MLR 82 1

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

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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

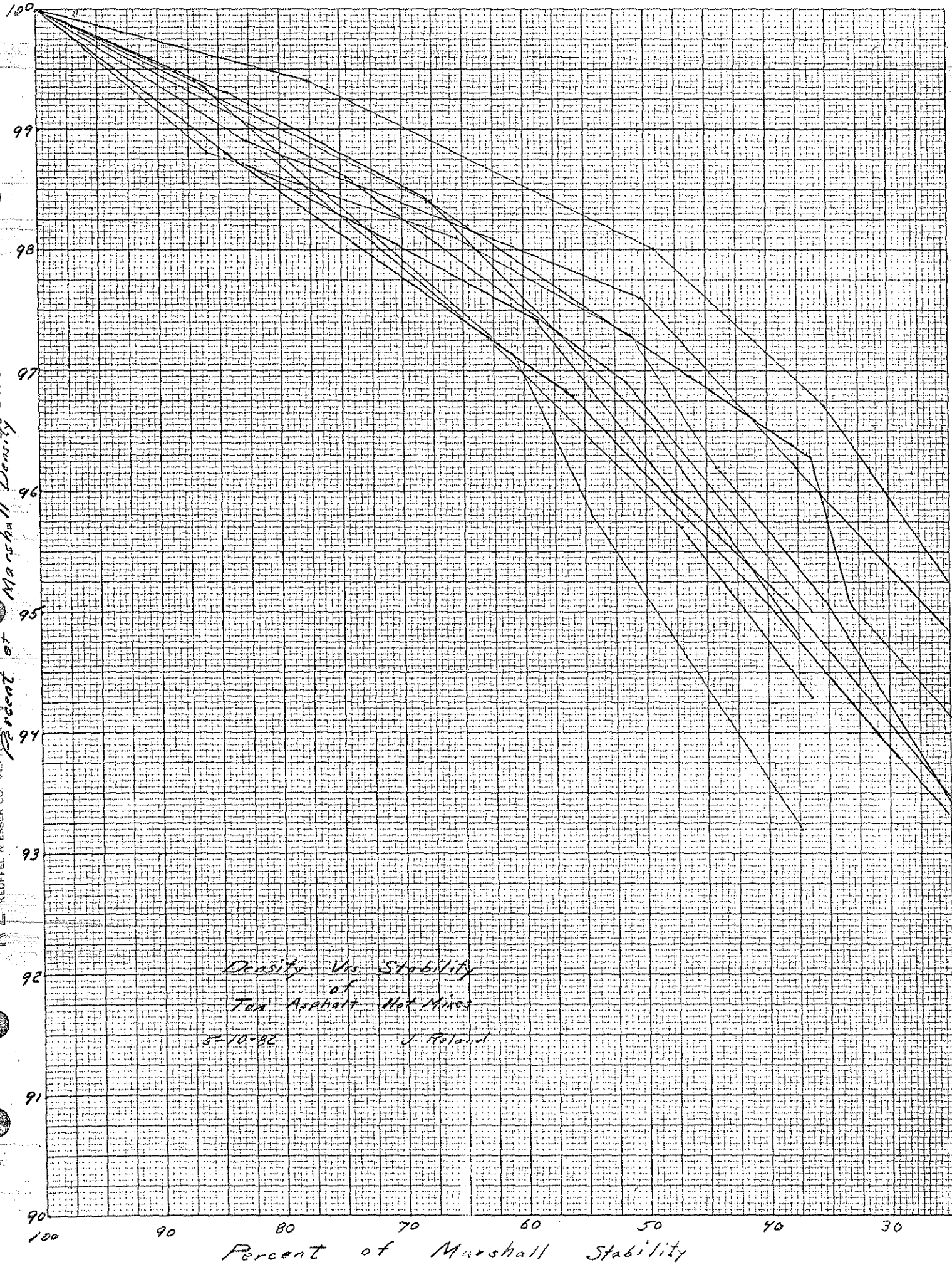
The same graph shows that to obtain 75 percent of 50 blow Marshall stability a density greater than 98 percent was required for all ten mixes. To obtain 50 percent of 50 blow Marshall stability then a density equal to or greater than 96 percent was required for nine of the ten mixes tested.

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 Density
100
90
80
70
60
50
40
30
Percent of Marshall Stability
Density Vs. Stability
of
Tex Asphalt Hot Mixes
5-10-82
J. Roland
K+E 10 X 10 TO 1 INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 1470

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.R.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	2700	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 (Wonth - 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		

Specific Gravity Determination

	12 Blow			7 Blow					
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	1000	1025	1100			
Flow 0.01 In.	13	13	13	15	16	16			
Average Load	1515		13	1042		16			
		54.4 %			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. ABC1-442
Project No.
Project No.
County (Polk BGP-000B(6)-74-77) (ABD1-108)

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	1138.0	1138.0
Wet Weight	1164.5	1164.5	1165.0	1153.0	1151.5	1153.5	1127.5	1138.0	1138.0
Wt. in Water	662.5	661.5	663.0	650.0	649.0	[illegible]	630.0	[illegible]	[illegible]
Difference	503.0	503.0	502.0	503.0	502.5	503.0	497.5	499.0	499.0
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	890	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 Below	

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

Specific Gravity Determination

	12 Blow			7 Blow					
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	657		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. 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	Koch 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	Koch 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. (ABCI-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		
	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 %			56.0 %		

	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-448)
Project No.
Project No (Adair - SN-6085(9)..51-09) (ABDI-169)
County

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

	4								
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. ABCI-449
Project No.
Project No.
County (Hardin HES-20-5(23)--2H-42) (ABDI-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	108 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	8	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. ABCI-449
Project No.
Project No.
County (Hardin HES-20-5(23)--2H.42) (ABDI-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	90-10	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	ABTL 322	+4 (58) 3480	3480	
		-4 (42) 2520	6000	
50	ABTL 323	6000	12,000	

Batch Wt Agg.	12000		
Pen. Asphalt	Pen. 92		
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	1162.0	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. (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	AATL-322	-4 (58) 3480	3480	
		-4 (42) 2520	6000	
50	AATL 323	6000	12,000	

Batch Wt Agg.	12000		
Pen. Asphalt	Pen. 82		
Lab No. Asph.	AB9-290		
% 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	1117.0	1117.5	1117.0			
Wet Weight	1130.0	1133.5	1134.5	1118.5	1119.0	1119.0			
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	ABD1-656	+4(63) 5292	5292	
		-4(37) 3108	8400	
30	ABD1-655	3600	12,000	

Batch Wt Agg.	12,000		
Pen. Asphalt	06-10	Pen 82	
Lab No. Asph.	ABD-290		
% 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	1330	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 %		

	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. (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	ABT1-656	+4 (63)	5292	5292	
		-4 (37)	3108	8400	
30	ABT1-655		3600	12,000	

Batch Wt Agg.	12,000		
Pen. Asphalt	AC-10	Pen 82	
Lab No. Asph.	ABT-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	400			
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. ABCI-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. ABCI-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.	12000		
Pen. Asphalt	AC-10	Pen. 110	
Lab No. Asph.	ABO-6		
% Asphalt	6.25		
Batch Wt Asph	800		
Date Tested	3-23		

Specific Gravity Determination

	50 Blow			32 Blow			18 Blow		
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		

Absolute	H.R.B.

Wt. A.C. Start	3100	2200	
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	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.	ABO-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. (ABD1-145)
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	AAT1-576	+8 (43) 2838	2838	
		-8 (57) 3762	6600	
30	AAT1-577	+4 (55) 1980	8580	
		-4 (45) 1620	10200	
15	AAT1-578	1800	12000	

Batch Wt Agg.	12000		
Pen. Asphalt	AC-10	Pen. 94	
Lab No. Asph.	ABD-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	1197.5	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	2.274	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	AAT1-576	+8 (43) 2838	2838	
		-8 (57) 3762	6600	
30	AAT1-577	+4 (55) 1980	8580	
		-4 (45) 1620	10200	
15	AAT1-578	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		

Specific Gravity Determination

	12 Blow			7 Blow					
Wt. in Air	1153.0	1143.0	1153.5	1139.0	1138.0	1136.5			
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

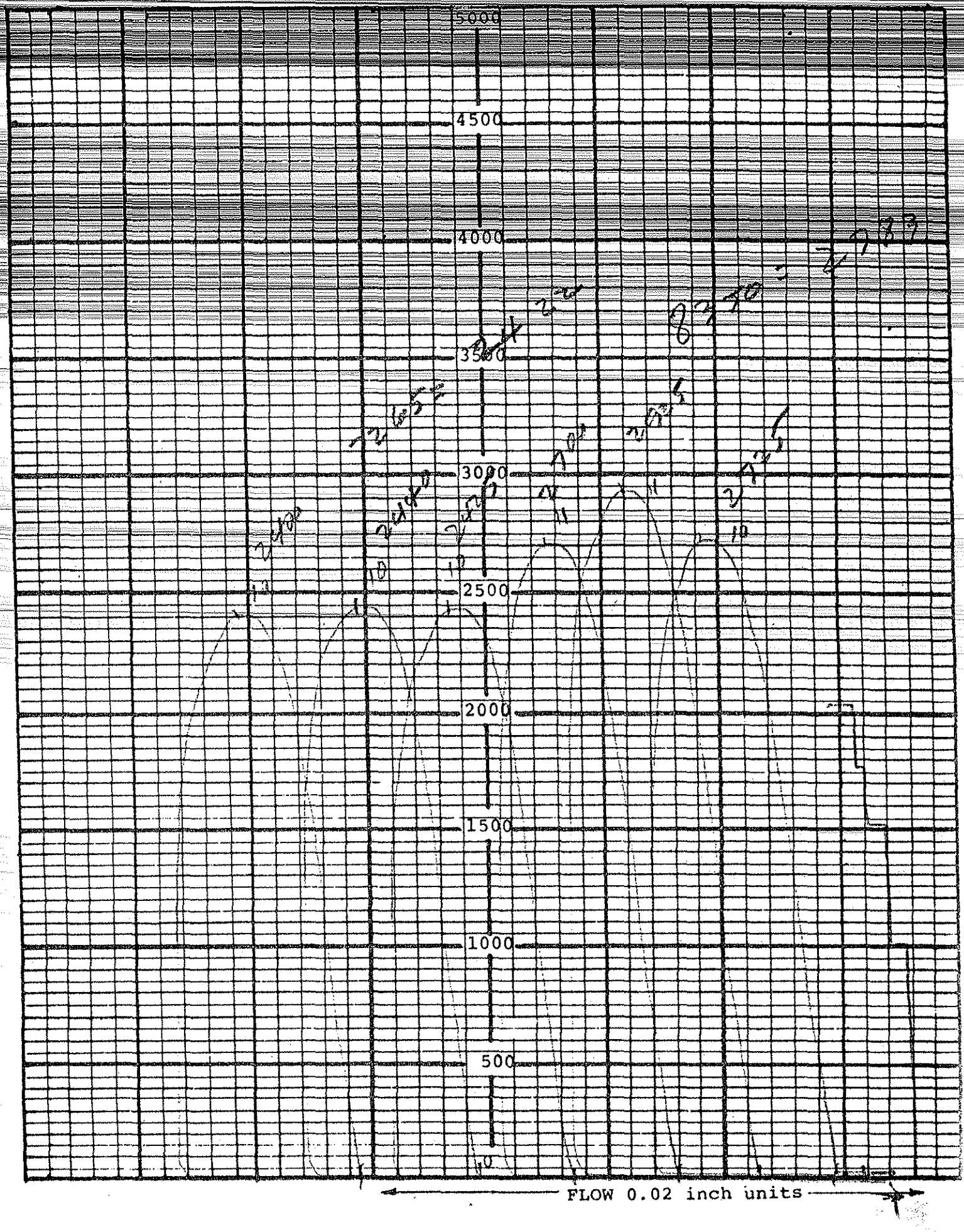
	S.S.D.	Bulk S.S.D.
Sp. Gravity		
Absorption		

