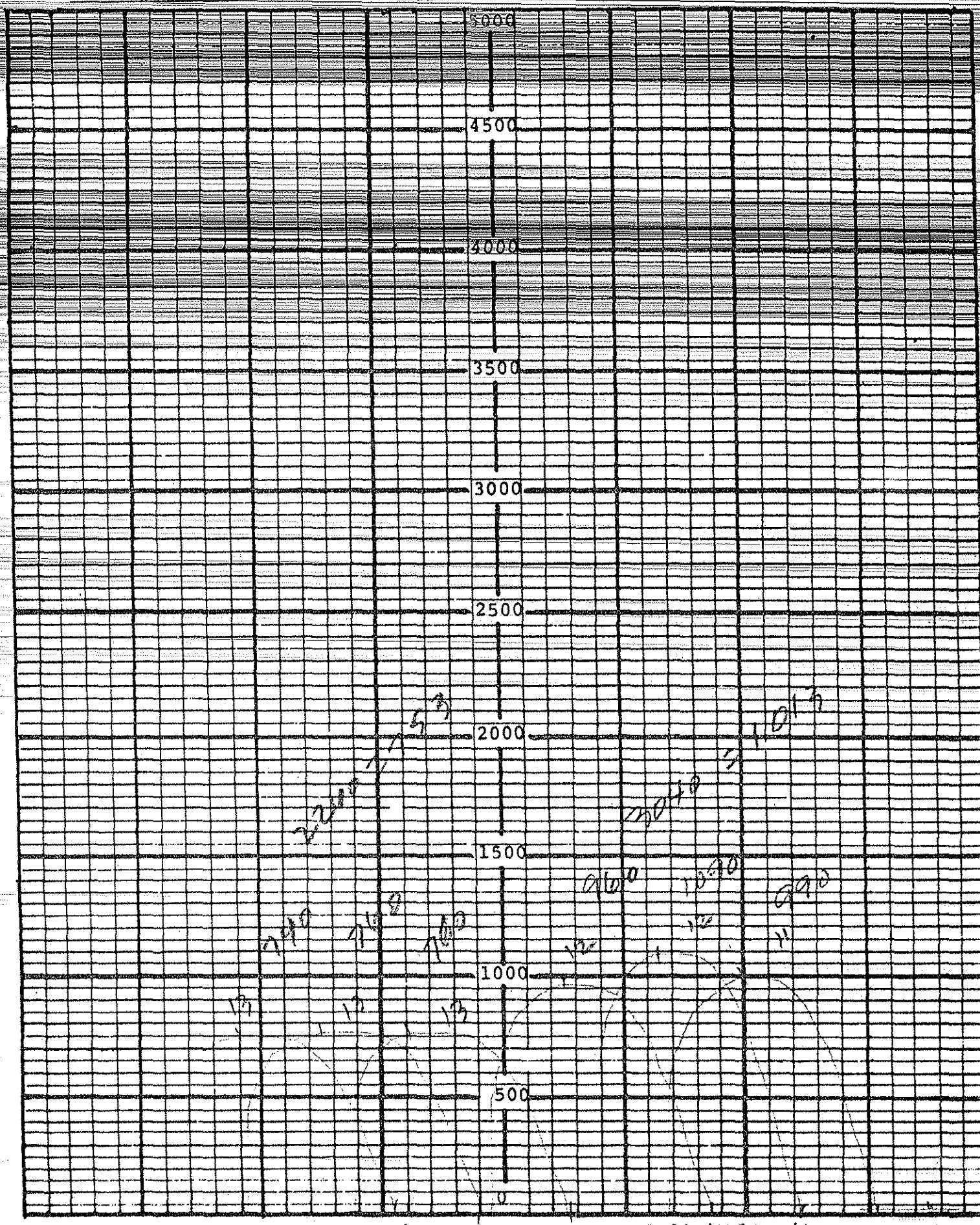
Date 9-24 Percent AC 6 Stability 32 Flow 50 Lab No. RBC-147



