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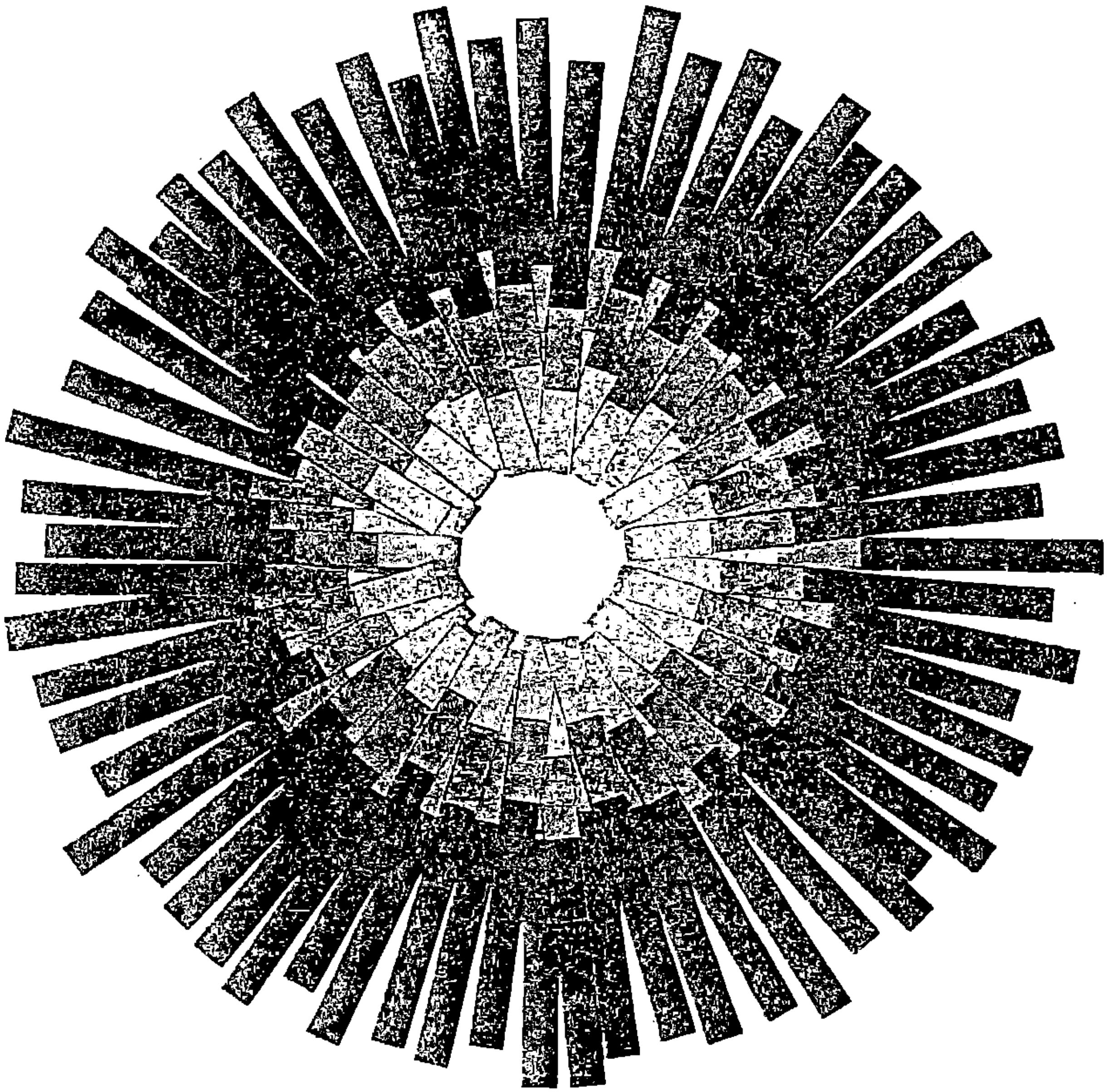
THE MANUFACTURE OF ASPHALT CONCRETE MIXTURES IN THE DRYER DRUM



R. W. Beaty

B. M. Bunnell

Presented at
CTAA Annual Meeting

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Quebec City, Quebec, Canada

THE MANUFACTURE OF ASPHALT CONCRETE MIXTURES IN THE DRYER DRUM

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INTRODUCTION:

Over the past several years, several dryer drum mixing processes have been developing here in the United States and abroad. Common to each of these processes is the simultaneous drying, heating and coating of aggregates with penetration grade asphalt cements. The cold aggregates are proportioned, usually volumetrically, at the cold feed system and are fed into a rotating drum dryer. The asphalt (and water and additives, in some cases) is sprayed onto the cold aggregate prior to their entry into the dryer drum, or within the drum after charging, and the drying, heating and coating process is carried out as the material is conveyed through the length of the drum.

The primary objective of the drum mixing processes is to hold emissions of particulate matter from the exhaust stack to a minimum by coating and agglomerating the fine aggregate particles with asphalt, thus preventing their entrainment in the gases passing through the drum. The aim is to eliminate or greatly reduce the dust collection equipment normally required.

All of the drum mixing processes currently under development utilize a parallel flow dryer-mixer; the logic being that in this manner the hottest flame and gases in the drum exist at the charging end, where the asphalt is best protected by moisture and is least exposed in thin films to the effects of oxidation and burning. Also, a parallel flow dryer is most efficient in controlling dryer discharge temperature to low levels, a desirable objective in the drum mixing process.

Tests of materials mixed in the dryer drum, both here and in Europe, reveal no harmful effect on the asphalt cement or the mixture. Indeed, hardening of the asphalt in the drum mixing process has been shown to be somewhat less than that occurring in conventional pugmill mixing operations.