Absolute	H.R.B.

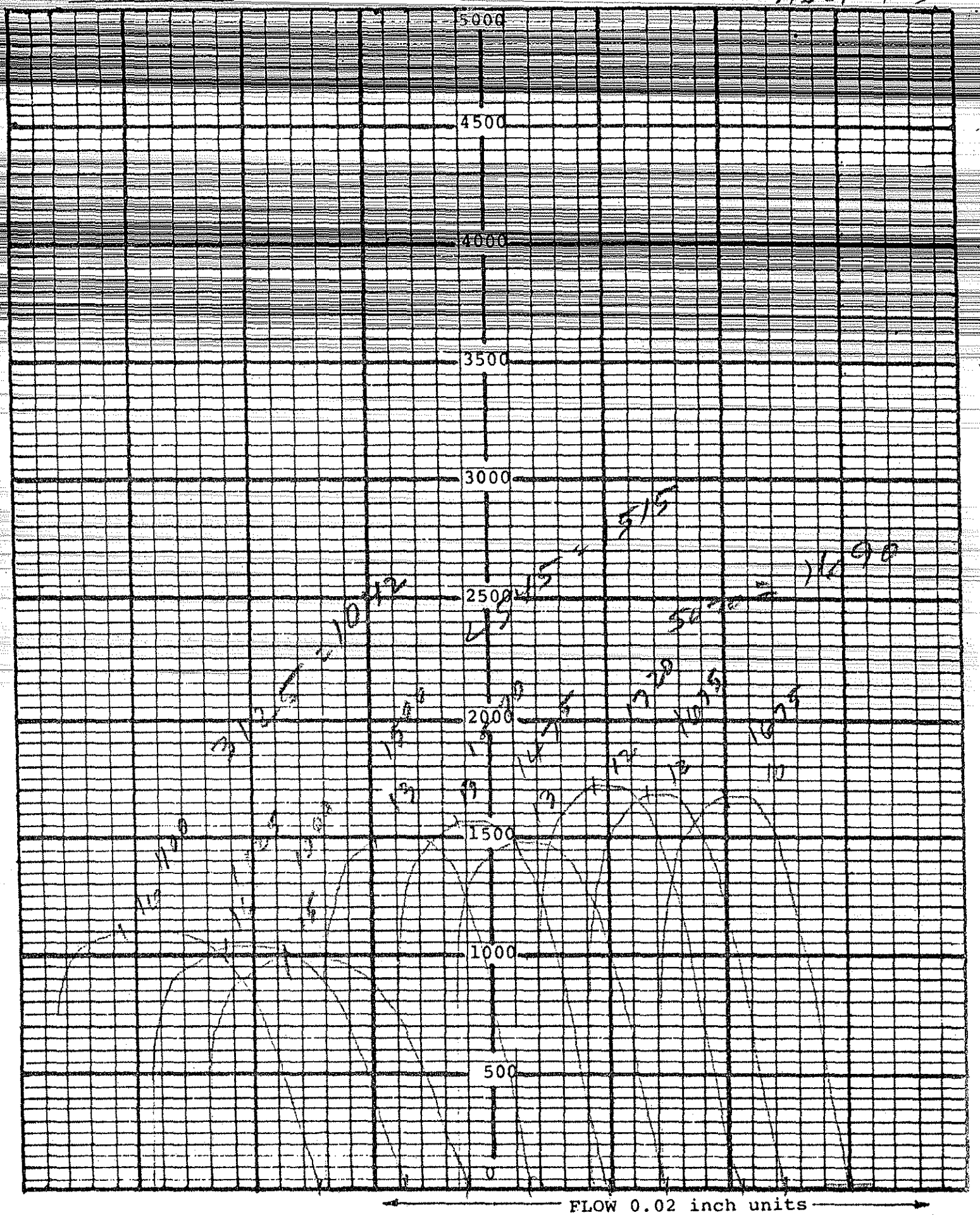
Wt. A.C. Start	1166		
Wt. A.C. Reqd.	766		
Wt. A.C. Left	400		