Date 3-26 Percent AC 14 Stability 32 Flow 50 Lab No. 448

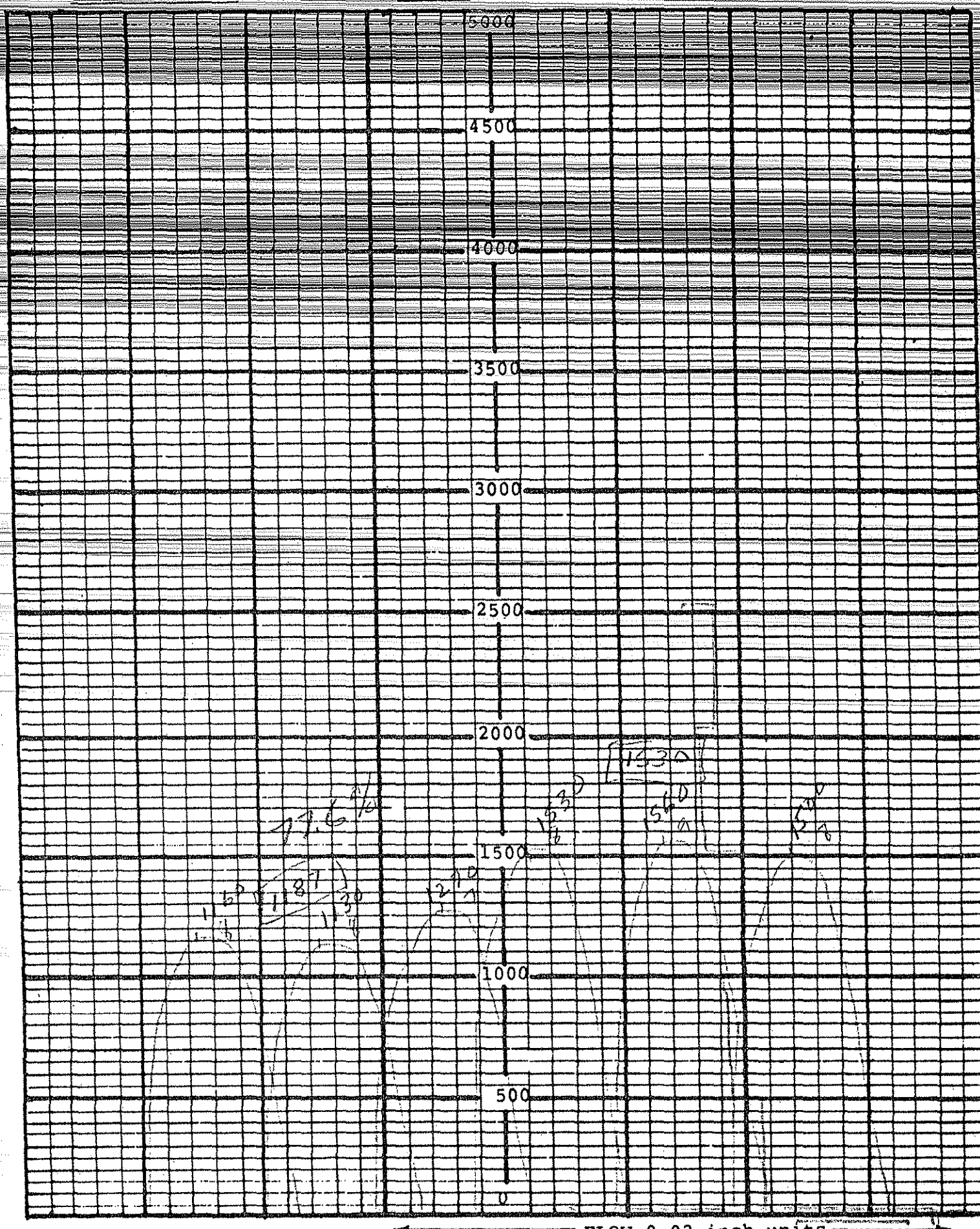


Date 2-26 Percent AC 7 Stability Flow 12 Lab No. 1-48



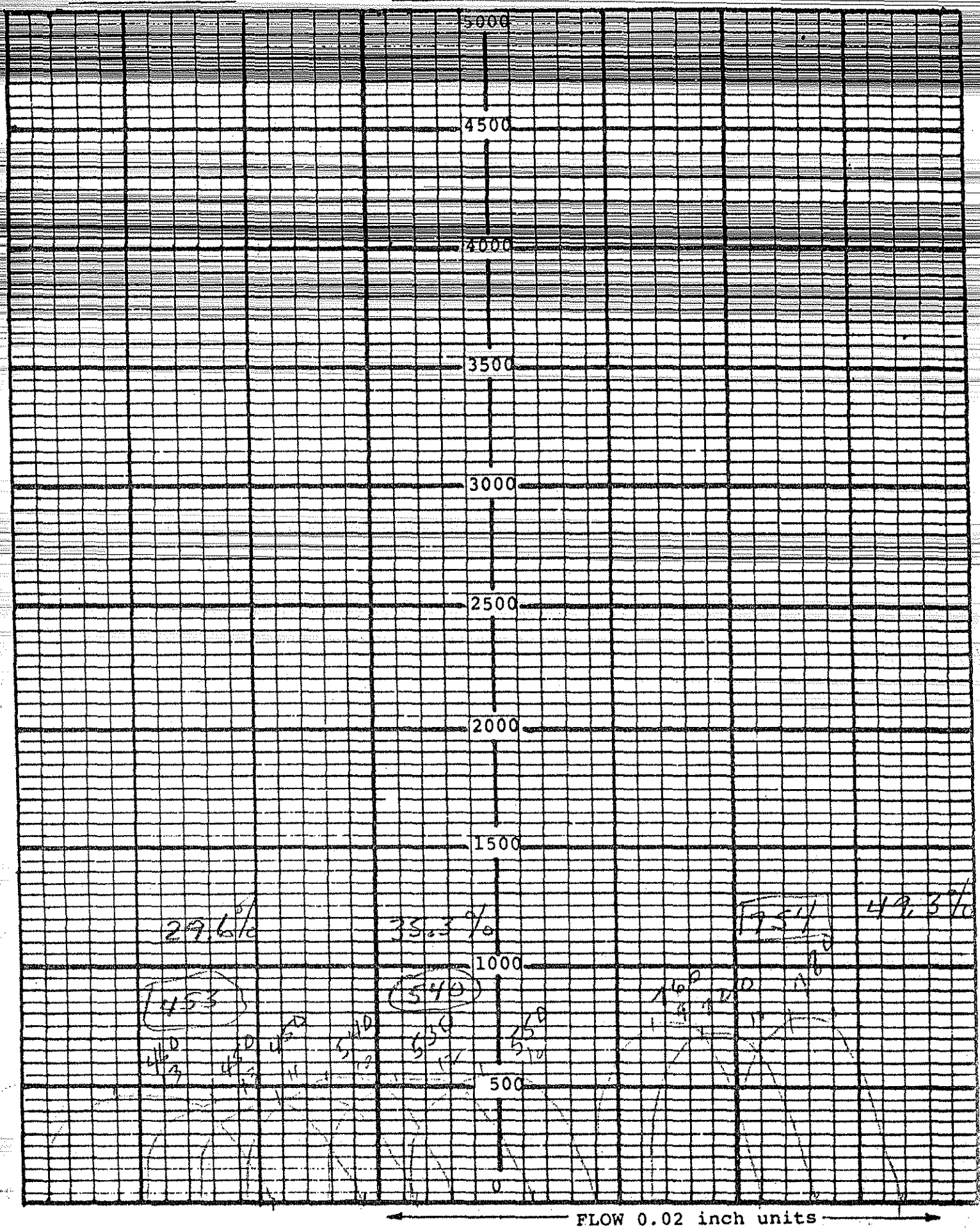
ABCI-449