EUROPEAN DEVELOPMENT:

The Staublos (dust free) process, as developed in Europe, involves the pugmill blending of the cold, wet aggregates with the paving grade asphalt prior to their entry into the dryer drum. Since 1969, eleven Staublos plants have been placed in five western European countries, and development continues at this date.(1) Proportioning of aggregates at the cold feed is a key element of the process, as it is in the drum mixing processes being developed in the United States. European drum mixing practice involves heating of the mixture to conventional hot mix temperatures; i.e. approximately 300° F. In most cases, the paving grade asphalt used is in the 90 - 100 penetration range.

UNITED STATES DEVELOPMENT:

Since 1970, development of the drum mixing process has been carried out in the United States, using two different approaches. In one method, asphalt and water are simultaneously injected inside the dryer drum onto the aggregates. The mixture of hot asphalt and water produces a foaming mass to entrap the fine particulate matter quickly.

The other method developed in this country involves the spraying of hot asphalt onto the cold, wet aggregates just prior to their entry into the drum.

With both of the methods being employed in the United States, the desired objective is to produce the mix at a relatively low temperature, in the 200° F. to 220° F. range. Some residual moisture is credited with assisting in compaction of the mixture, in spite of the relatively high viscosity of the asphalt at this low temperature.

To date, approximately 40 drum mixing plants are in operation in the United States. Test programs carried out by the Federal Highway Administration, [2,3] as well as State Highway Departments, have revealed that the quality of the mix is not harmed in the drum mixing process. It has become apparent, however, that some type of emission control equipment will be required if currently proposed air pollution codes are to be met in the drum mixing process. At the present time, it appears that a high efficiency wet scrubber is the most likely solution to this problem.

INITIAL FIELD EXPERIENCE:

After two years of experience with drum mix units in the field, it seemed to Barber-Greene personnel that additional questions were raised whenever solutions to field problems had been found. We noted that the moisture content of a mix would often change sharply with aggregate source, even though aggregate type, type mix and mix temperature would remain the same. Density specifications were met with low temperature (220° F.) mixes containing 2% moisture and also by low temperature mixes containing considerably less than 1% moisture. High and low moisture mixes were being compacted at temperatures less than 190° F.

Two items appeared to remain constant. The penetration values for asphalt extracted from the mix from drum mix plants was consistently higher than the values expected from conventional hot mix. Also, it seemed to us that high energy vibratory compactors were consistently required to meet density specifications whenever a low temperature drum mixer product was used.

Late in the summer of 1972, Barber-Greene felt that controls achievable only in a laboratory were required if we wished better insight into the effect of process parameters.

LABORATORY INVESTIGATION:

A laboratory batch drum mix simulator was designed and constructed by Barber-Greene during the fall of 1972. Actual laboratory testing was then conducted by a well recognized independent laboratory, the Chicago Testing Laboratory, Inc. Data presented in this report is unpublished data provided by this laboratory. Evaluation and appraisals by W. K. Parr, Vice President of Chicago Testing Laboratory, form the basis for much of the following discussion, although the authors of this paper accept full responsibility for the evaluation and conclusions presented.

Variations in aggregate gradation, hydrophilic or hydrophobic characteristics of the aggregate, penetration grade of asphalt, mix temperature, and use of additives were process parameters investigated. Open graded mixes contained 5½ percent asphalt cement and dense graded mixes were made with 6 percent asphalt. A detailed outline of the test format and test methods used may be found in Appendix II.

The equipment consisted of a 16-inch diameter by 13-inch long batch drum mixer capable of processing a 10,000 gram mix within a normal drum mixer loading. A 500,000 BTU/hour burner with a 40:1 turndown ratio was mounted with a stainless steel combustion chamber on one end of the drum. An exhaust fan was connected to the drum through a rotating seal exhaust connection at the other end of the drum mixer.

ASPHALT HARDENING:

One of the first areas of concern when drum mixing was considered was the effect on the asphalt of exposure of high temperature gases and direct flame. In this study, it appeared that the process had no measurable effect on the ductility of the asphalt, since the asphalt recovered from all mixes had ductilities exceeding 110 cm at 77° F.

Penetration test results are tabulated in Tables 10 and 11. Results for those mixes containing 88 penetration asphalt are plotted in Figure #9 vs. mix temperature. Although there is a considerable scattering of data it appears that a higher mix temperature results in slightly more hardening. There is apparently no difference in hardening in open graded and dense graded mixtures. Also, no difference is discernible in mixes containing the silicone or the tall oil type additives. The actual range of percent retained penetration for the 88 penetration asphalt is shown as follows:

	% OF ORIGINAL PENETRATION (88)		
	MIN. VALUE	MAX. VALUE	AVERAGE VALUE
Without Additive:			
Limestone Dense Graded	71.6	90.9	76.7
Granite Dense Graded	72.7	81.8	
With Additive:			
Limestone Dense Graded	77.2	84.1	80.7
Granite Dense Graded	75.0	84.1	
Without Additive:			
Limestone Open Graded	73.9	81.8	77.2
Granite Open Graded	67.0	80.7	74.4
With Additive:			
Limestone Open Graded	84.1	86.4	84.9
Granite Open Graded	68.2	82.9	75.3

Four mixes made with 238 penetration asphalt were included in the study. The percent retained penetration ranged from 58.0 to 70.2 of the original penetration with an average percent retained of 61.7. This greater loss in penetration during mixing may be expected with softer asphalts. Allowance is made in The Thin Film Oven Loss Specifications for this.

The conventional mixes made at 290° F. averaged 67.7 penetration. Twenty-nine of the forty-six mixes made in the drum mixer exceeded this average value for conventional mixes.