APPENDIX C

Date 2-[illegible] Percent AC Stability Flow Lab No. 403

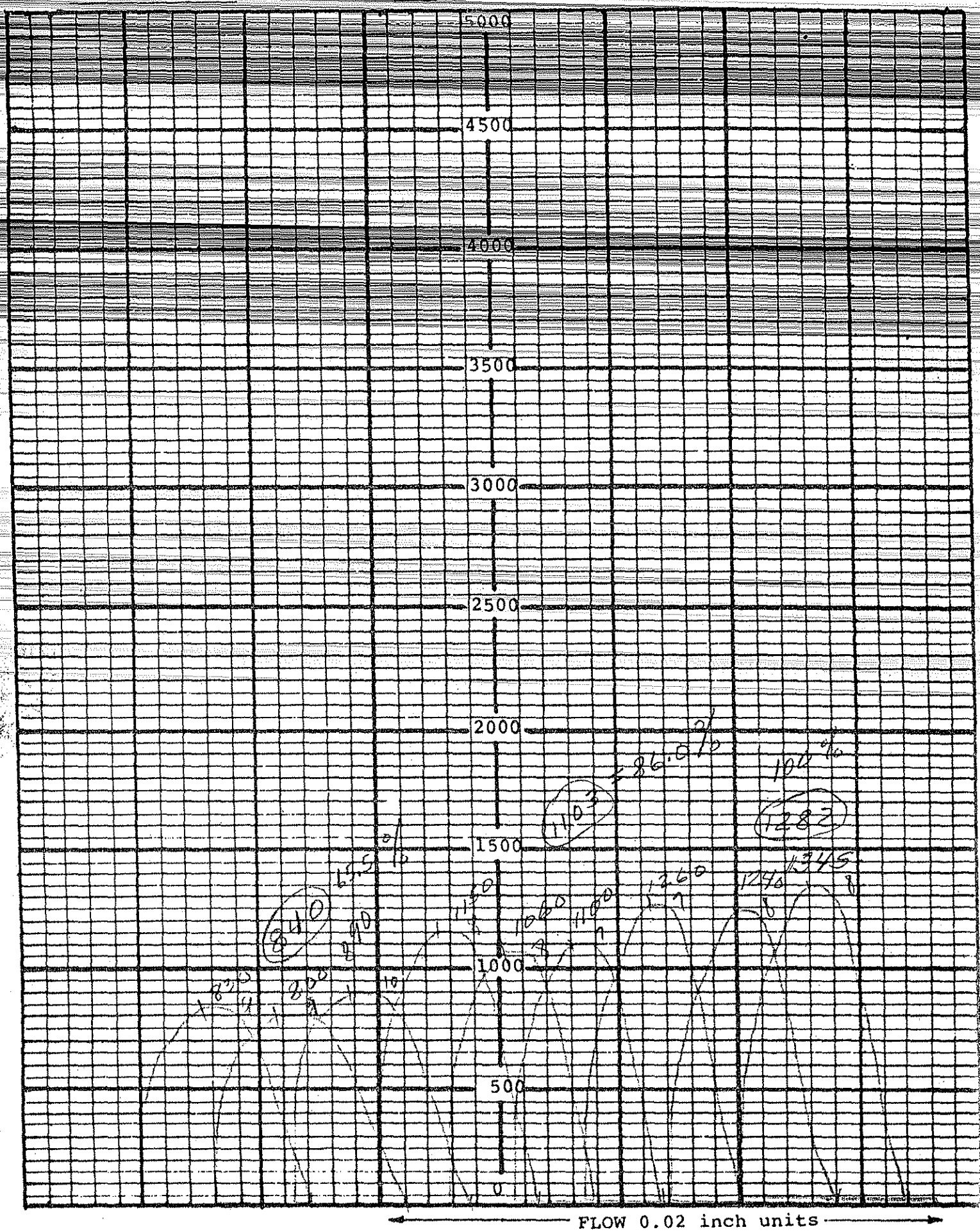


Date 2-22 Percent AC _____ Stability _____ Flow _____ ABCp-403

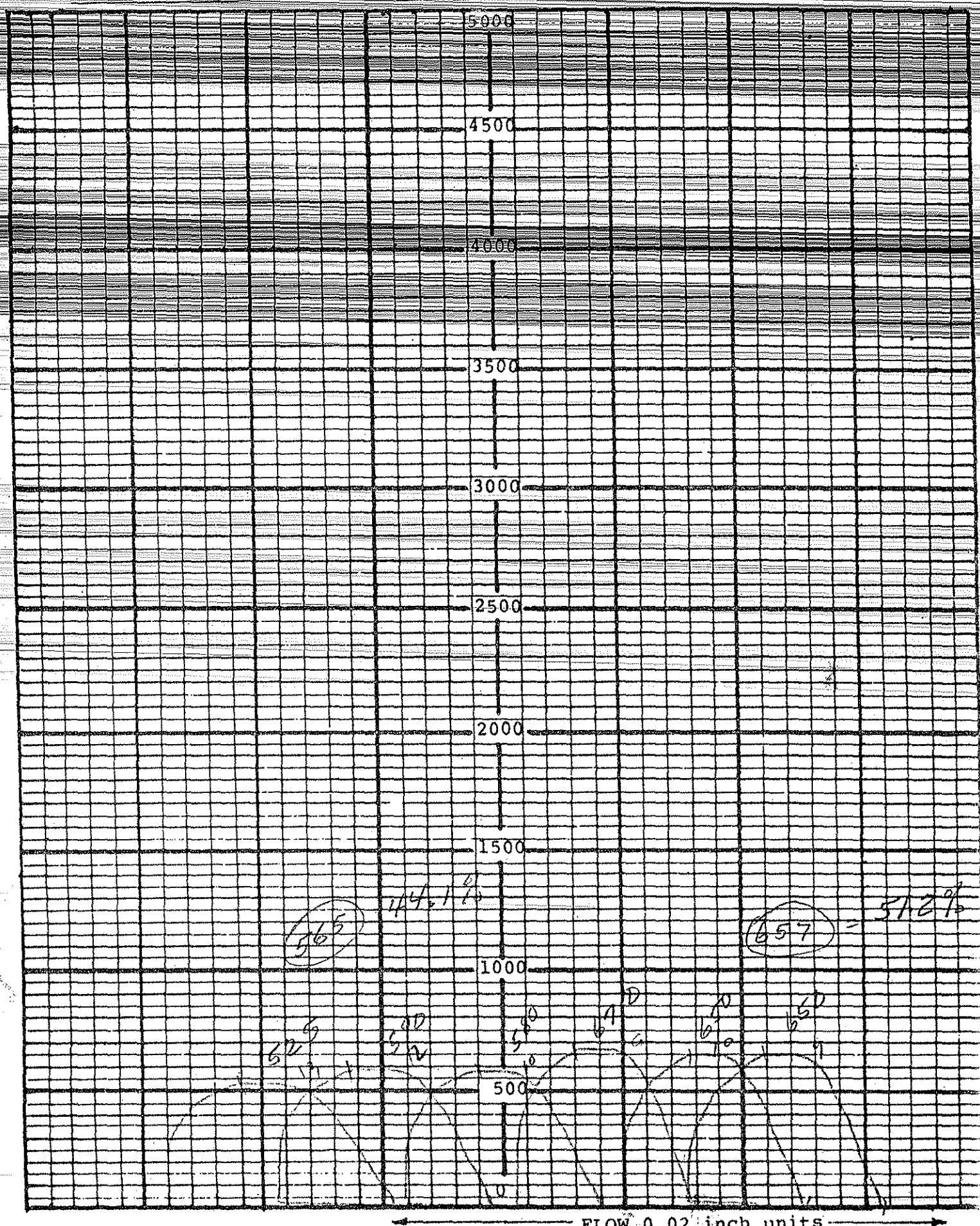


18 32 MBC1-442 50

Date 2-23 Percent AC Stability Flow Lab No. 442