Date 3-2 Percent AC Stability Flow 32 & 50 Lab No. 449



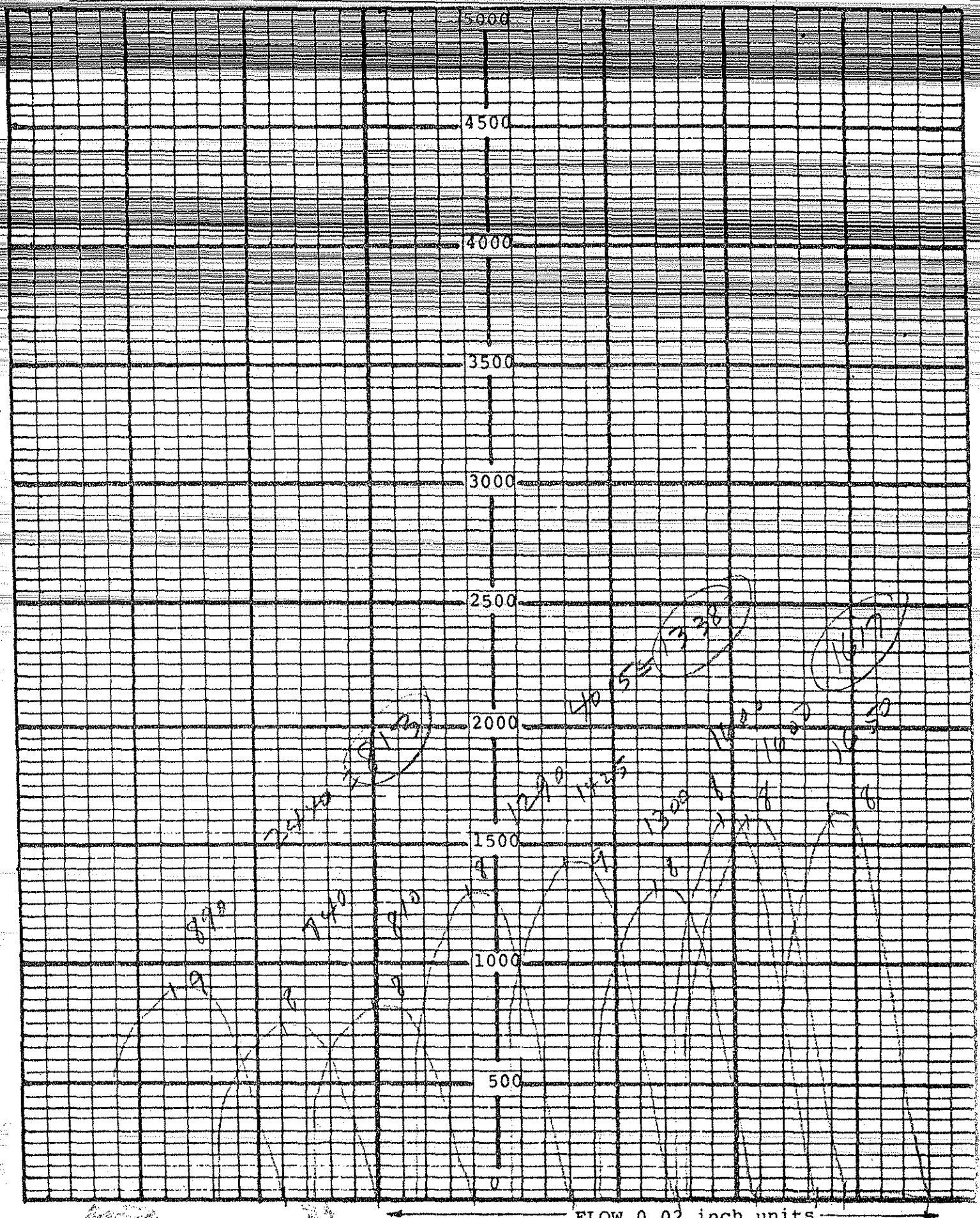
7 — 12 — 18 Blows 7-12-18

Date 3-2 Percent AC Stability Flow Lab No. 419

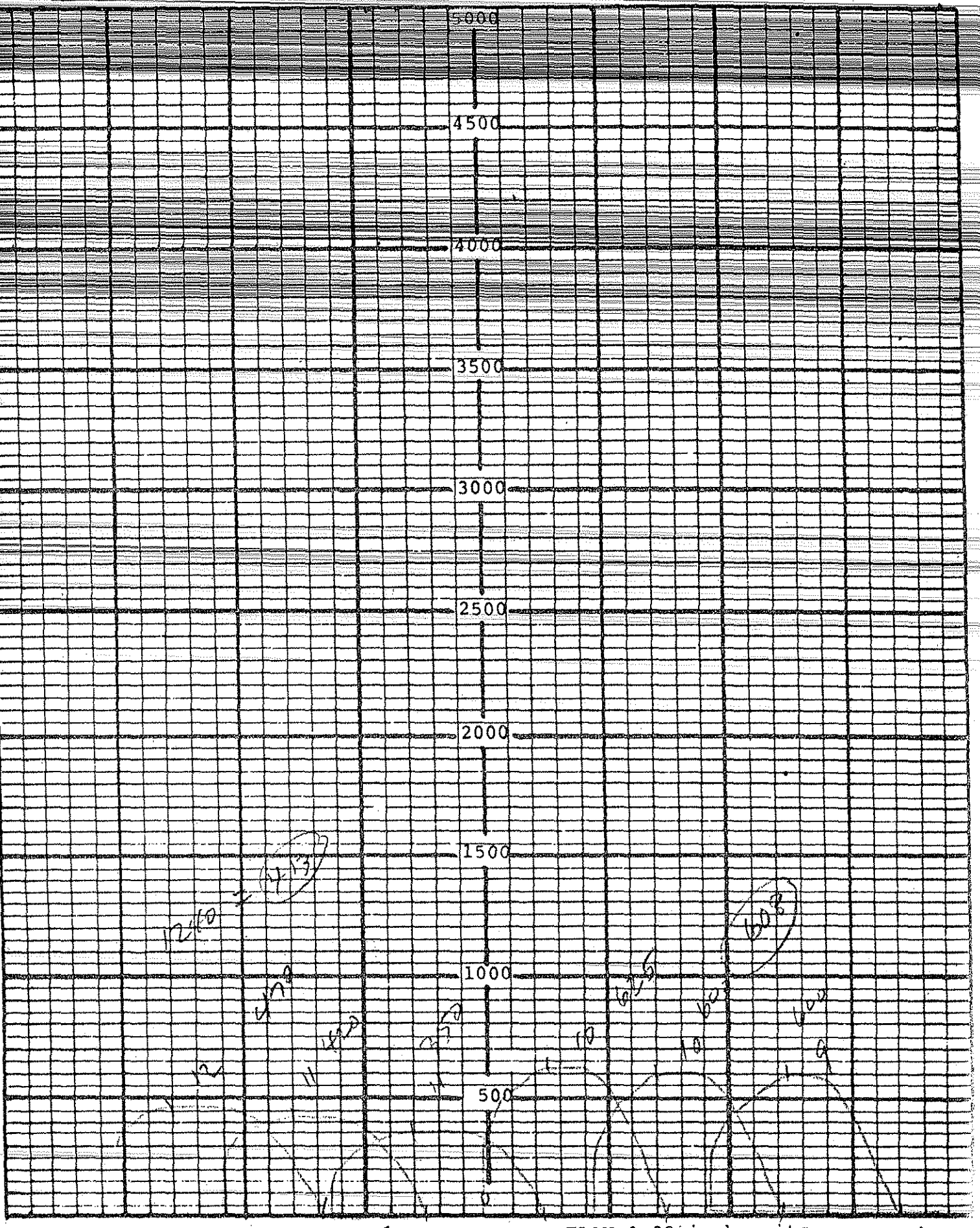


AB01-97