MARSHALL TESTS:

Six specimens were compacted from each mix. In most cases, all mix specimens were compacted at the mix temperature while a number of replicate mixes had three specimens compacted at the mix temperature and three specimens compacted at 275° F. The conventional or control mixes were all compacted at 275° F. Average values for the control mixes were used as the basis for calculating percent compaction.

The results plotted in Figure #5 show that compaction for dense graded limestone is a function of temperature. Furthermore, those specimens compacted at 275° F. were higher in density than those from the same mixes compacted at mix temperature. The average percent compaction of the seven replicate mixes compacted at 275° F. was 98.9% of the conventional mixes compacted at 275° F.

Marshall Stability appears to be more sensitive to compaction temperature than density. In Figure #5, we can see that a reduction of 3% compaction results in a loss of 800 lb. stability value for dense graded limestone mixes without additives. While the four mixes made with 238 penetration asphalt have a lower stability, the stability compaction temperature relationship has approximately the same slope.

Four dense graded limestone mixes made with 88 penetration asphalt containing additives show slightly higher percent compaction values and slightly higher stability values.

Figure #6 shows the same relationship for dense graded aggregate mixes when no additive is used. Three mixes containing tall oil additives show indications of a lack of temperature sensitivity with regard to compaction.

Figure #7 illustrates the same relationship for granite open graded mixes. Here, the six mixes containing additive appear to have a flat percent compaction curve and fairly flat stability curve.

Similar data for limestone open graded mixes are presented in Figure #8.

These results indicate that the lower temperature mixes require more compaction effort to obtain equal density or compaction. In the field the fact that high energy vibratory compaction appears to be a necessary prerequisite for attaining density with low temperature drum mixer mixes would appear to substantiate these laboratory results.

The silicone additives appeared to have no apparent effect on the compaction and stability properties of the mix.

WET STRENGTH TESTS:

The standard ASTM Immersion Compression test requires special equipment and testing procecures and would have required additional mixes. In its place, the Marshall test was utilized as a measure of the wet strength. This procedure was developed by the Corps of Engineers and described in Public Roads, Vol. 33, No. 3, August, 1964.

This procedure requires the compaction of six Marshall Test specimens. Three of these are tested after conditioning thirty minutes in a 140° F. water bath. The second set of three specimens are placed in a 140° F. water bath for 24 hours and then tested for stability. The ratio of wet to dry stability is expressed as percent retained wet strength.

The average wet strength values are summarized in Table 12. This data does not indicate any significant detrimental wet strength values. The open graded mixes appear to have less wet strength than the dense graded mixes, but this may be due to the higher design air voids in these mixes as compared with the dense graded mixes.

The data appears to indicate that limestone mixes containing tall oil additive have slightly lower wet strength than the mixes with no additive. The opposite is shown for the granite aggregate mixes. The tall oil-aluminum sulfate system can react with acidic type aggregates as well as basic (limestone) types. This suggests that active aggregates, such as rhyolite and quartzite, may require the same special coating aids required with conventional mixes.

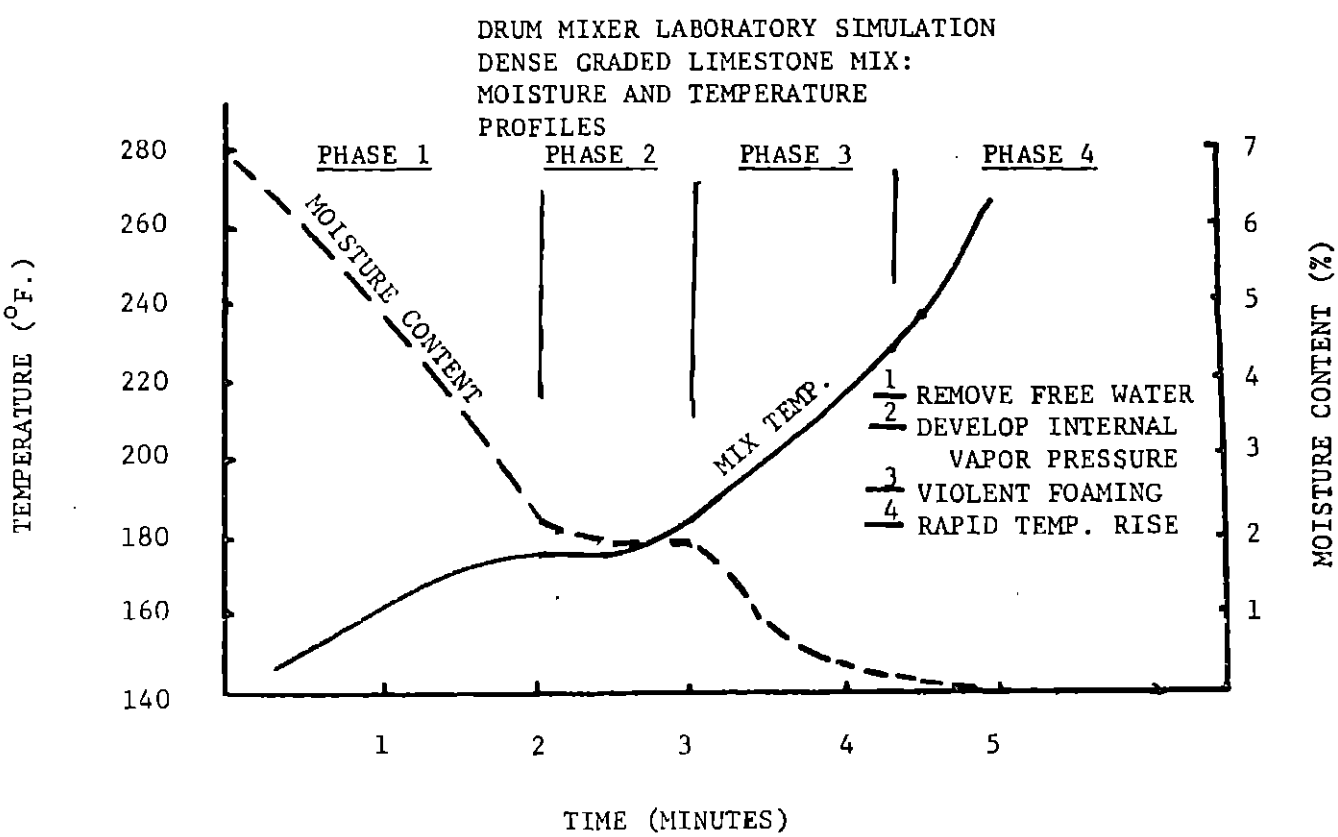
At any rate, the high retained wet strengths obtained in this study do not indicate adhesion is a serious problem with the aggregates studied.