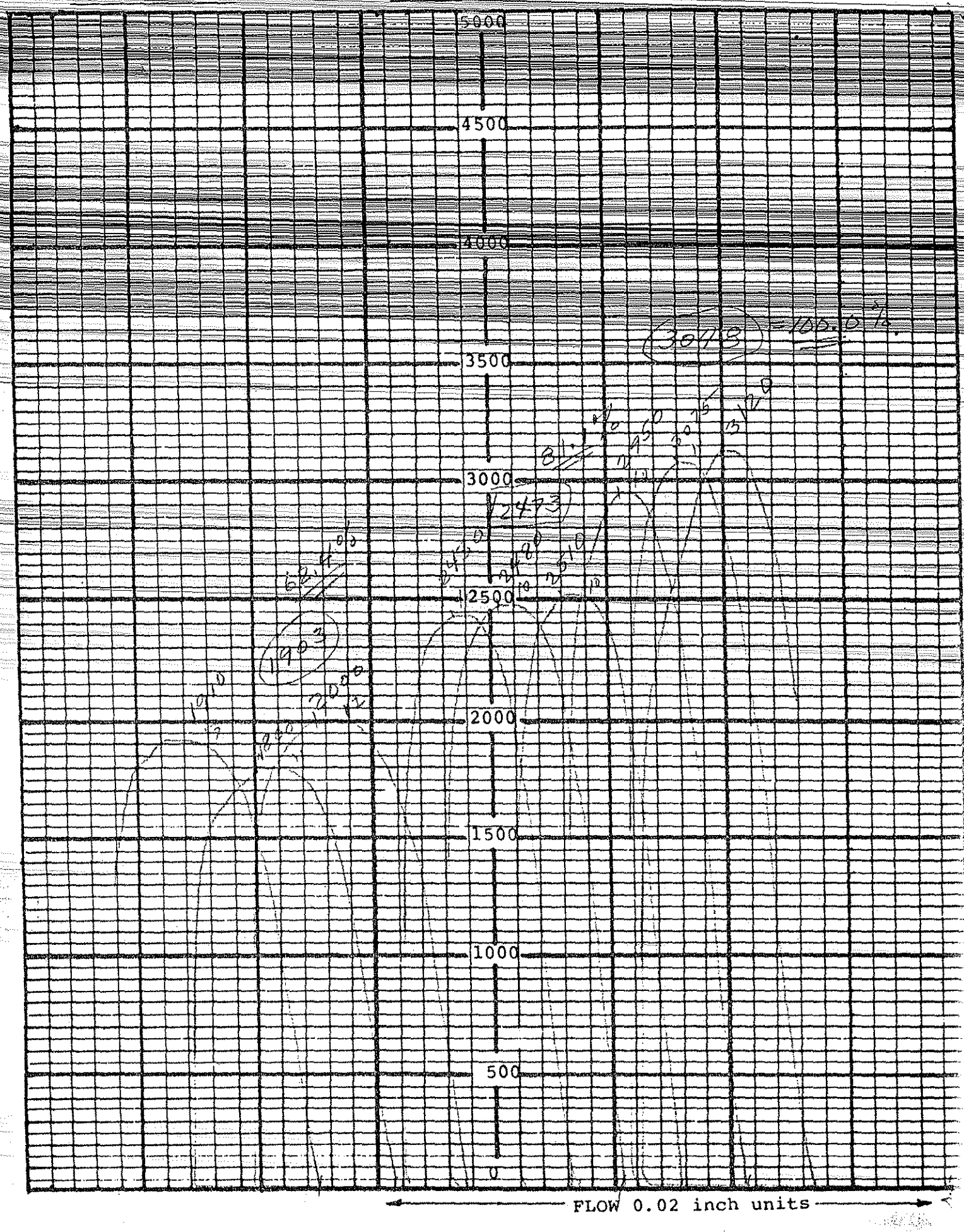


Date 2-23 Percent AC 7 Stability Flow 12 Lab No. 442

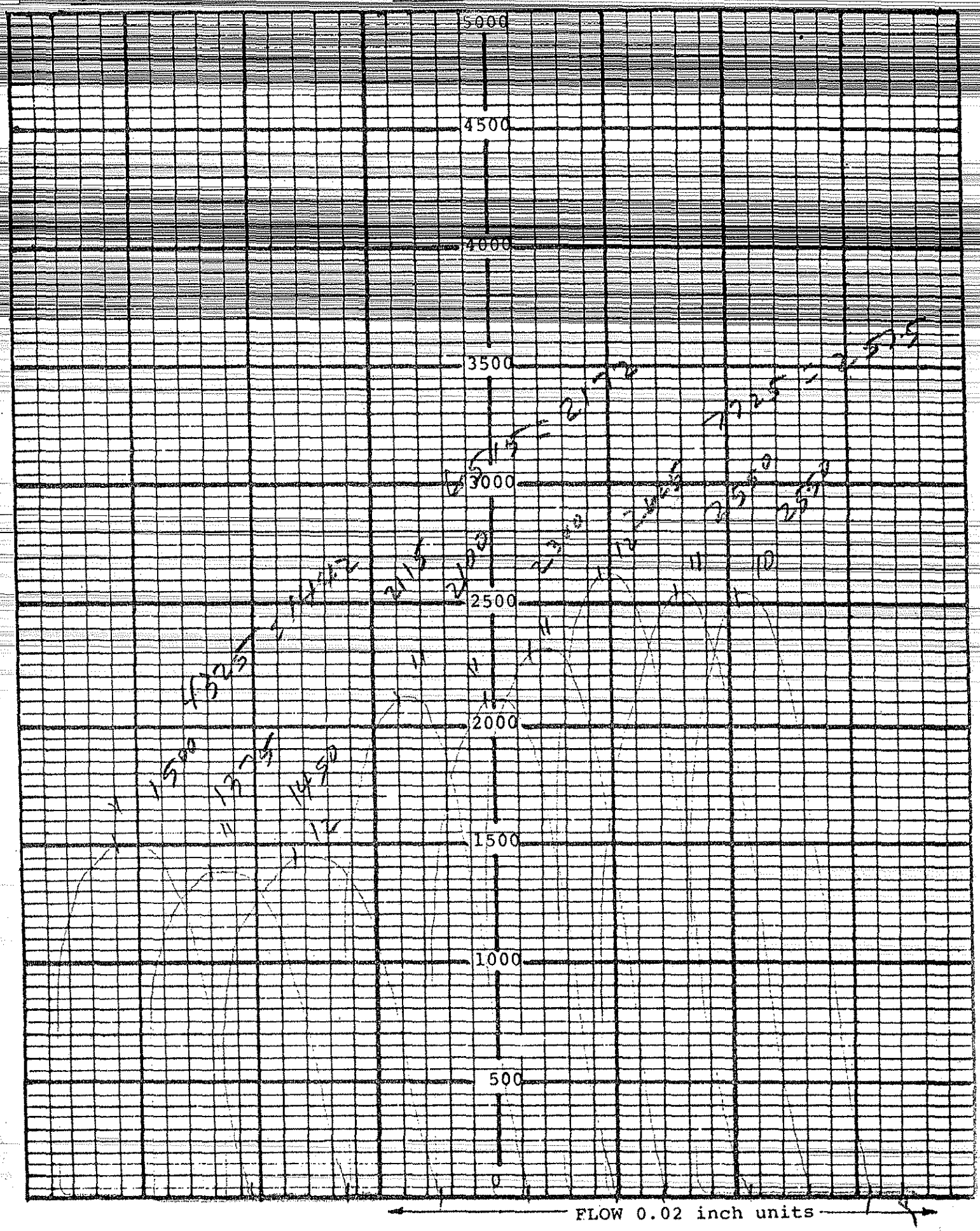


16 32 50

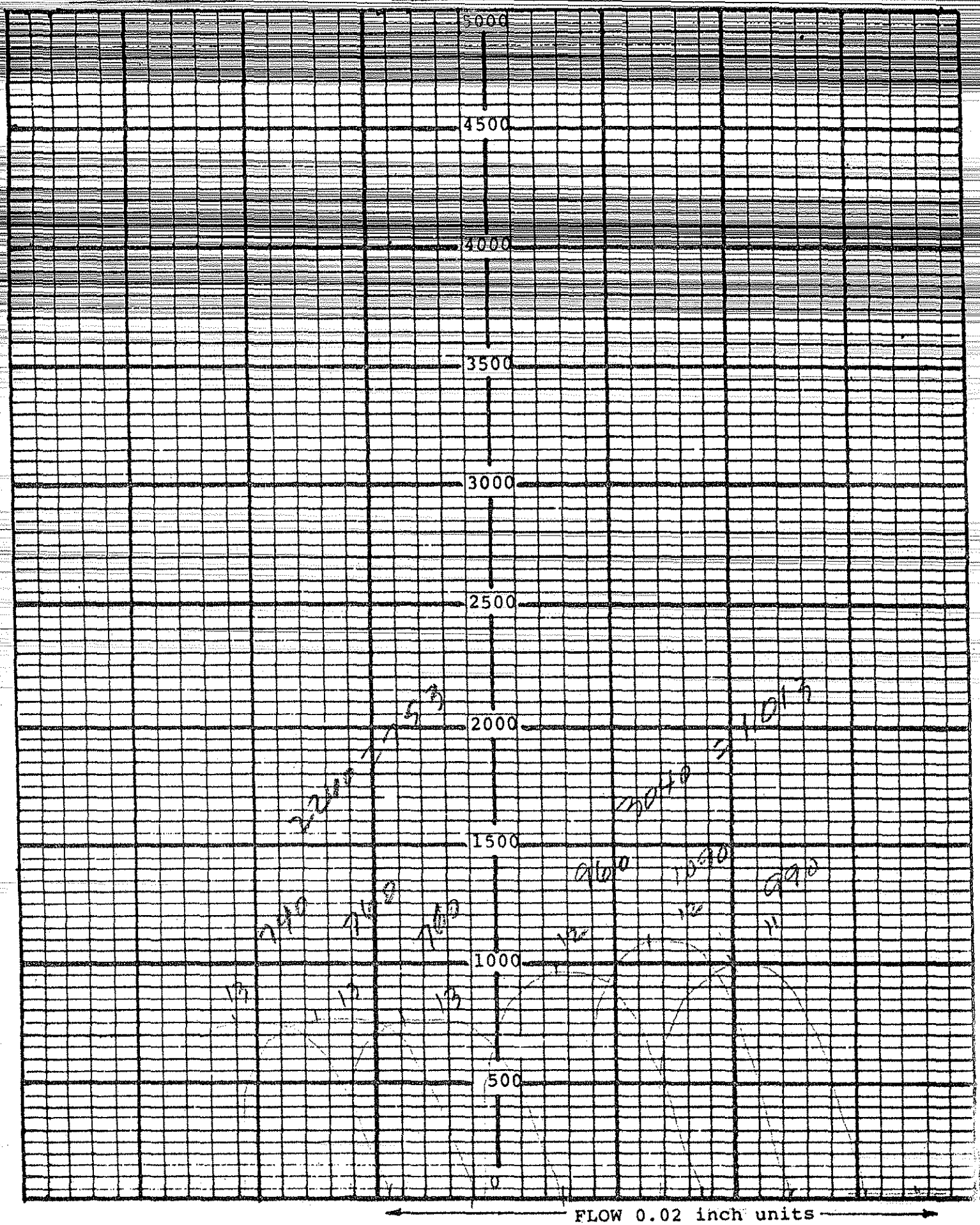
Date 9-24 Percent AC Stability Flow Lab No. RBC1-147