Date 3-11 (Percent AC Stability Flow Lab No. 16 # 50

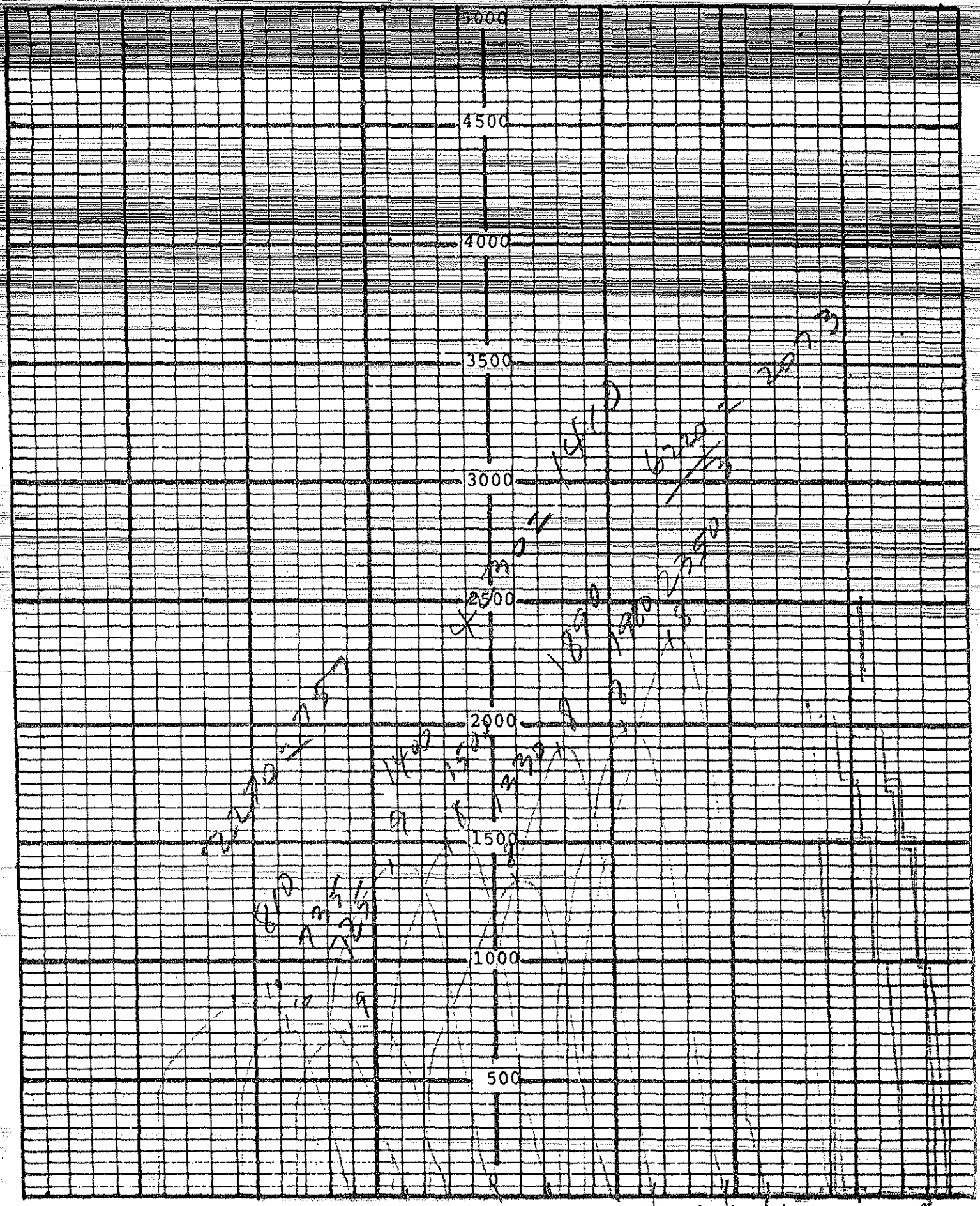


Date 3-11 Percent AC Stability 97 Flow Lab No. 7 12



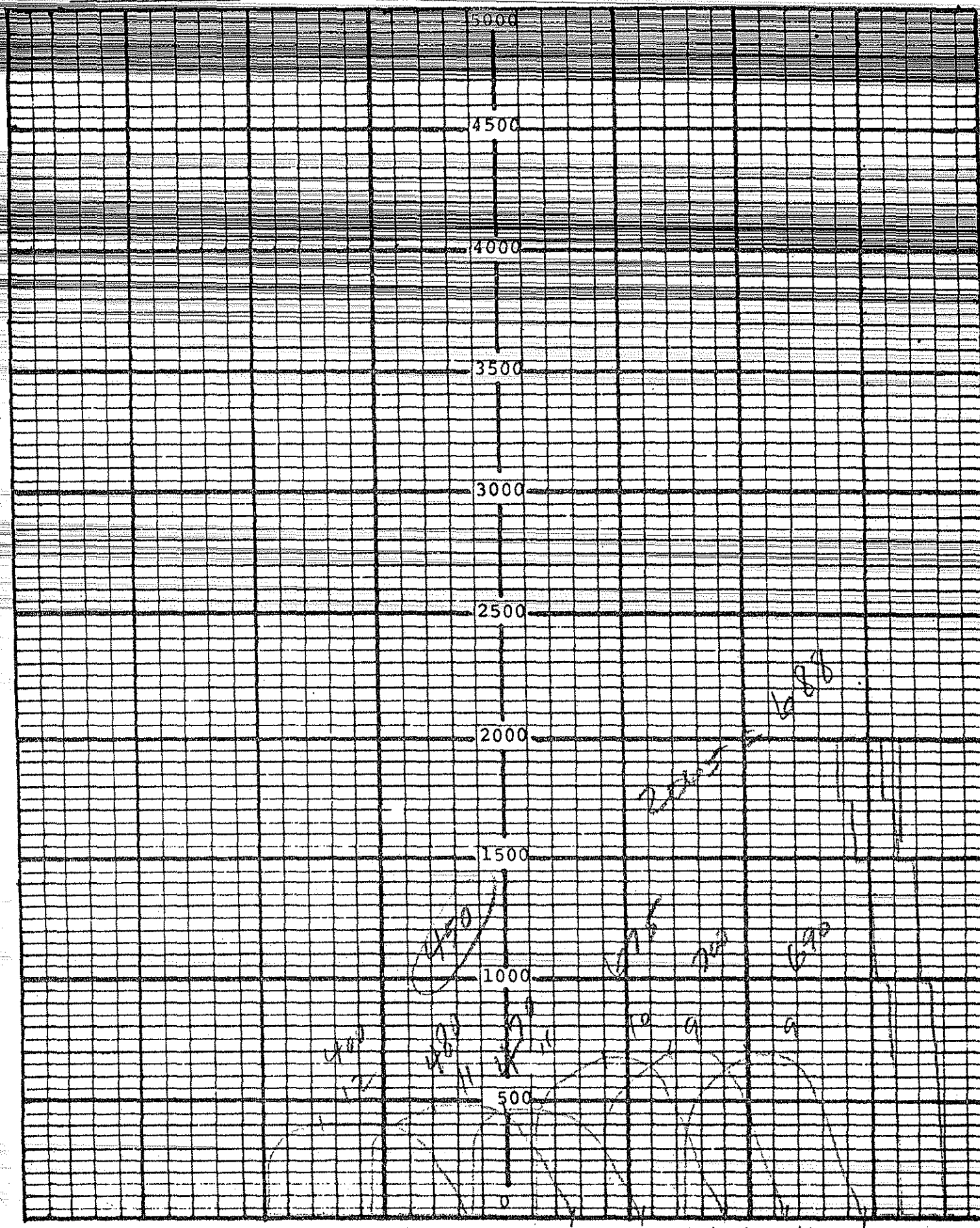
ABDI-168