TEMPERATURE - MOISTURE PROFILE AND VISUAL OBSERVATIONS

The temperature moisture profile was investigated in a series of six runs during which the mixer was stopped at 30-second intervals for moisture test samples. The aggregates and gradation types used are shown in Table 4.

Figures #2 and #10 show the moisture - temperature profiles obtained in these laboratory runs.

The profiles may be divided into phases as shown below:



Visual observations of the drum mixing batch process can be described in terms of the phases shown above. The description below is typical of observations made during the dense graded mix runs.

PHASE 1:

Surface and free moisture are readily removed from the aggregate in the early heating phase. Mix temperature rises and moisture content rapidly drops as time of heating (and mixing) increases. Balls of dust and asphalt form during this period. (See illustration #6). These balls were analyzed and found to be comprised of about 9 to 11% asphalt and 89 to 91% dust. These balls were most noticeable during the runs in which dense graded limestone aggregate was used. The higher dust content is the obvious explanation.

PHASE 2:

At about 170 to 180^{o} F. the moisture level and mix temperature level off as heating time increases. The exhaust temperature has dropped close to minimum values and begins to level off.

The balls of material look darker during this time but do not change in any other manner. It seems reasonable to assume that moisture entrapped in the balls of material as well as internally absorbed moisture in the aggregate is being vaporized at this time but has not generated sufficient pressure to escape into the gas stream.

PHASE 3:

Between 180 and 200^{o} F. foaming of the asphalt is initiated. The balls of dust and asphalt begin to expand and break apart (see illustration #6). The mix temperature will begin to rise and the moisture content drops rapidly with time. It is at this time that we can see the asphalt foaming and spreading rapidly.

During this phase, the veil of material in the drum mixer changes from aggregate color to a veil with black streaks which quickly changes to a completely black veil.

PHASE 4:

Most of the moisture has been removed, foaming is insignificant and the aggregate has been coated. The mix temperature will rise rapidly when this phase is reached.

With open graded mixes the above phases are less distinct. Foaming was less obvious but the foaming that occurred started at lower temperatures (about 170° F.) and continued to a significant degree at higher mix temperatures (250° F. and higher). The change in veil from a streaky appearance to a black veil is slower and less dramatic in the case of open graded mixtures.

Silicone additives caused smaller bubbles to form. The veil changed slowly as with open graded mixes, but no observable difference in final mix coating could be seen.

RESIDUAL MOISTURE CONTENT IN MIXES:

In discussing moisture removal, it should be noted that the amount of moisture remaining in the mixes is considerably less than that reported from field projects.[2,3] Tables #5 and #6 show the moisture test results for both dense graded and open graded mixes. Moisture test samples were taken immediately after mixing and later when the mix was quartered to obtain the extraction and Marshall test samples.

CONCLUSIONS AND OBSERVATIONS:

Significant observations and conclusions based on the results of this laboratory investigation may be summarized as follows:

1. Mixing and coating can be achieved in drum mixing at relatively low temperatures (200 - 220° F.). This apparently occurs while the asphalt is below conventional mixing viscosity temperature and is accomplished by entrapped moisture vapor causing foaming of the viscous asphalt films.

2. At low temperatures (190 - 210° F.), the laboratory mixes sampled immediately after mixing had some moisture present. In a short time, however, this transient moisture is lost from the mix.

3. Mixes made at the lower temperature range (190 - 210° F.), under standard compaction effort, had lower compacted densities than those made and compacted at higher temperatures. Their stabilities are also lower. This would indicate low temperature mixes would require additional field compaction effort. The magnitude of the variations with temperature, however, would not seem suff-

icient to prevent satisfactory compaction if temperature were the only factor involved.

4. On the limited number of mixes made with tall oil - aluminum sulfate adhesion additive, there is evidence that mix temperature has less effect on compaction. This was noted specifically in the open graded mixes.

5. Silicone additive had no effect, adverse or otherwise, on the properties of mixes made in the drum mixer.

6. No significant adverse hardening of the asphalt used was noted in the study. Hardening does occur but it is significantly less than that occurring in the Thin Film Oven Loss Test and the average degree of hardening is slightly less than was found with conventional laboratory mixes. These results are in general agreement with previously published field data [2,3].

7. No significant loss of strength due to water immersion, as measured by the Marshall Test on 24 hr. 140^{o} F. immersed specimens was noted. In other words, satisfactory asphalt adhesion to the aggregate was attained in the mixes made in the drum mixer.

SUMMATION:

The experiments appear to indicate that the drum mix process is capable of producing a mix comparable with the conventional hot mix process. Further indications are that if adequate compactive energy is available and a properly designed and controlled mix used, the pavement may be comparable to that laid using conventional hot mix.