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

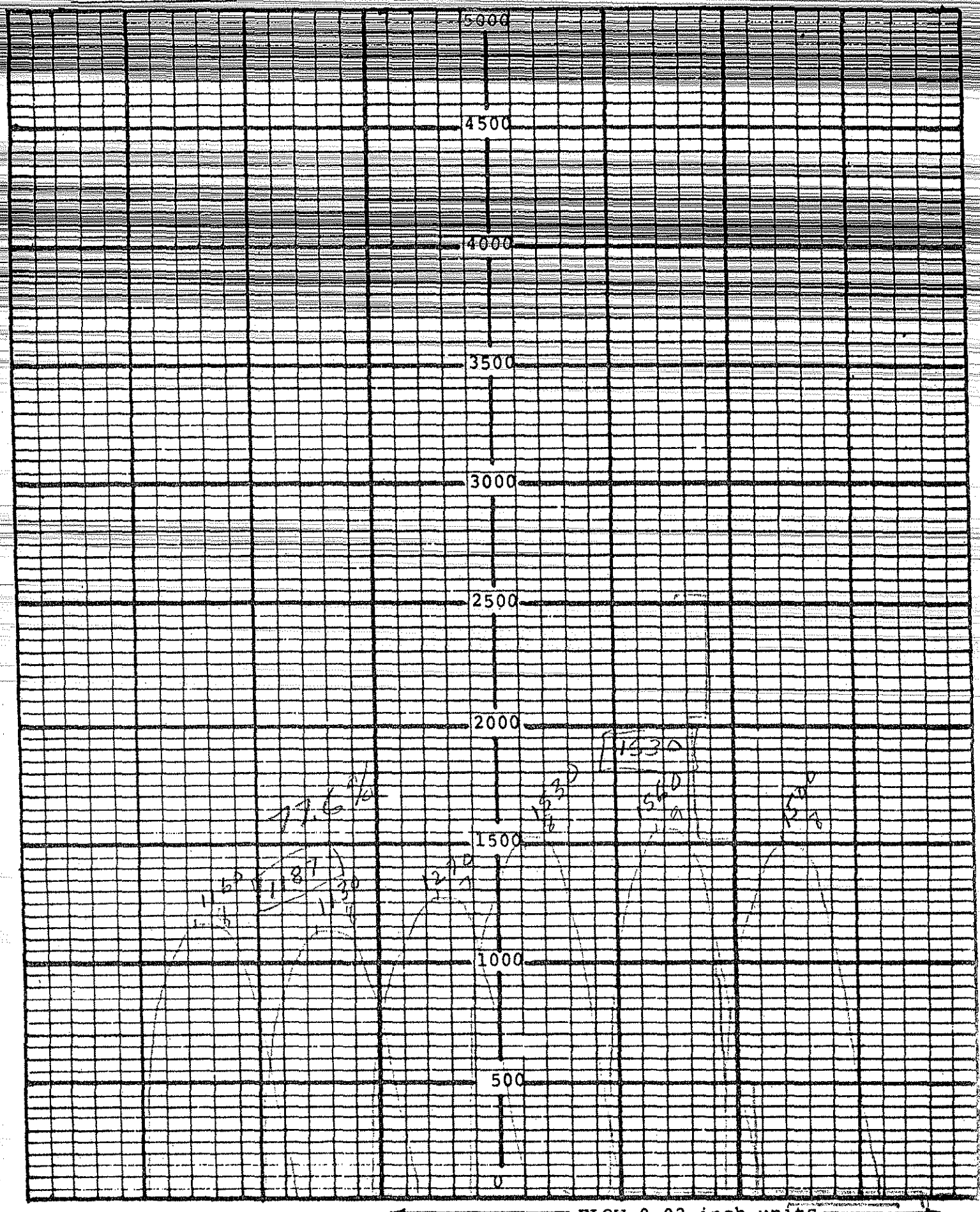


Date 2-26 Percent AC 7 Stability Flow 12 Lab No. 1-448



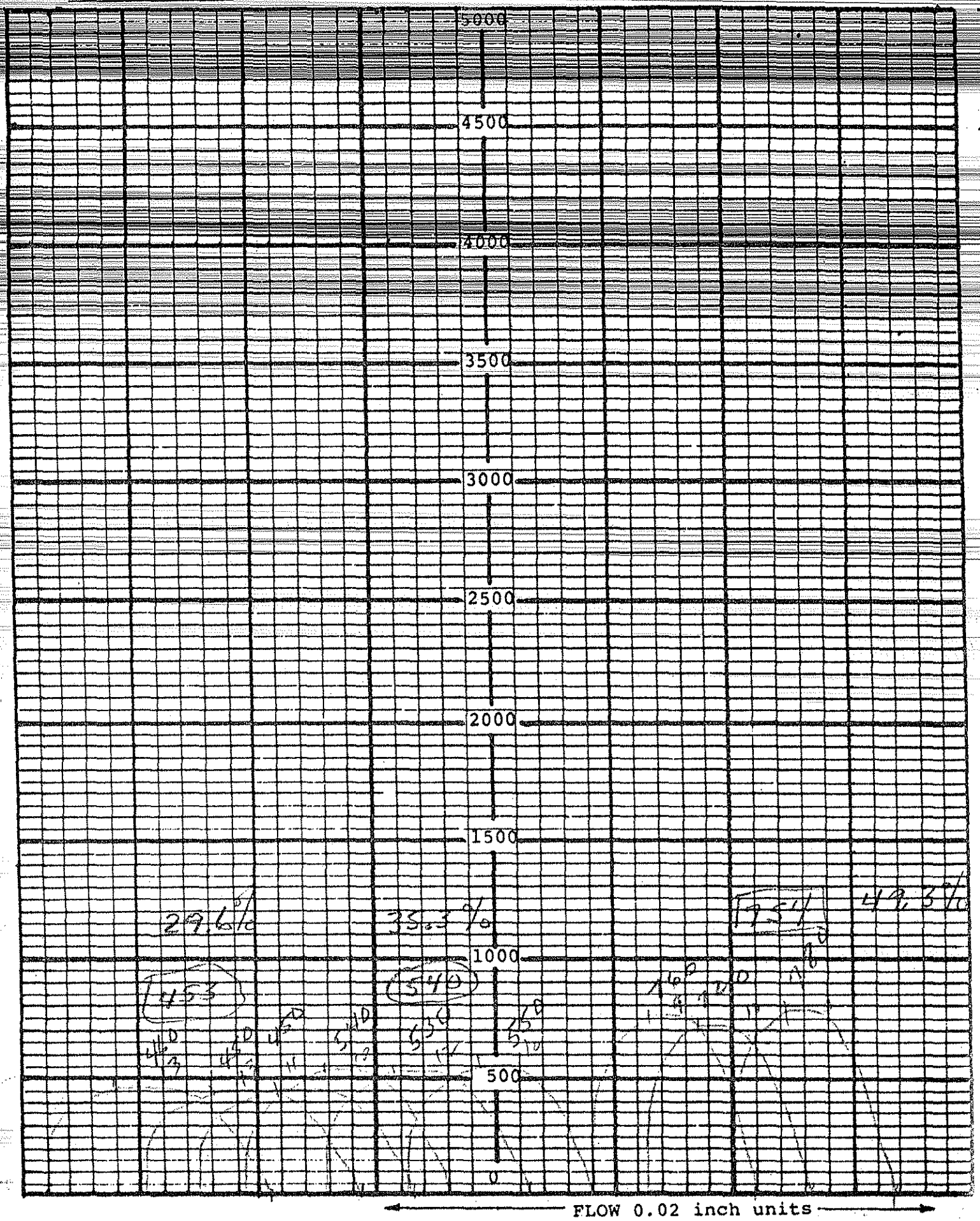
ABCI-449

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



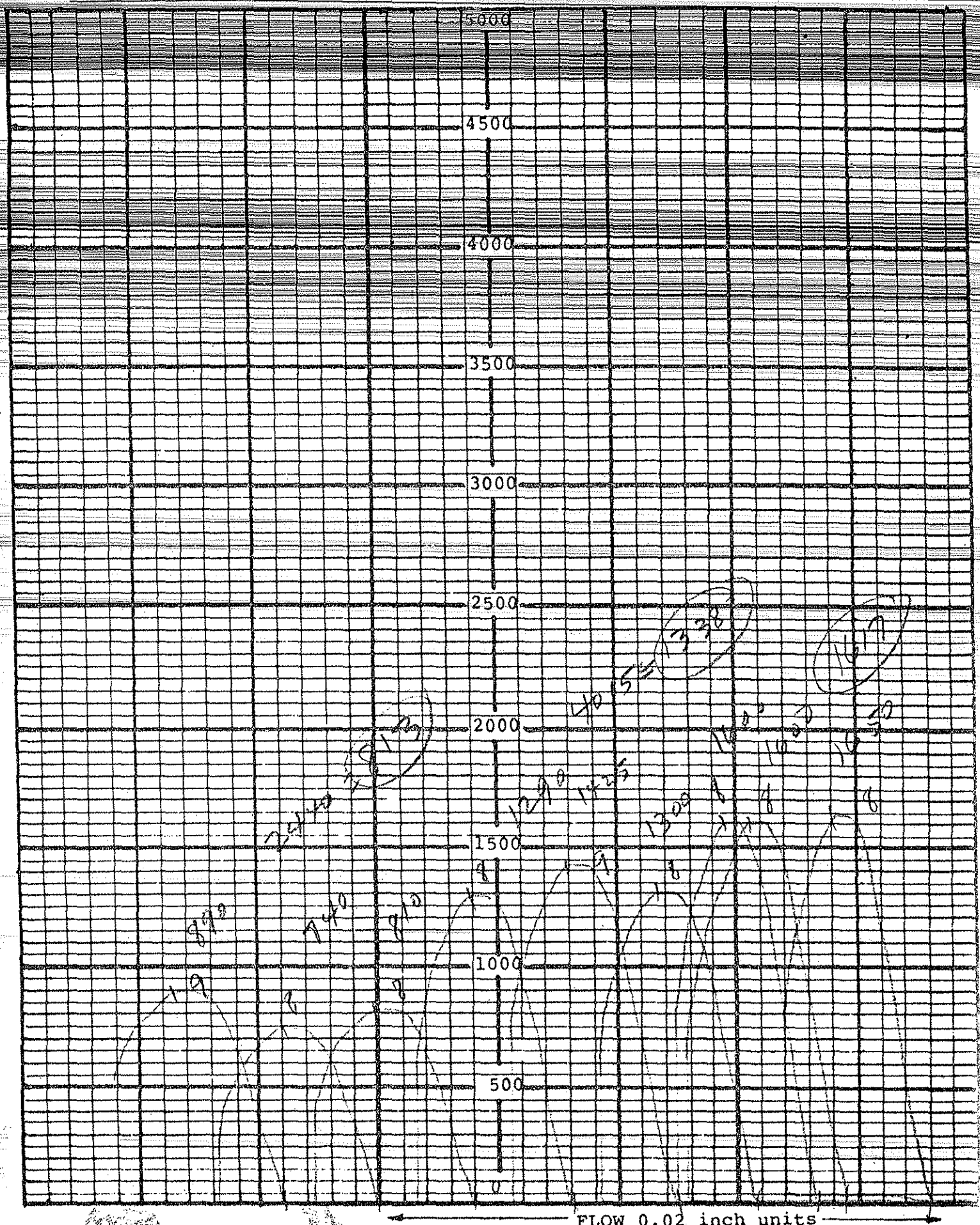
7 — 12 — 18 Blows 7-12-18

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