Date 3-15 Percent AC ____ Stability ____ Flow ____ Lab No. 168 1/2 1/2



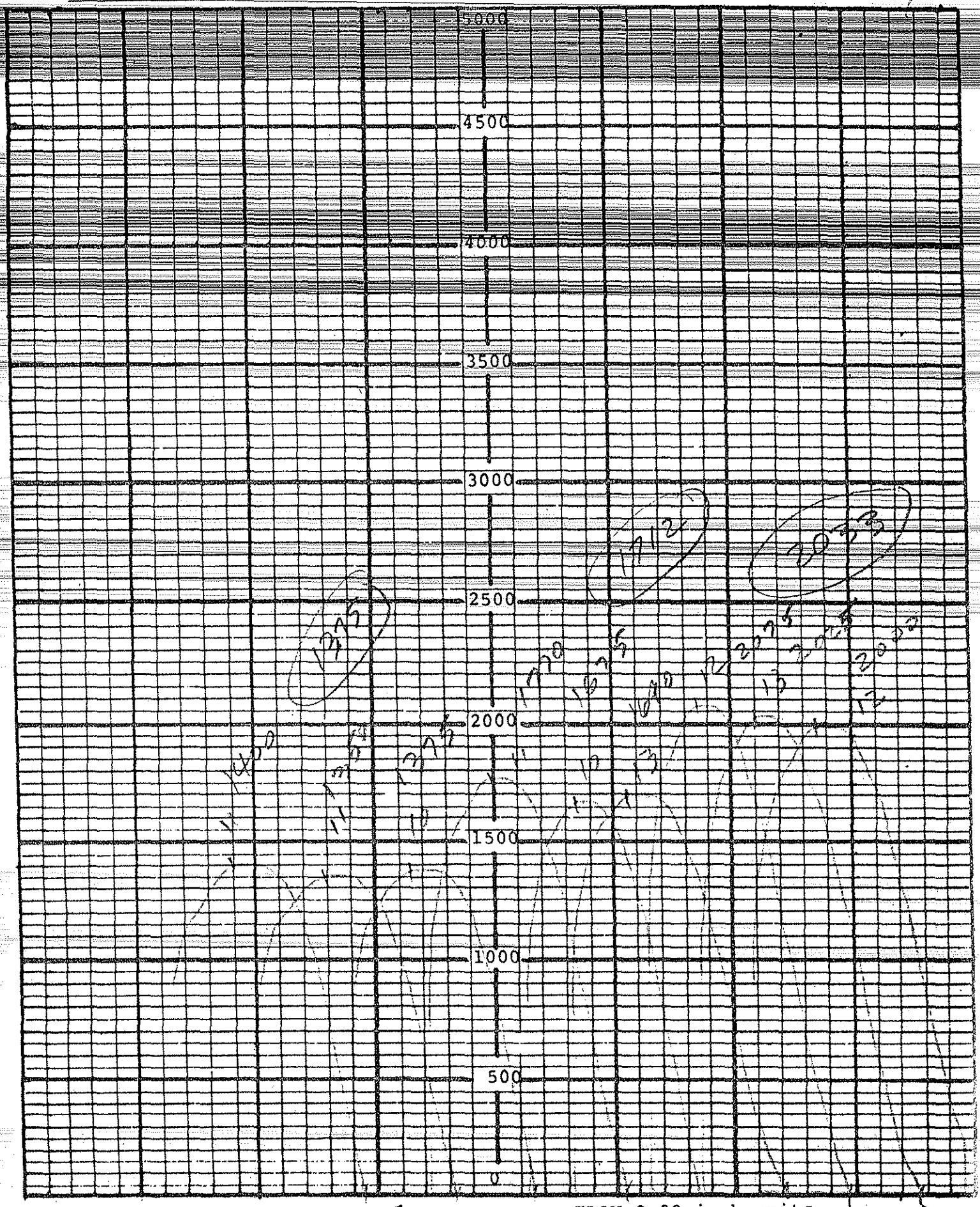
168

Date 2-15 Percent AC ____ Stability ____ Flow ____ Lab No. 1 12

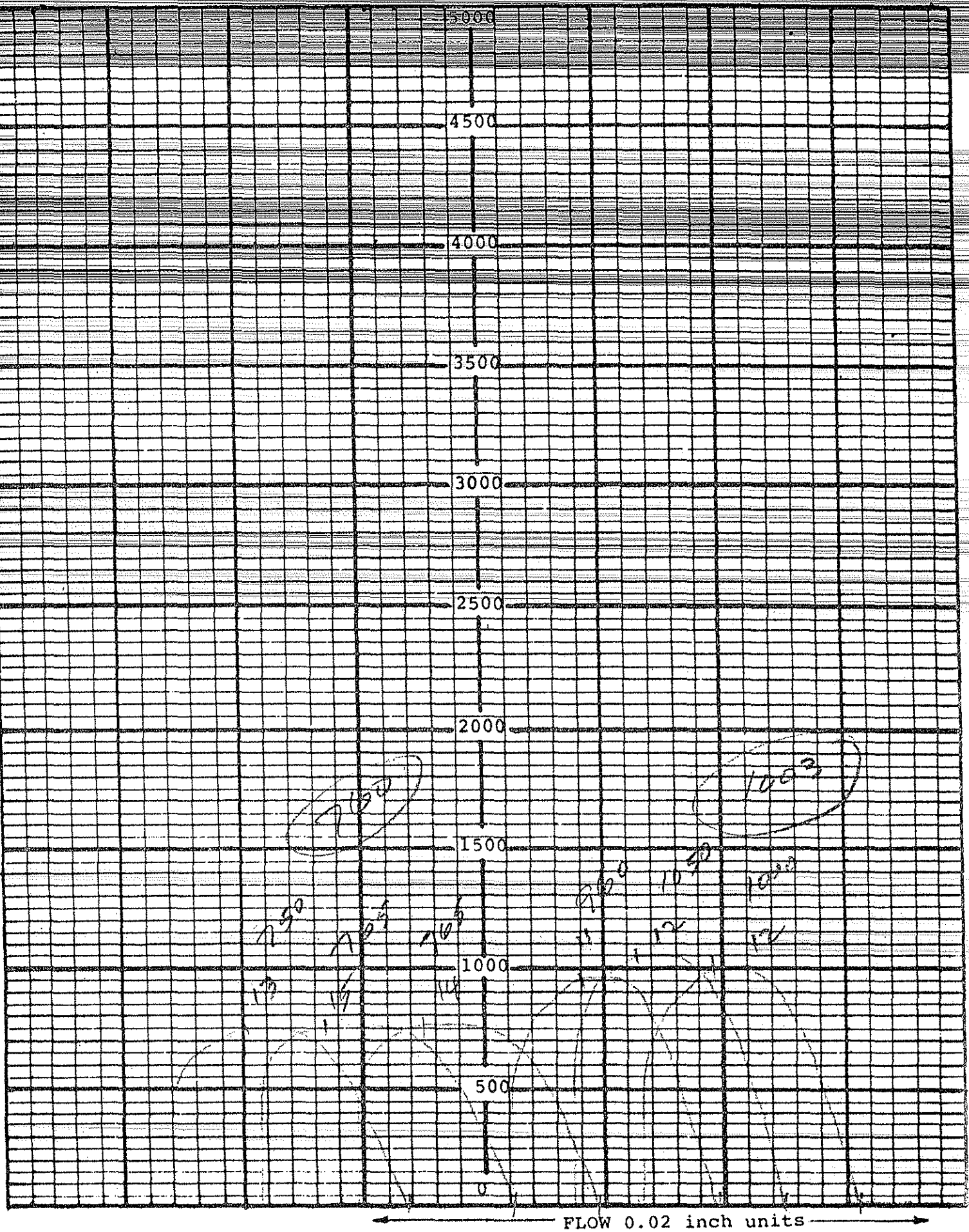


ABCL 444