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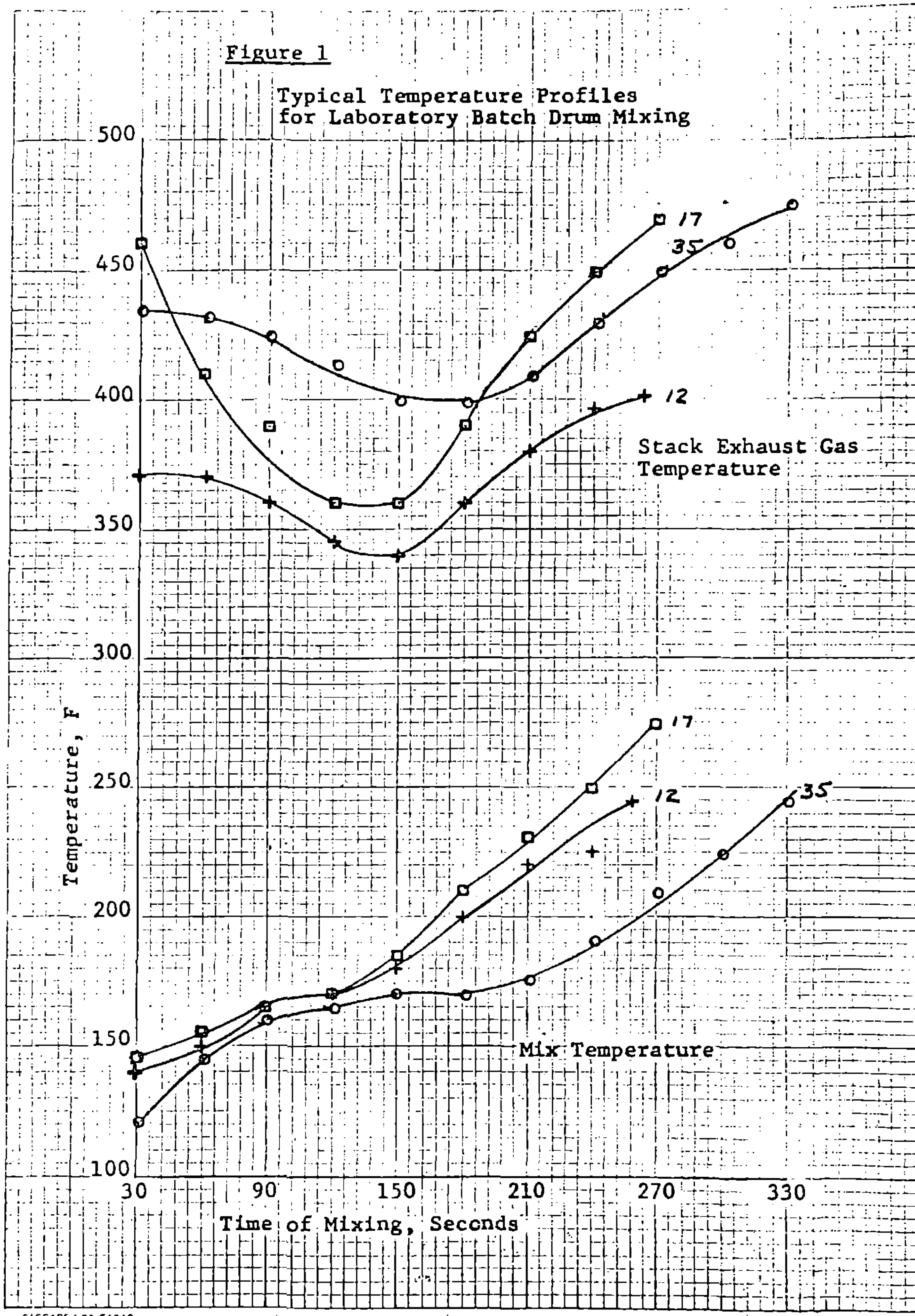
Figure 1