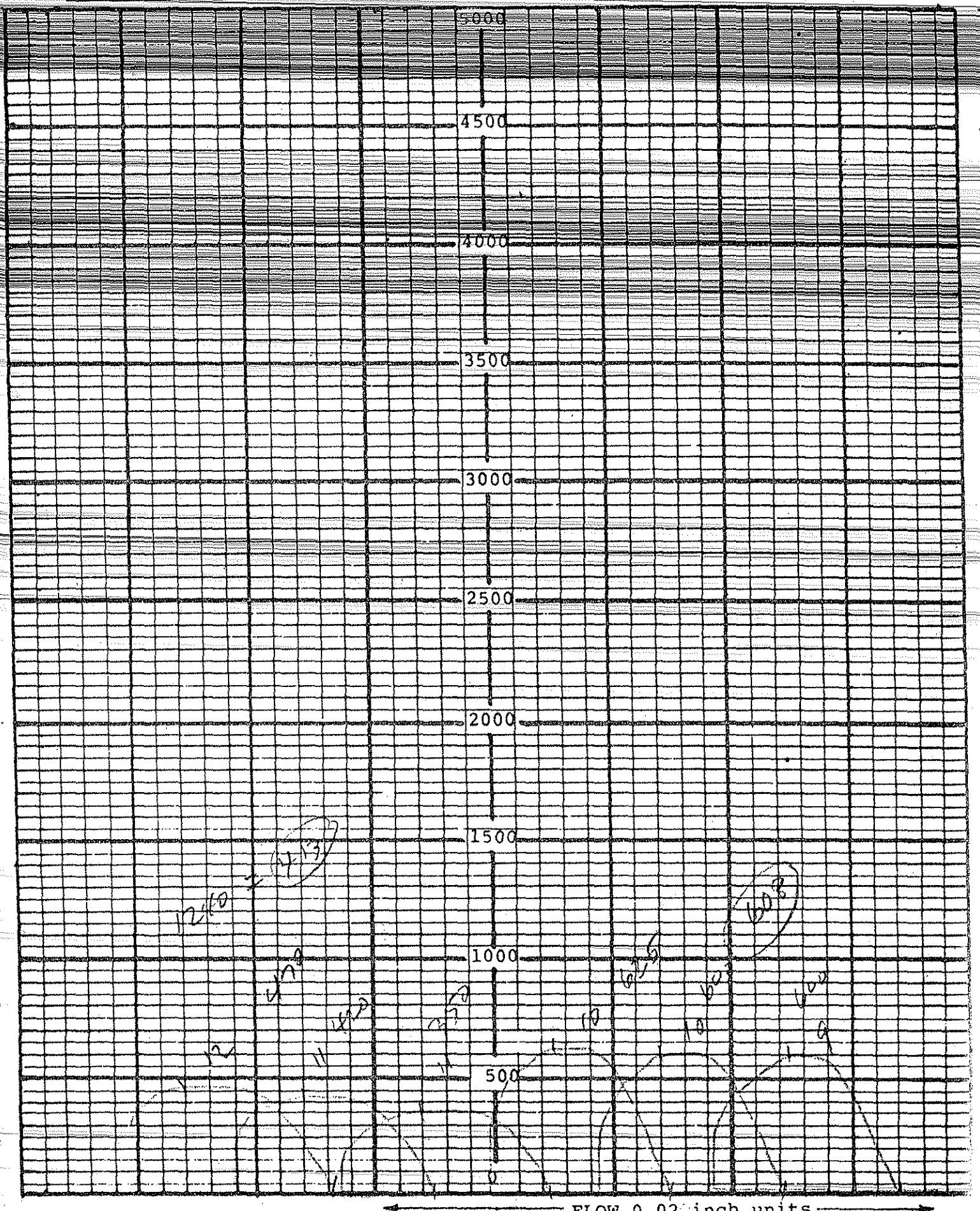


ABL-97

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

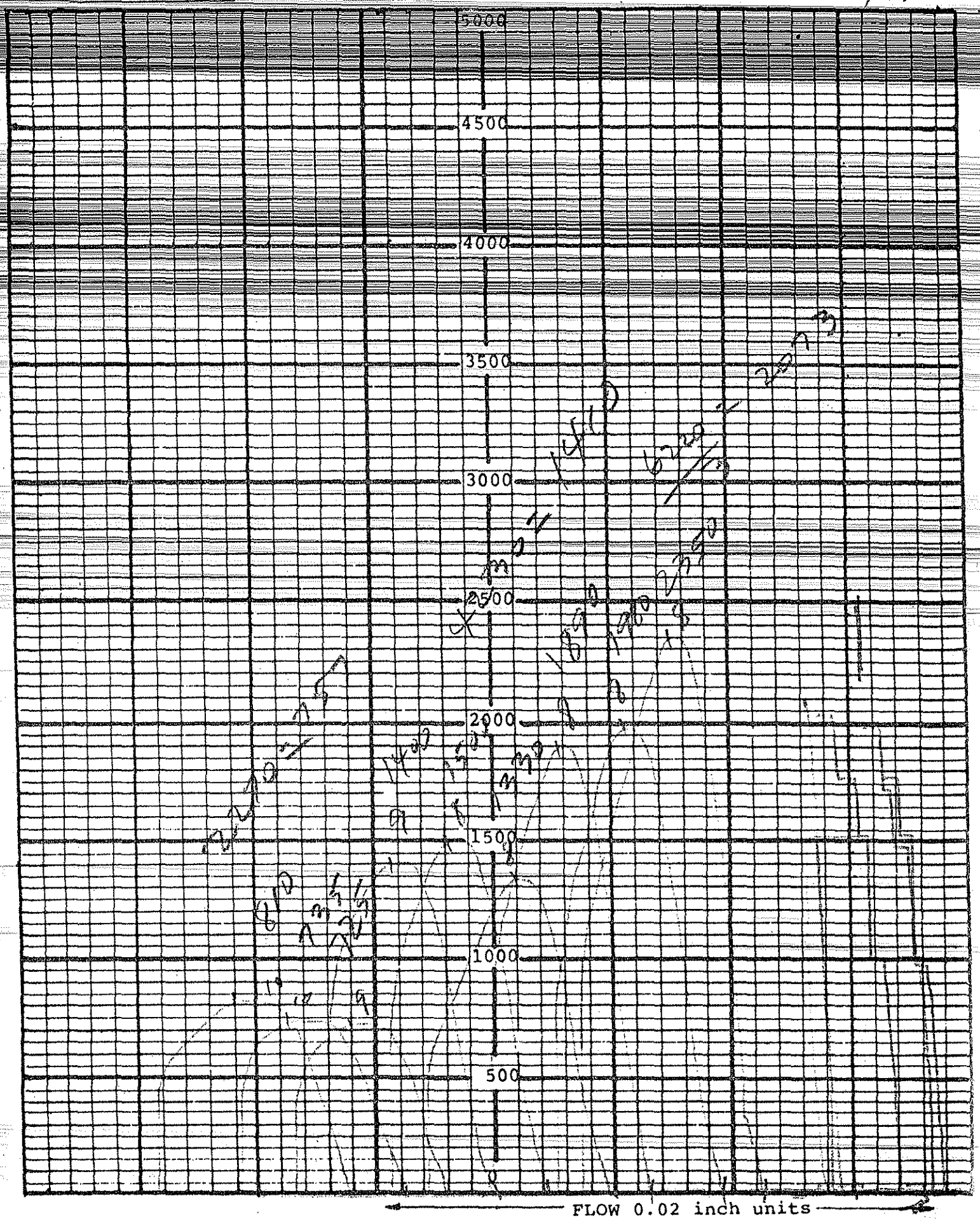


Date 3-11 Percent AC _____ Stability _____ Flow 97 Lab No. 7 12



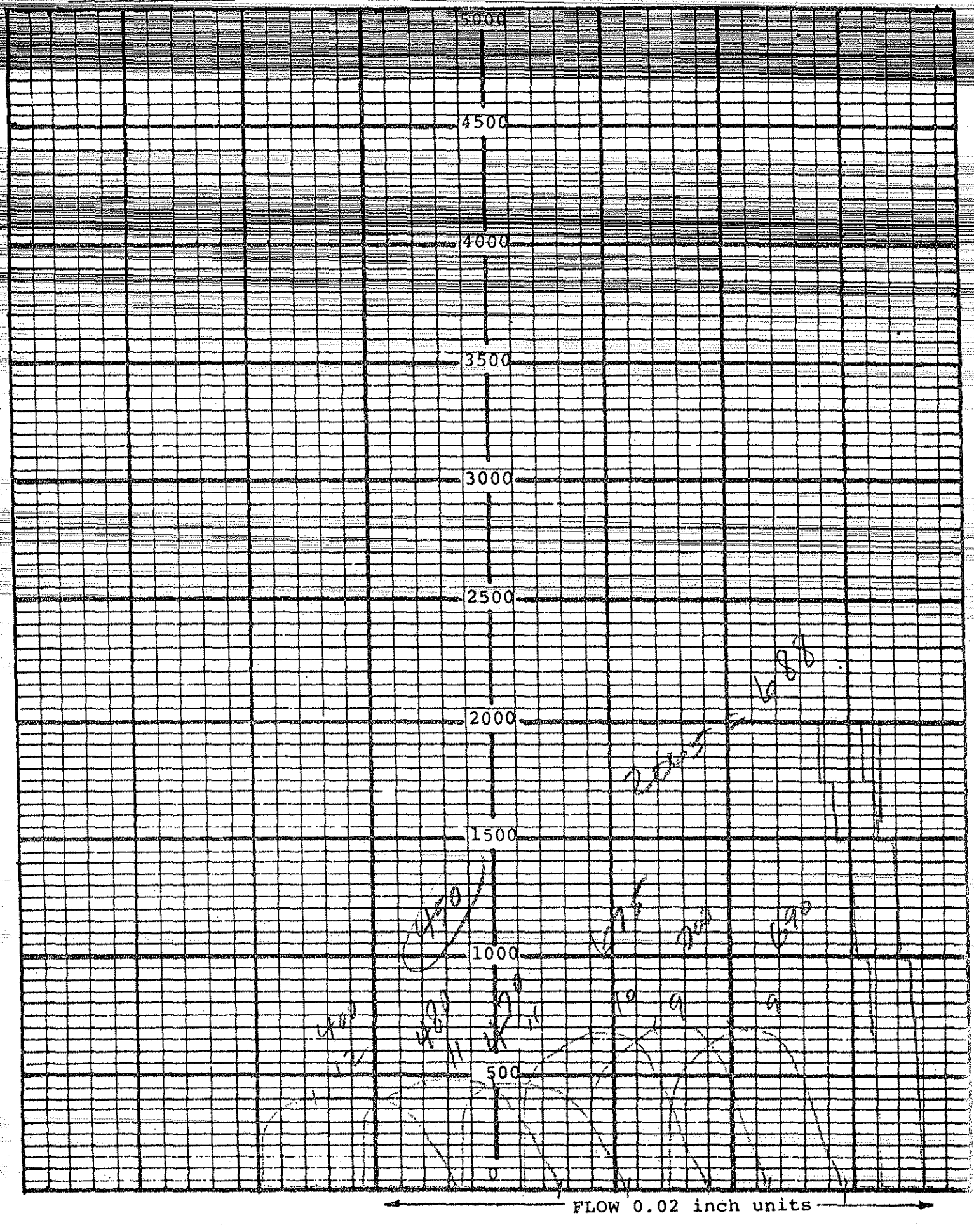
A-BDI-168

Date 3-15 Percent AC _____ Stability _____ Flow 168 Lab No. [illegible]