Date 3-19 Percent AC _____ Stability _____ Flow _____ Lab No. 18 32 50

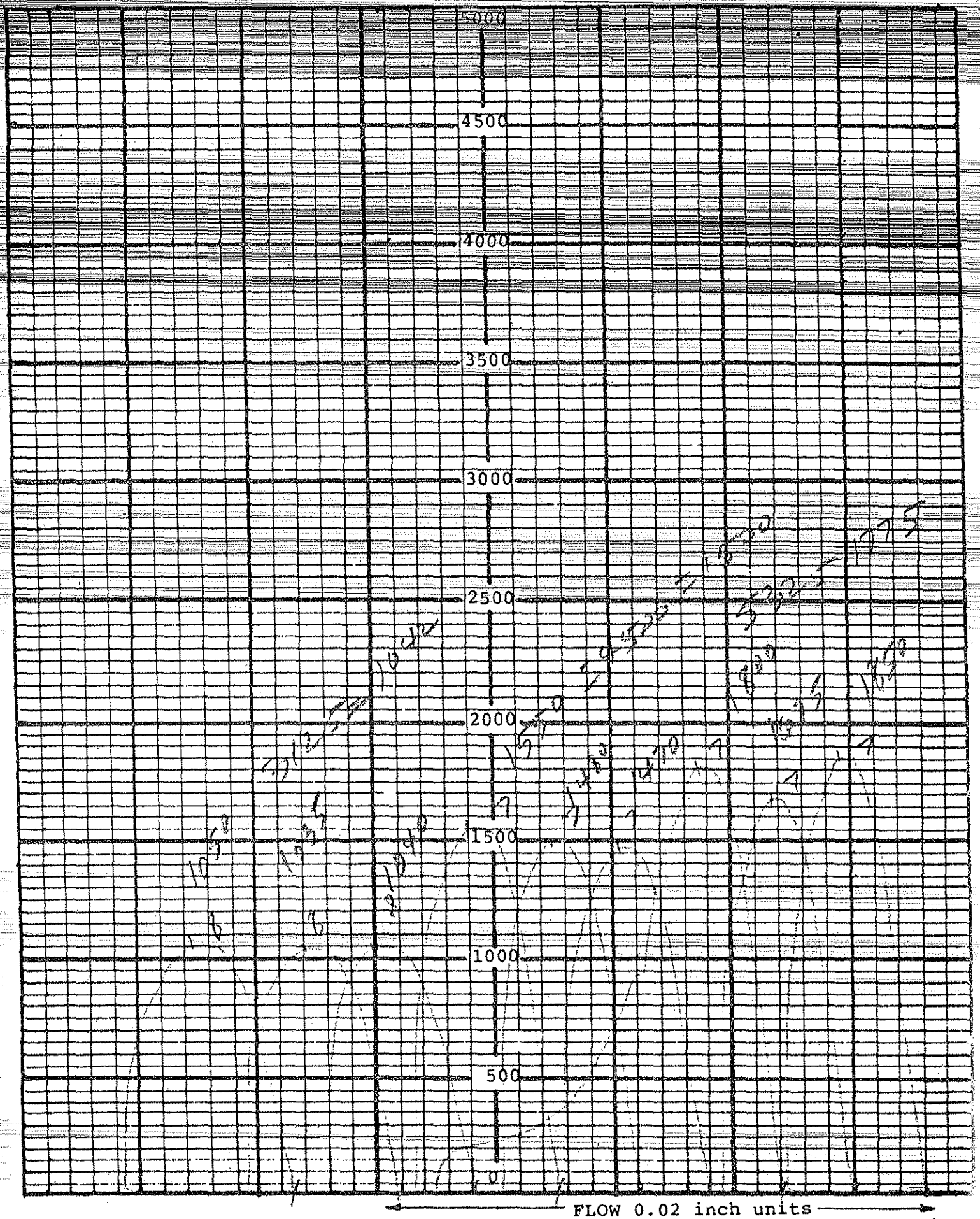


Date 3-19 Percent AC Stability 44 Flow Lab No. 1/12

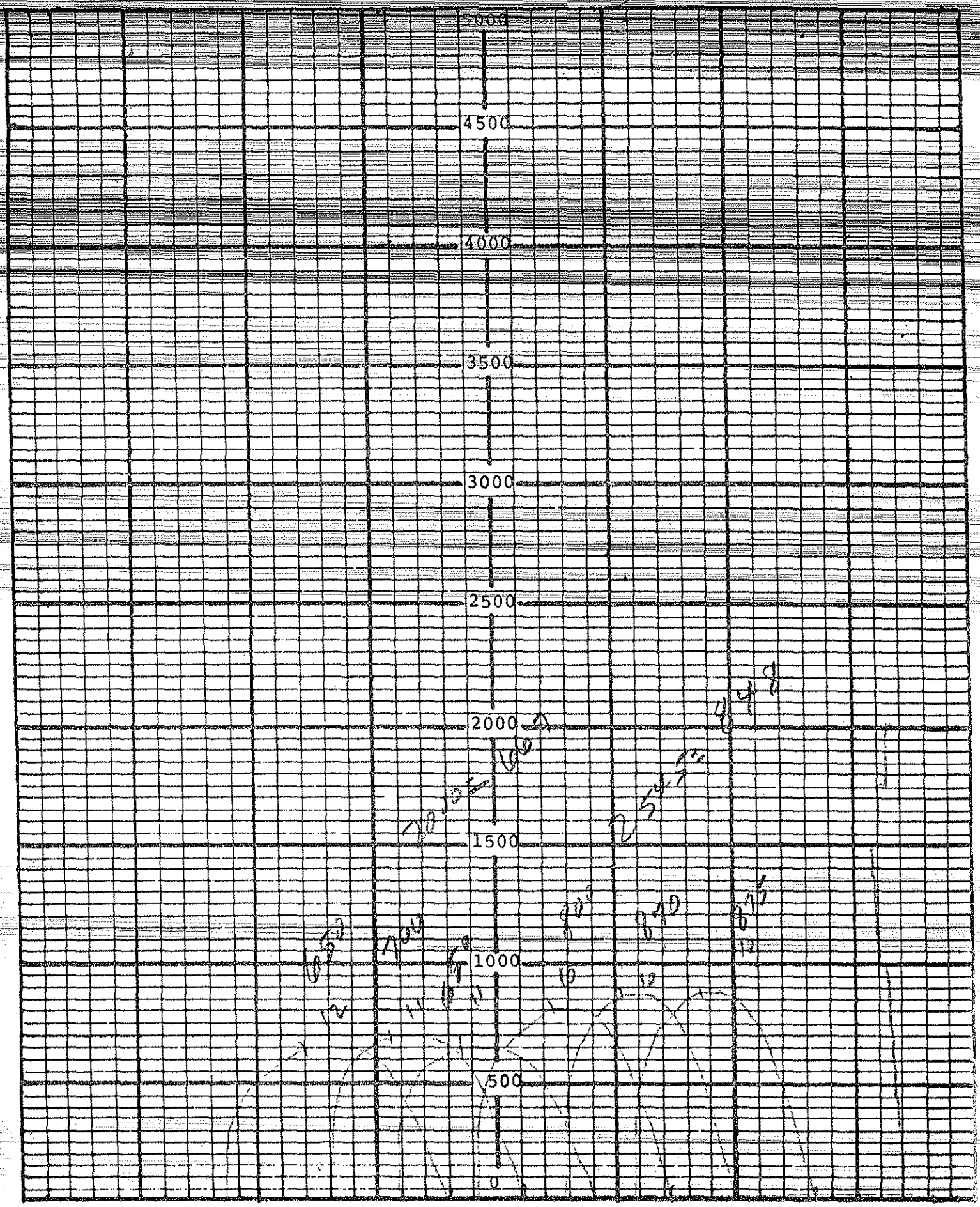


ABDI 152 (152)