Typical Temperature Profiles for Laboratory Batch Drum Mixing



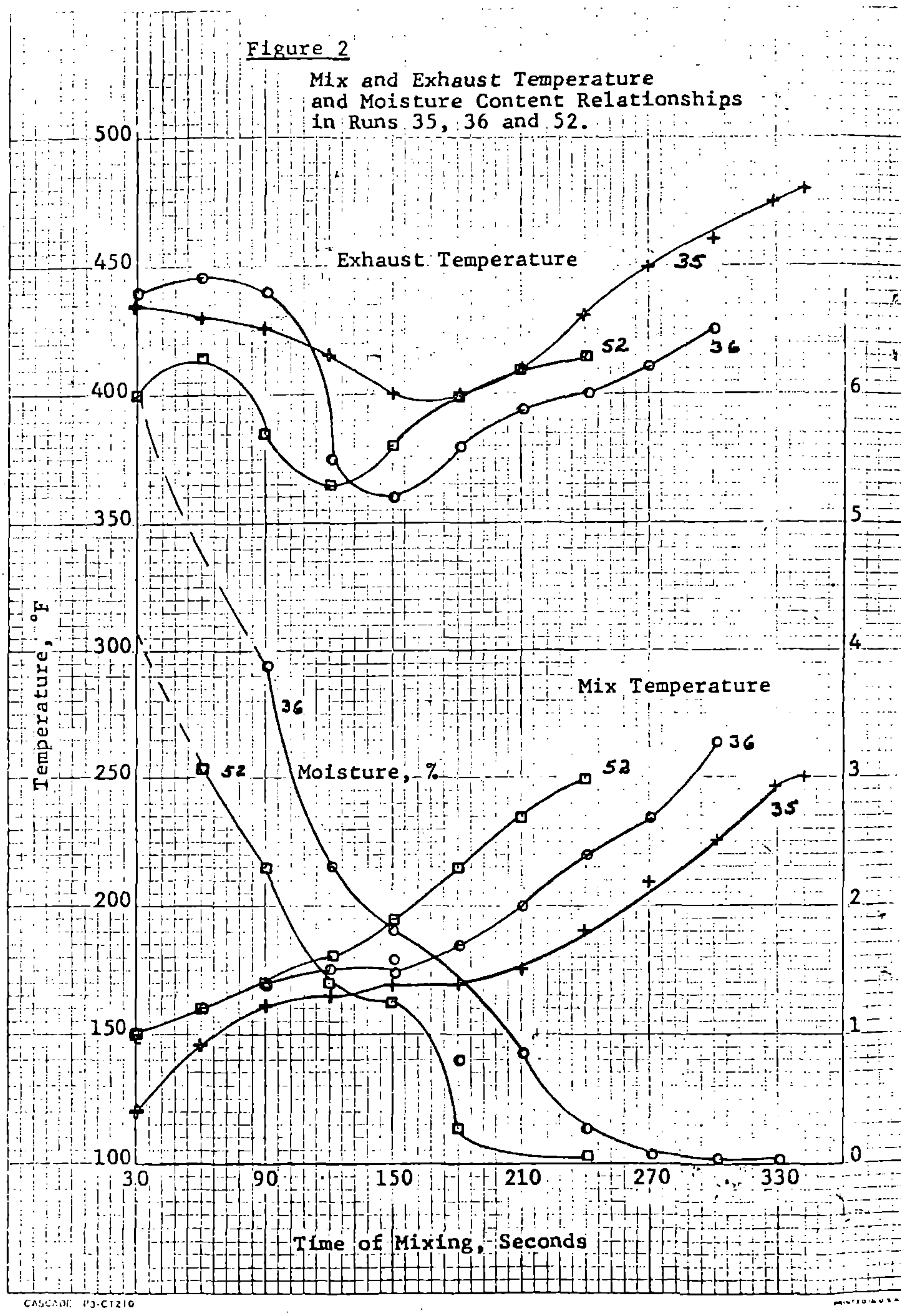
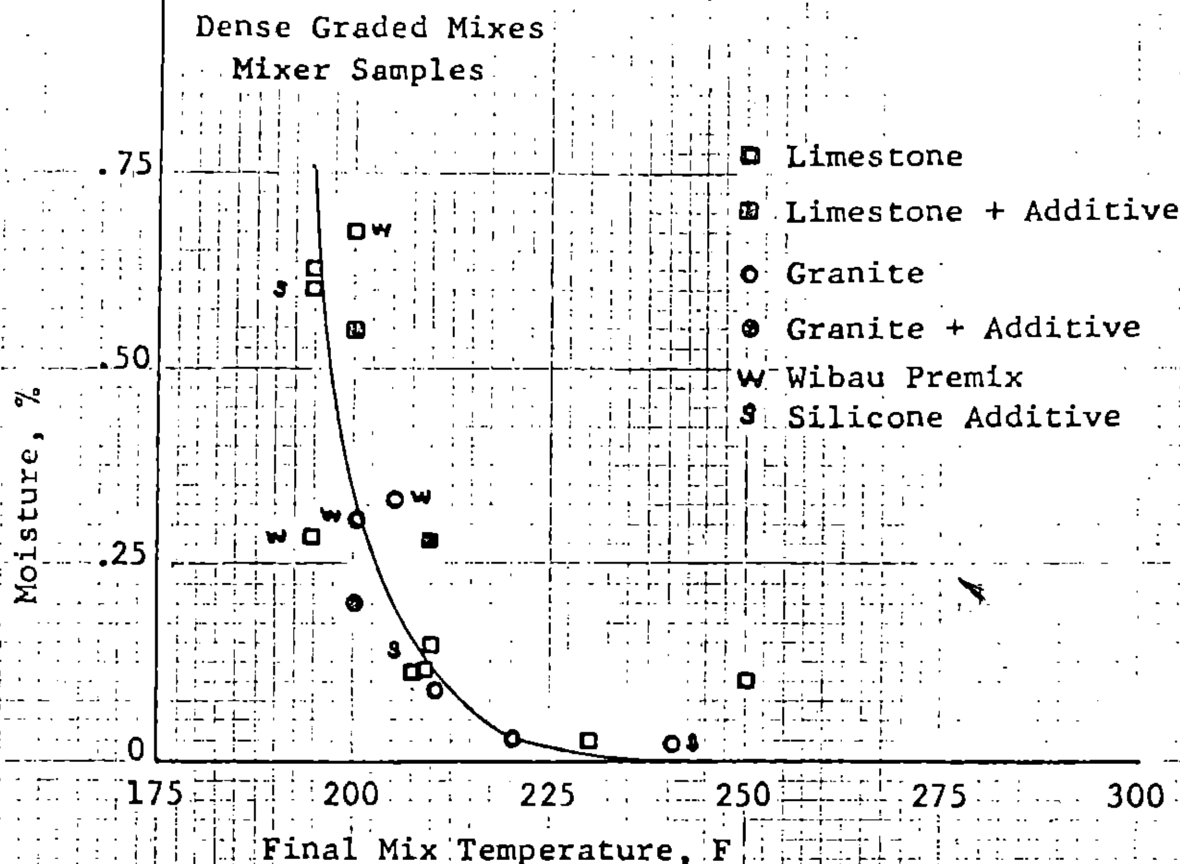


Figure 2

Mix and Exhaust Temperature and Moisture Content Relationships in Runs 35, 36 and 52.