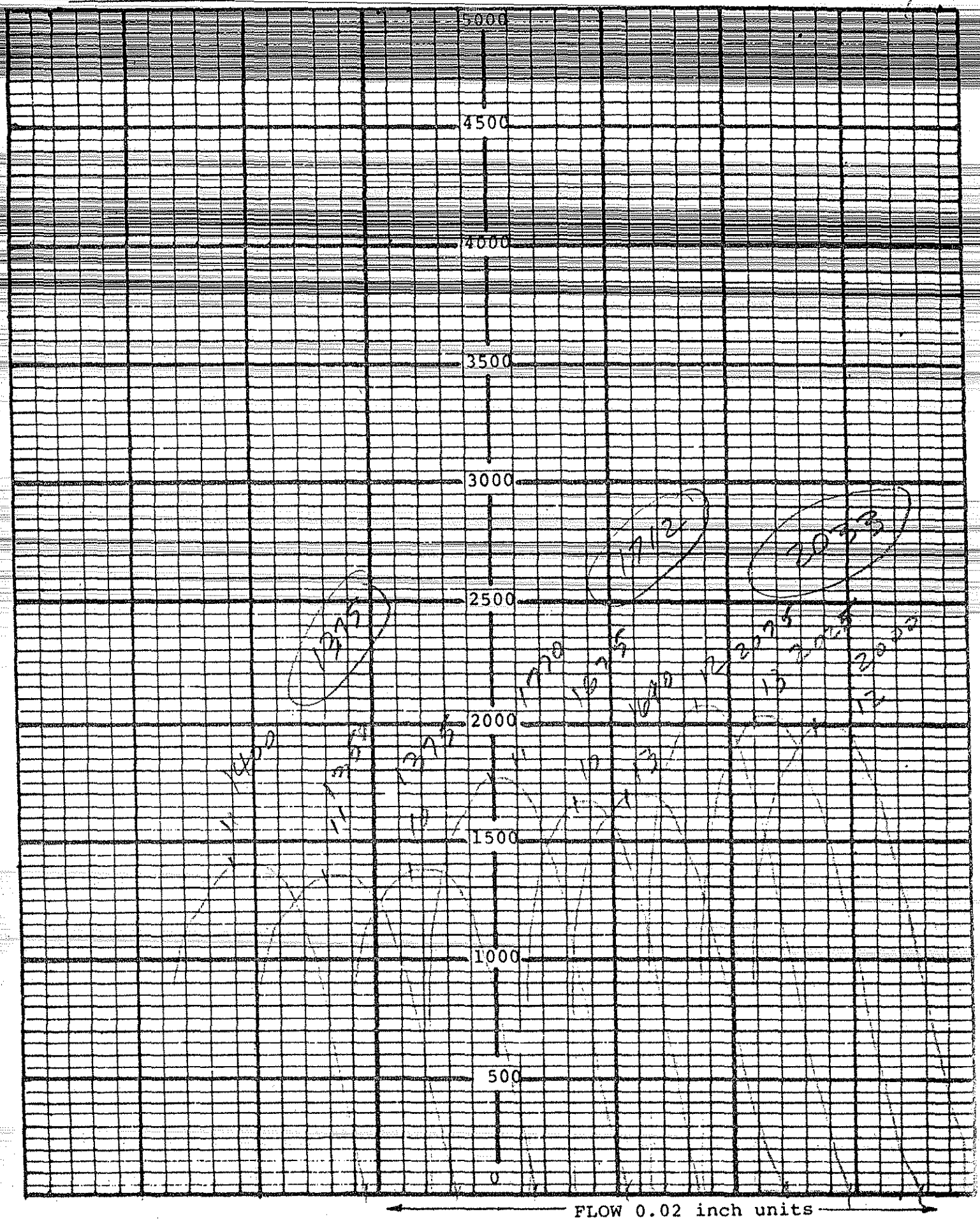
168

Date 3-15 Percent AC _____ Stability _____ Flow _____ Lab No. 1 12

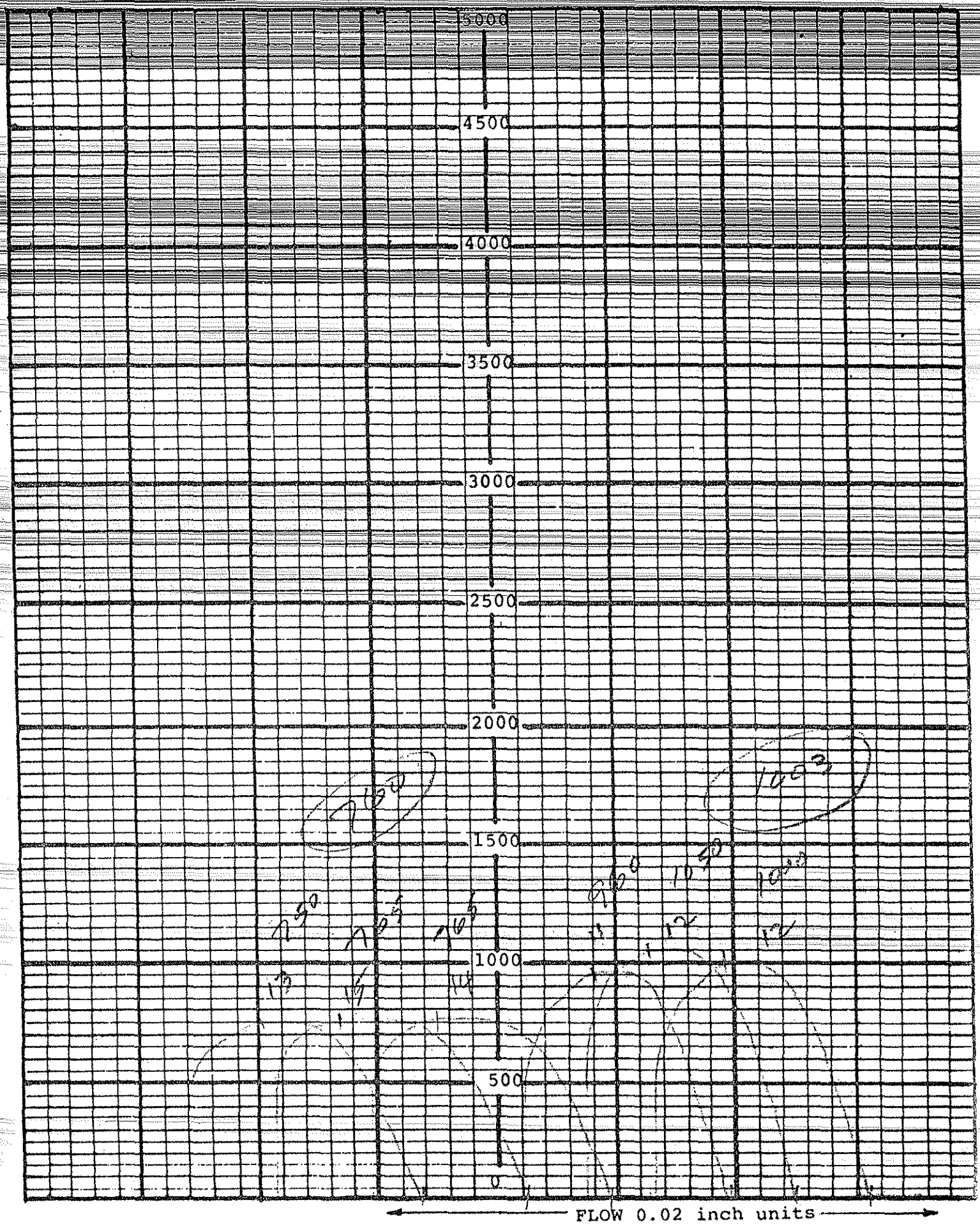


ABCL 444

Date 3-49 Percent AC _____ Stability _____ Flow _____ Lab No. 18/32/50

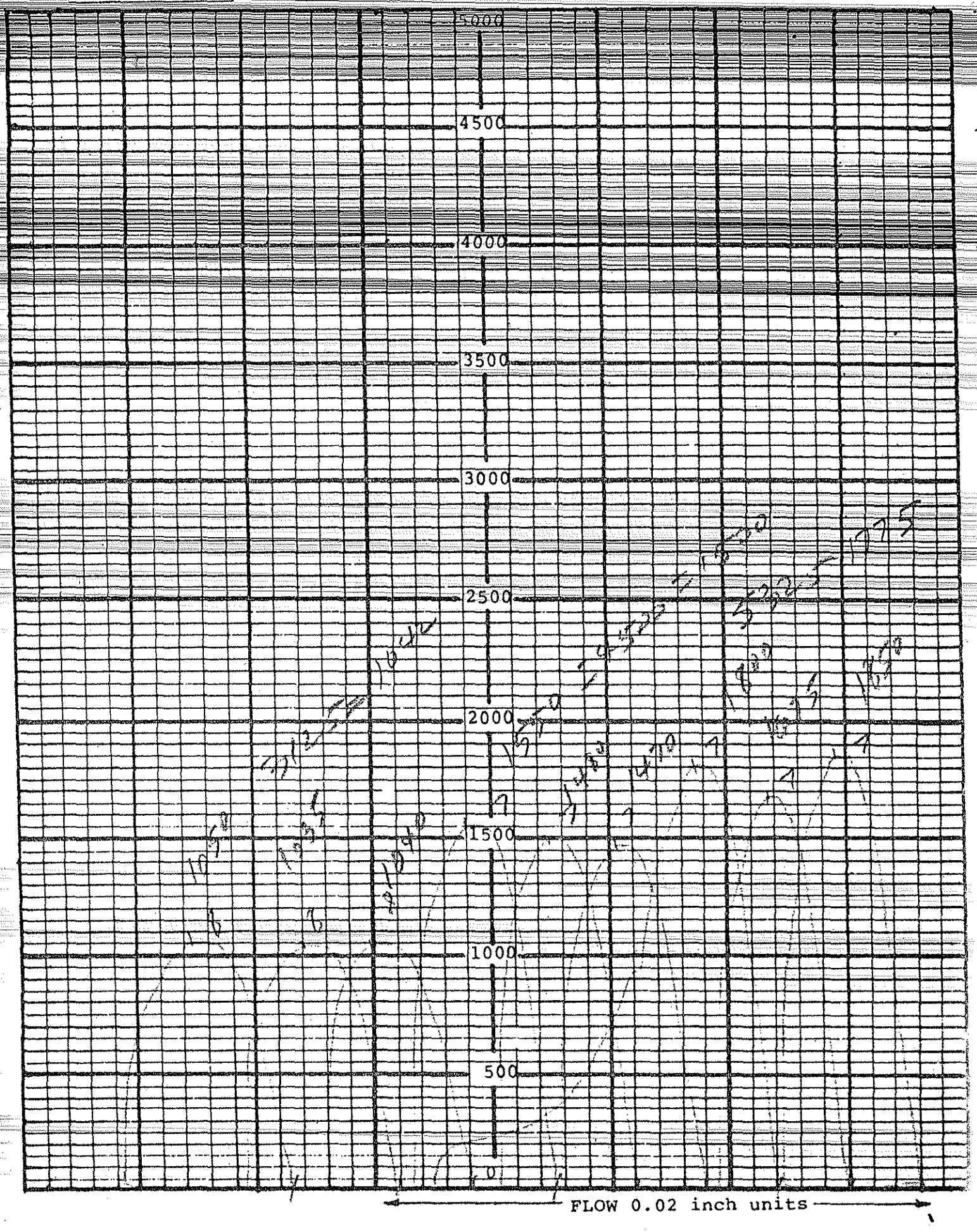


Date 3-12 Percent AC Stability 44 Flow Lab No. 1/12

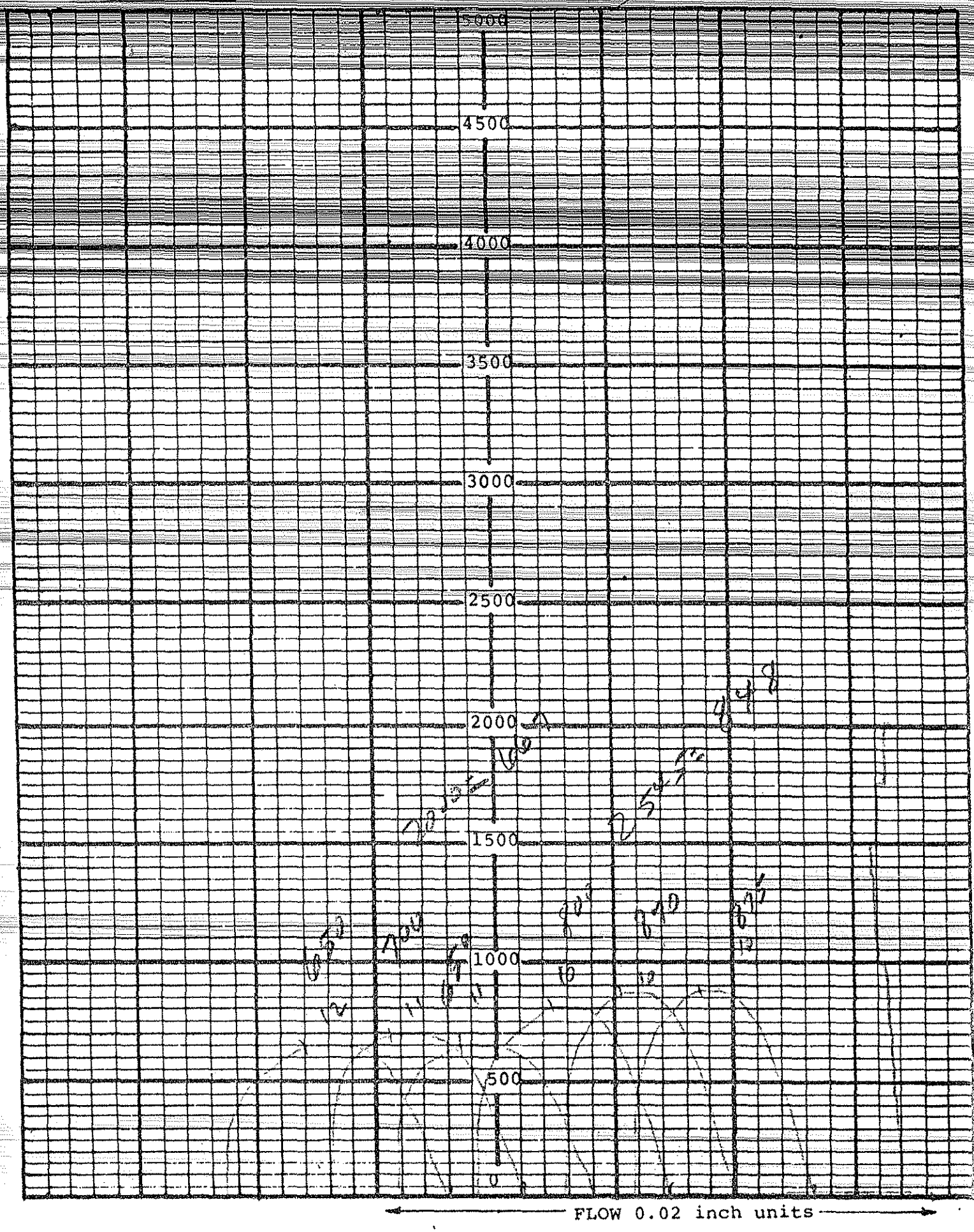


ABDK 152 (152)