Date 3-29 Percent AC ____ Stability ____ Flow ____ Lab No. 32 5

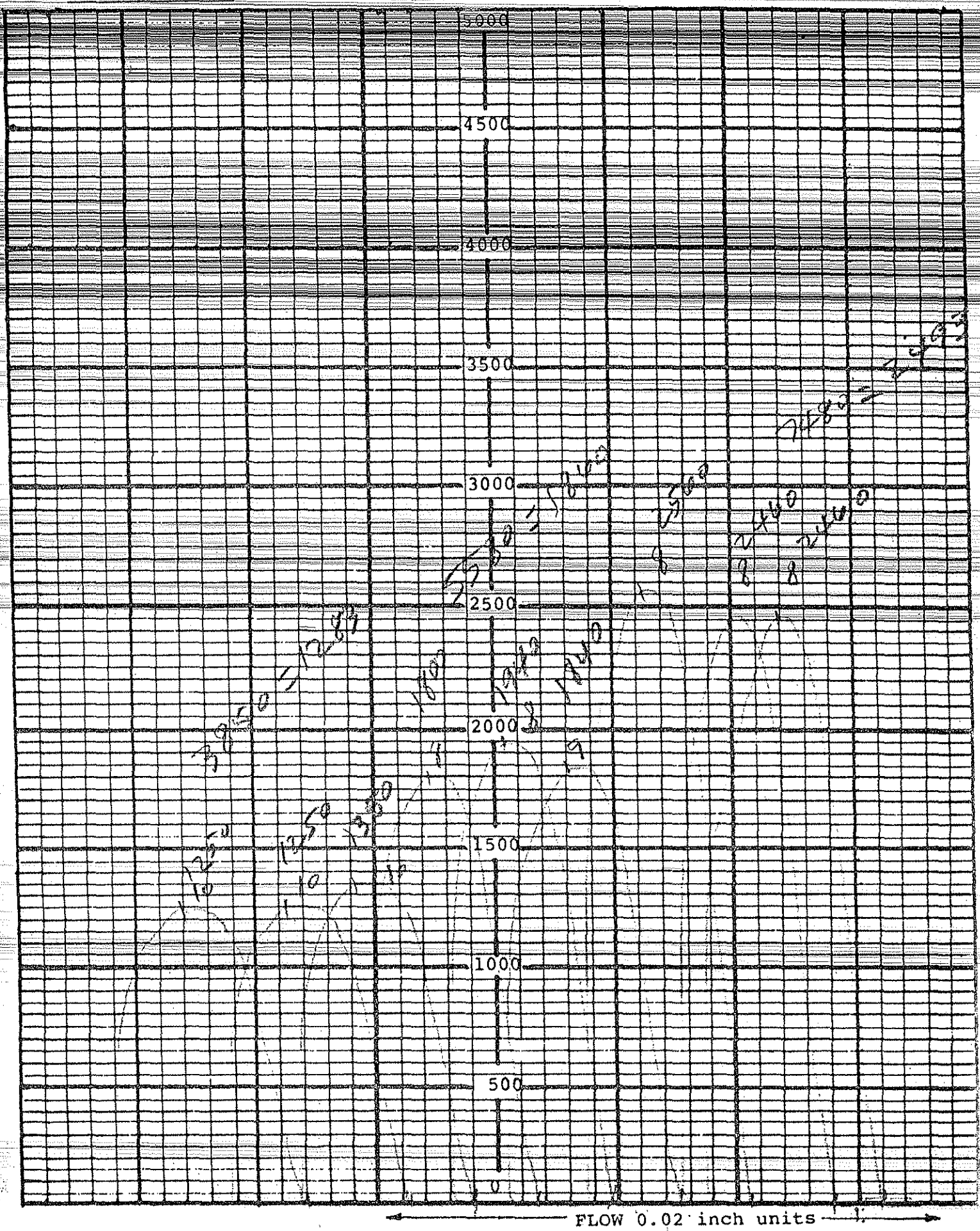


Date 7-23 Percent AC Stability 52 Flow Lab No. 7 12

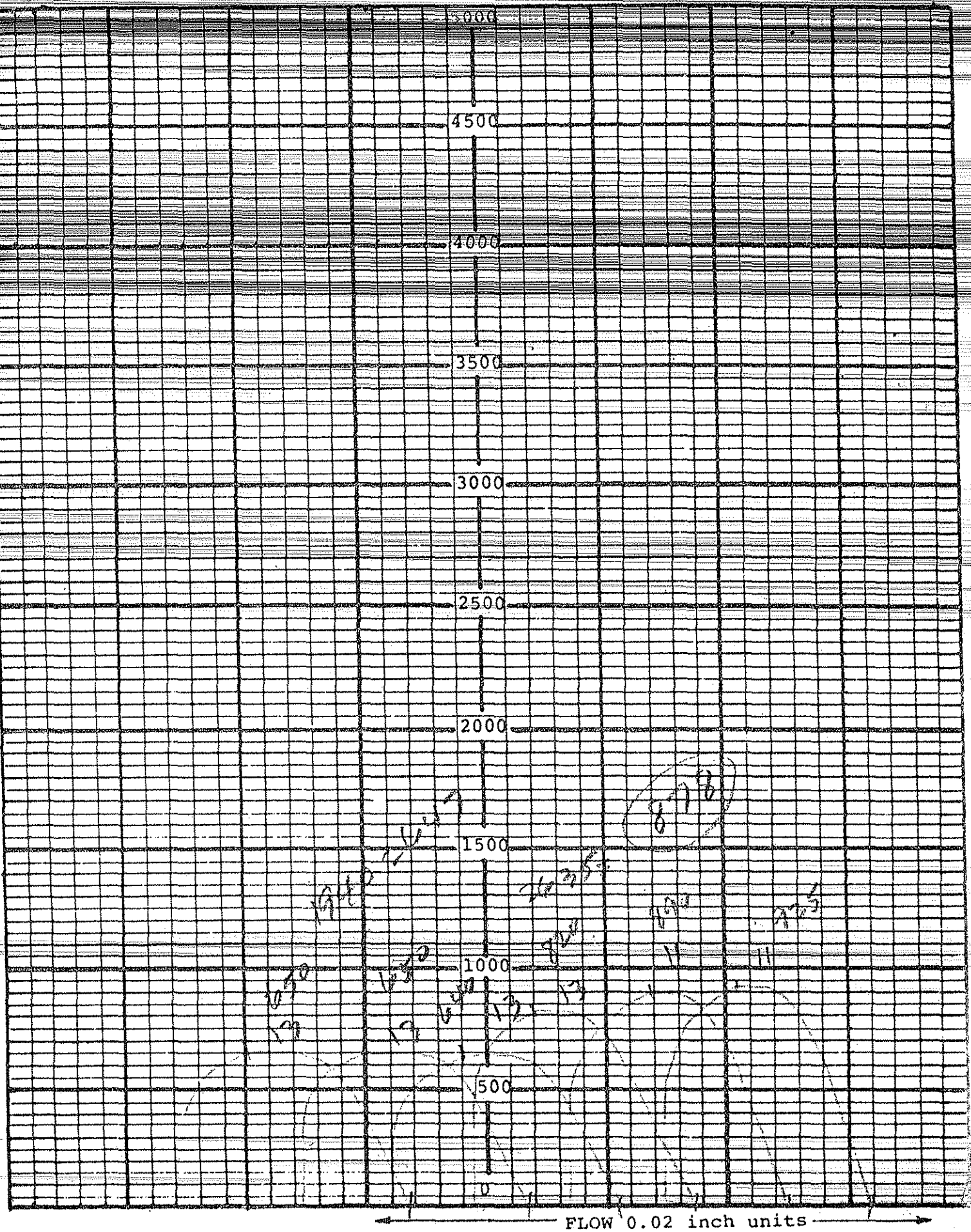


ABDI-145

Date 3-24 Percent AC Stability Flow Lab No. 16 32/50



Date 3-24 Percent AC Stability 145 Flow Lab No. 7/12



Form 1295
3-74

BITUMINOUS WORK SHEET

Project No. FM-89 (2)- 55-89 Lab. Nos. ABC8 -318
Project No.
Project No.
County Van Buren

Aggregates

% Aggregate	Agg. Lab. No.	Indivi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight

Batch Wt Agg.			
Pen. Asphalt			
Lab No. Asph.			
% Asphalt			
Batch Wt Asph			
Date Tested	8-30-78		

Specific Gravity Determination

	35 Blow			40 Blow			45 Blow		
Wt. in Air	Ave.			Blow					
Wet Weight	of								
Wt. in Water	50								
Difference	Blow								
Sp. Gravity									
Average	2.41			2.37		2.39	2.40	2.40	2.41
	95% = 2.29			98.3		99.1		99.1	

Marshall Stability

Load - Lbs.	2608			1775		2170	2400	2620	2480
Flow 0.01 In.	7			9		8	7	10	9
Average Load				2257					
				88.0				91.8	

	S.S.D.	Bulk S.S.D.	Absolute	H.R.B.
Sp. Gravity				
Absorption				

Wt. A.C. Start			
Wt. A.C. Reqd.			
Wt. A.C. Left			

Form 1295
3-74

BITUMINOUS WORK SHEET

Project No. FM-89(3)-55-89 Lab. Nos. ABC8-319
Project No.
Project No.
County Van Buren

Aggregates

% Aggregate	Agg. Lab. No.	Indivi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight

Batch Wt Agg.			
Pen. Asphalt			
Lab No. Asph.			
% Asphalt			
Batch Wt Asph			
Date Tested	8-30-78		

Specific Gravity Determination

	10 Blow			25 Blow			50 Blow		
Wt. in Air	Ave.								
Wet Weight	of			Blow					
Wt. in Water	50								
Difference	Blow								
Sp. Gravity									
Average	2.42			2.31		2.37	2.38	2.39	2.39

95% = 2.30 — 95% — 95% — 95%

Marshall Stability

Load - Lbs.	2168			1130		1670	1750	1880	2100
Flow 0.01 In.	14			11		11	11	13	13
Average Load									

	S.S.D.	Bulk S.S.D.	Absolute	H.R.B.
Sp. Gravity				
Absorption				

Wt. A.C. Start			
Wt. A.C. Reqd.			
Wt. A.C. Left			

Form 1295
3-74

BITUMINOUS WORK SHEET

Project No. P-193-0(2)-30 33 Lab. Nos. ADC8 - 309
Project No.
Project No.
County Fayette

Aggregates