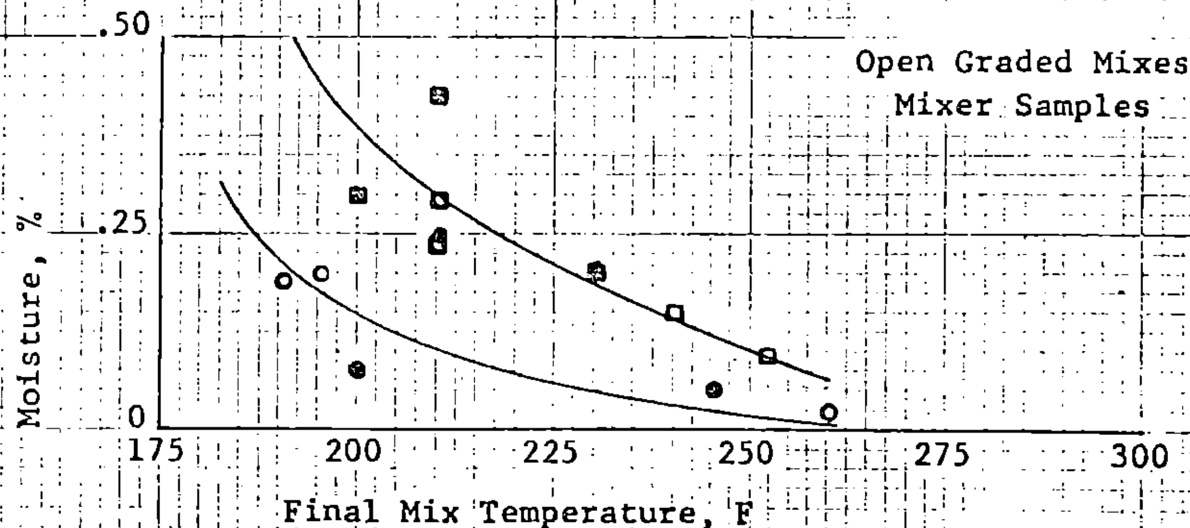
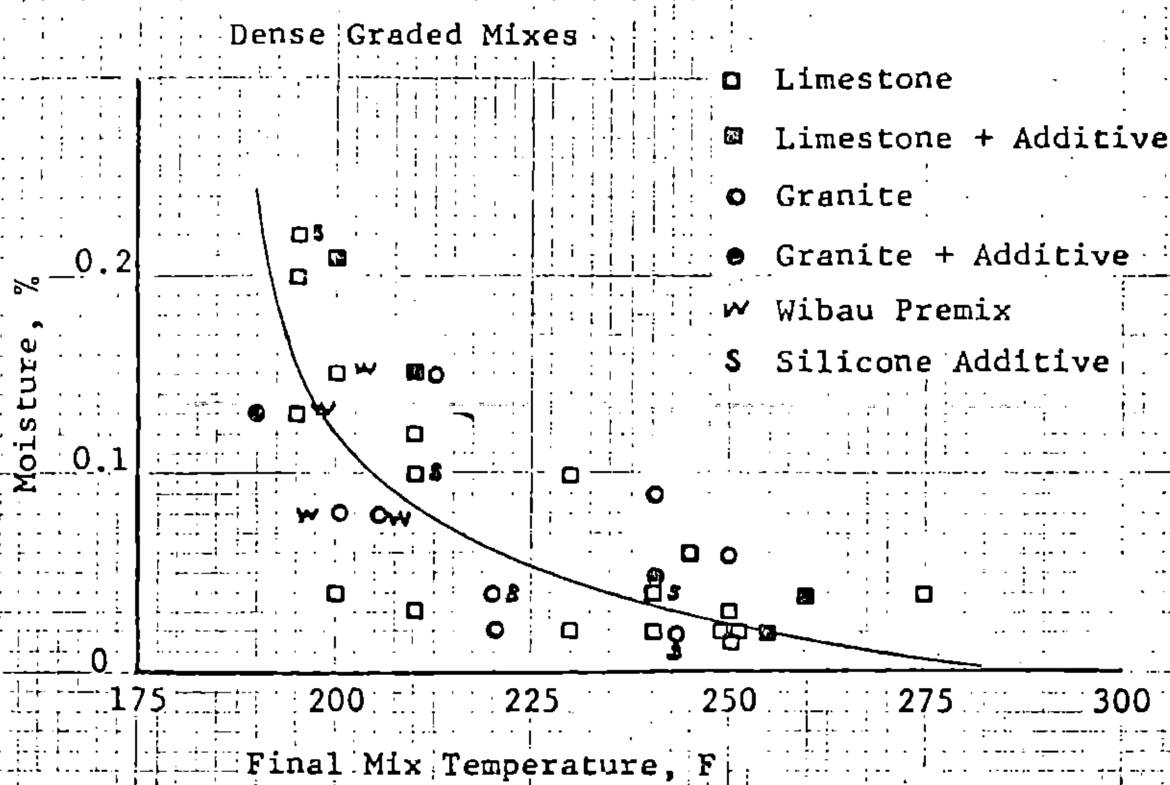


Figure 3: Moisture Content of Drum Mixed Samples Taken Immediately at End of Mixing.