Date 3-29 Percent AC _____ Stability _____ Flow _____ Lab No. 32 50

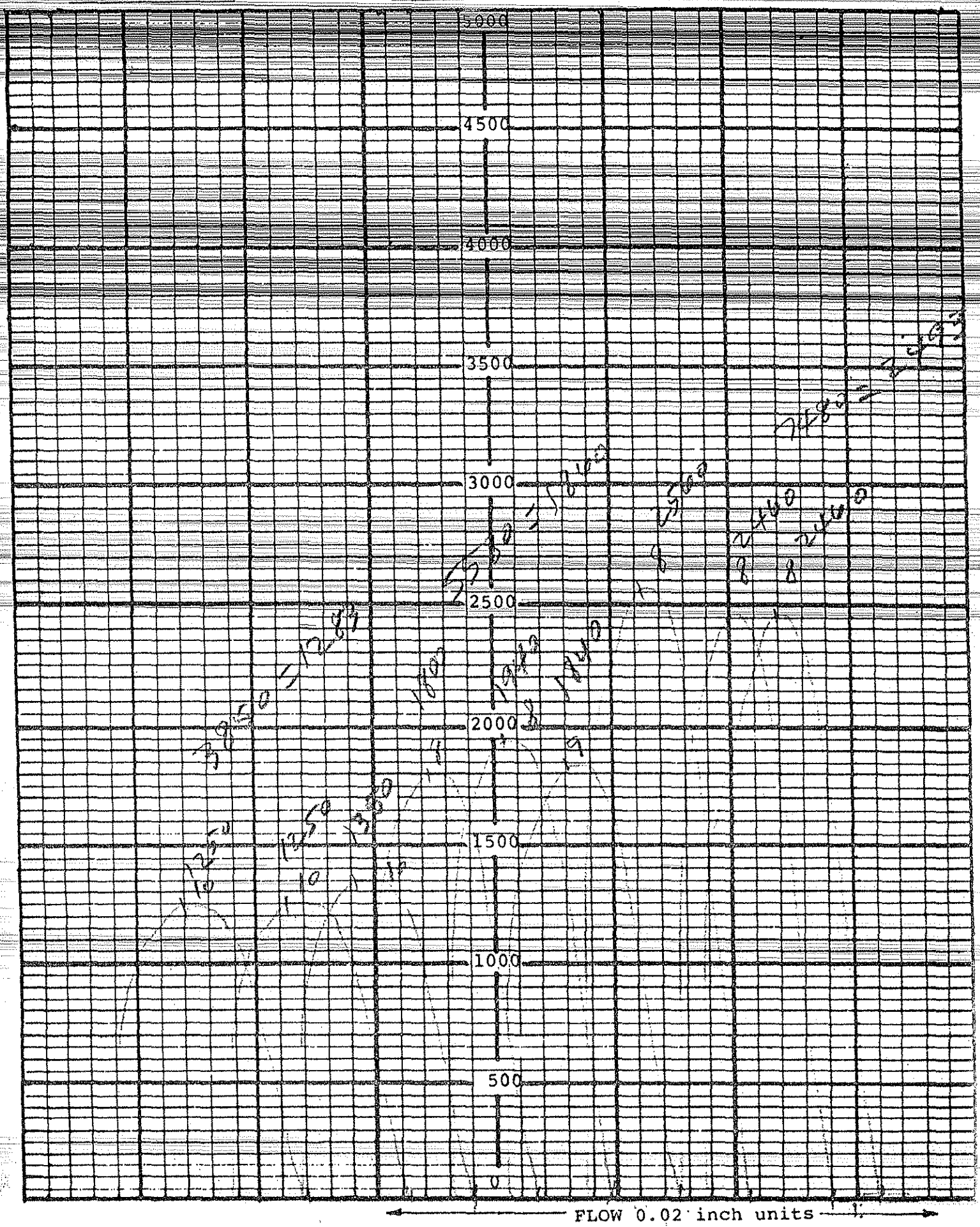


Date 7-23 Percent AC Stability 52 Flow Lab No. 7 12

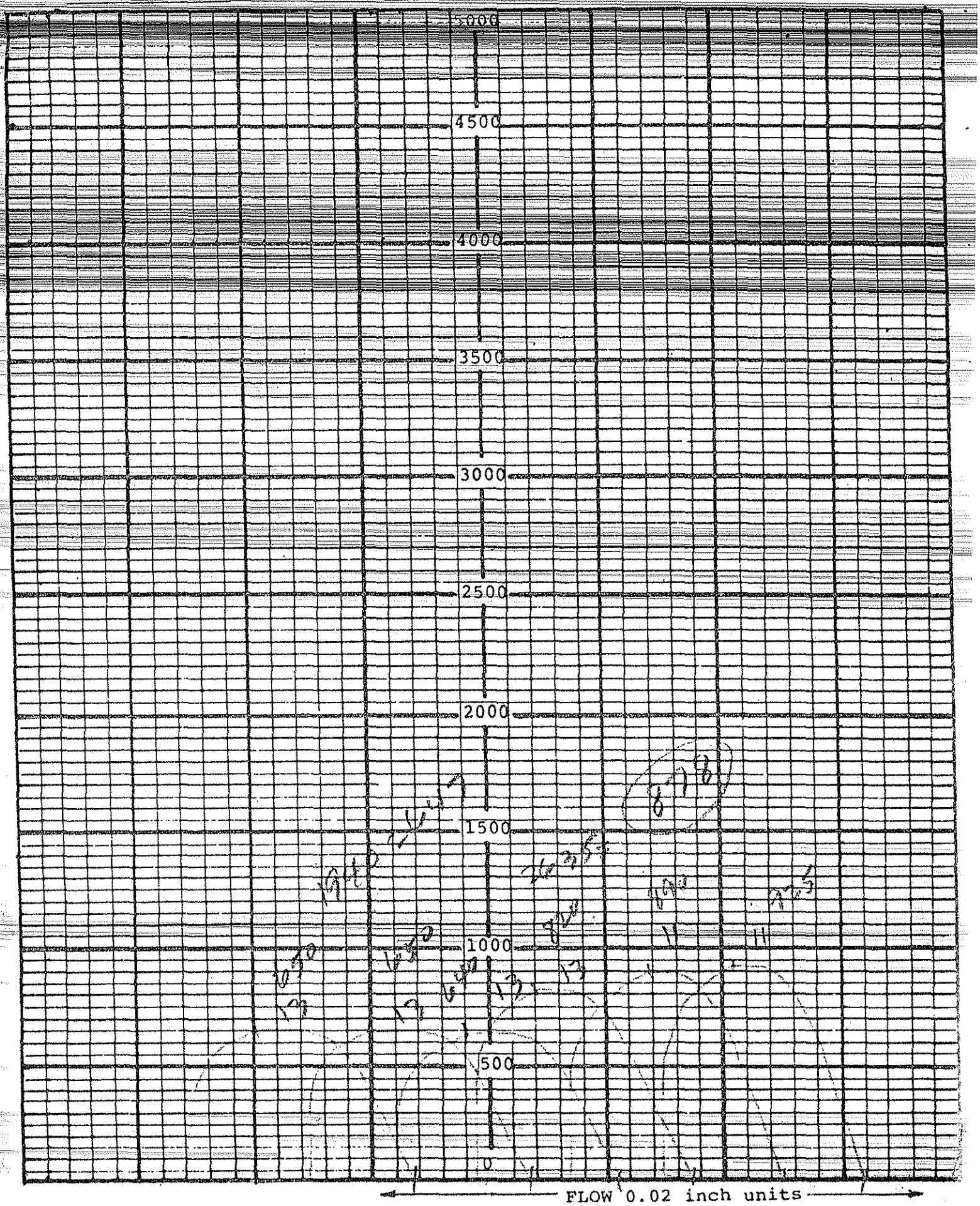


ABDI-145

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

				38		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	2.31
				98.3		99.4		99.1	

95% = 2.29

Marshall Stability

Load - Lbs.	2608			1775		2170	2400	2630	2480
Flow 0.01 In.	7			9		8	7	10	9
Average Load				787					
						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		20 Blow		25 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

Marshall Stability

Load - Lbs.	2168			1130		1670	1750	1880	2100
Flow 0.01 In.	14			11		11	11	12	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	2.22		2.14	2.15	

95% = 2.23

Marshall Stability

Load - Lbs.	2192			1350	1250		810	800	
Flow 0.01 In.	7			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 (6)-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

				10 Blow			20 Blow		25 Blow	
Wt. in Air	Ave.									
Wet Weight	of									
Wt. in Water	50									
Difference	13 low									
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										
				38.1			57.1		65.7	

	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		40	Blow	45	Blow
Wt. in Air	Ave.								
Wet Weight	of			Blow					
Wt. in Water	50								
Difference	Blow								
Sp. Gravity									
Average	2.29			2.23		2.25	2.26	2.28	2.28
				97.4		98.3	98.9		

95% = 2.18

Marshall Stability

Load - Lbs.	1167			975		1150	1370	1450	1340
Flow 0.01 In.	7			10		8	6	7	7
Average Load									
				83.6					

	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			