% Aggregate	Agg. Lab. No.	Indivi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight

Batch Wt Agg.			
Pen. Asphalt			
Lab No. Asph.			
% Asphalt			
Batch Wt Asph			
Date Tested	8-30-78		

Specific Gravity Determination

		10 Blow		5 Blow	
Wt. in Air	Ave.				
Wet Weight	of				
Wt. in Water	50				
Difference	Blow				
Sp. Gravity					
Average	2.35	2.22	2.23	2.14	2.15

95% = 2.23

Marshall Stability

Load - Lbs.	2192	1350	1250	810	840
Flow 0.01 In.	17	12	13	17	16
Average Load					

	S.S.D.	Bulk S.S.D.	Absolute	H.R.B.
Sp. Gravity				
Absorption				

Wt. A.C. Start			
Wt. A.C. Reqd.			
Wt. A.C. Left			

Form 1295
3-74

BITUMINOUS WORK SHEET

Project No. FM-33(a)-55-33 Lab. Nos. ABC8-314
Project No.
Project No.
County Fayette

Aggregates

% Aggregate	Agg. Lab. No.	Indivi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight

Batch Wt Agg.			
Pen. Asphalt			
Lab No. Asph.			
% Asphalt			
Batch Wt Asph			
Date Tested	8-30-78		

Specific Gravity Determination

		20 Blow		25 Blow		
Wt. in Air	Ave. of 50 Blow	10 Blow				
Wet Weight						
Wt. in Water						
Difference						
Sp. Gravity						
Average	2.33	2.23	2.27	2.27	2.27	2.28
95% = 2.21		95.7	97.4		97.9	

Marshall Stability

Load - Lbs.	2100	800	1180	1220	1380	1300
Flow 0.01 In.	7	10	8	8	8	7
Average Load		990	1199	1220	1380	1300

	S.S.D.	Bulk S.S.D.	Absolute	H.R.B.
Sp. Gravity				
Absorption				

Wt. A.C. Start			
Wt. A.C. Reqd.			
Wt. A.C. Left			

Form 1295
3-74

BITUMINOUS WORK SHEET

Project No. M-2808 (1)- 81-77 Lab. Nos. ABC8-335
Project No.
Project No.
County Polk ATB

Aggregates

% Aggregate	Agg. Lab. No.	Indivi. Wt. Agg.	Comb. Wt. Agg.	Sp. Gr. Weight

Batch Wt Agg.			
Pen. Asphalt			
Lab No. Asph.			
% Asphalt			
Batch Wt Asph			
Date Tested	8-30-78		

Specific Gravity Determination

	30 Blow			40 Blow			45 Blow		
Wt. in Air	Ave.								
Wet Weight	of								
Wt. in Water	50								
Difference	Blow								
Sp. Gravity									
Average	2.29			2.23		2.25	2.26	2.28	2.28

95% = 2.18 97.4 98.3 98.7

Marshall Stability

Load - Lbs.	1167			975		1150	1370	1450	1340
Flow 0.01 In.	7			10		8	6	7	7
Average Load									

	S.S.D.	Bulk S.S.D.	Absolute	H.R.B.
Sp. Gravity				
Absorption				

Wt. A.C. Start			
Wt. A.C. Reqd.			
Wt. A.C. Left			