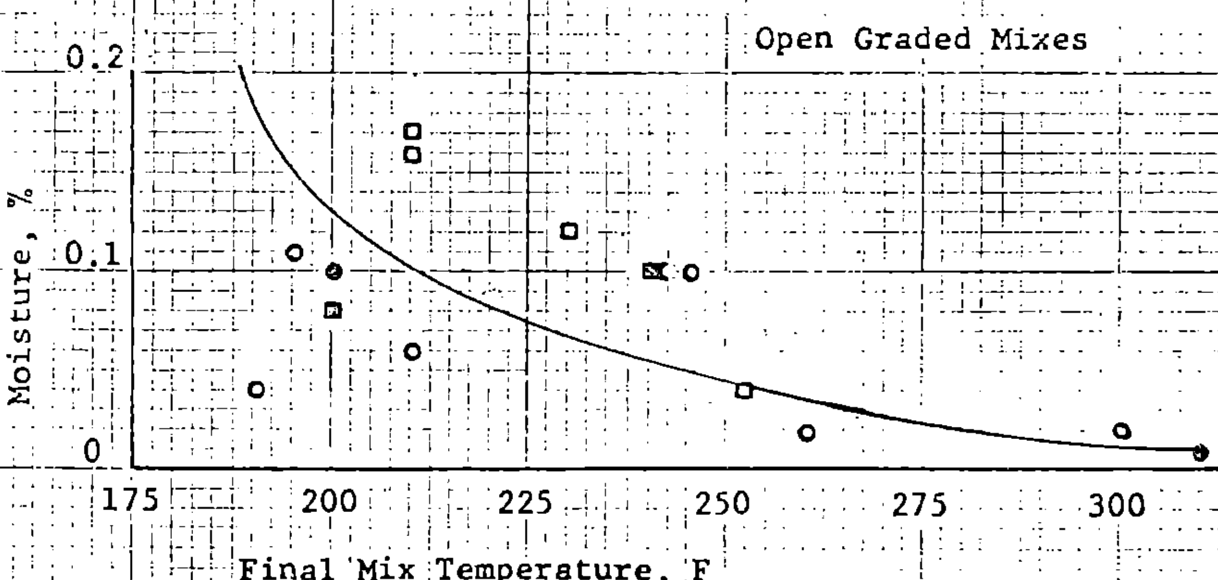


Figure 4: Moisture Content of Drum Mix Samples Sampled after mixing and quartering for extraction test sample.

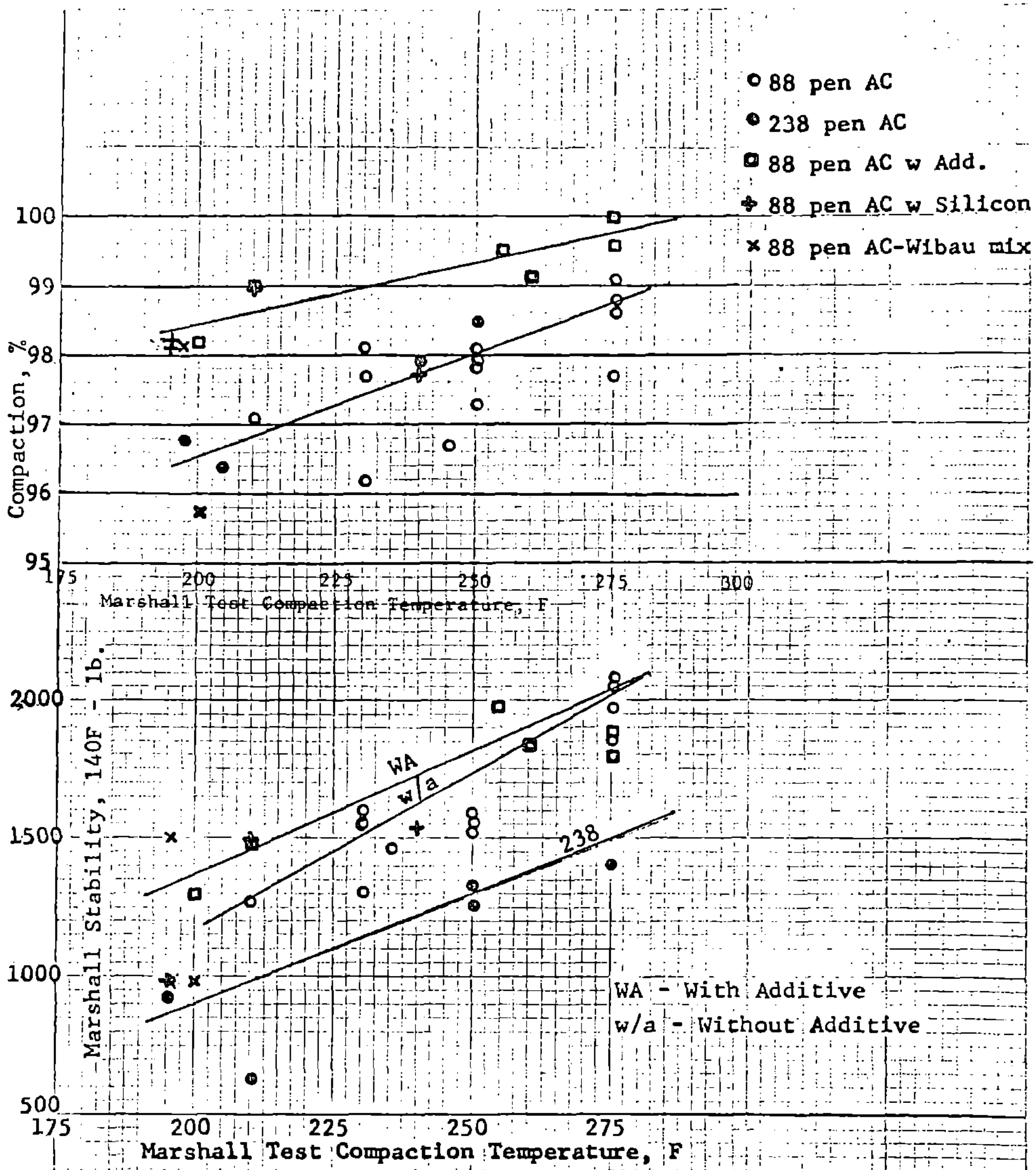


Figure 5: Compaction Temperature versus % Compaction and Marshall Stability Value

Dense Graded Limestone Aggregates

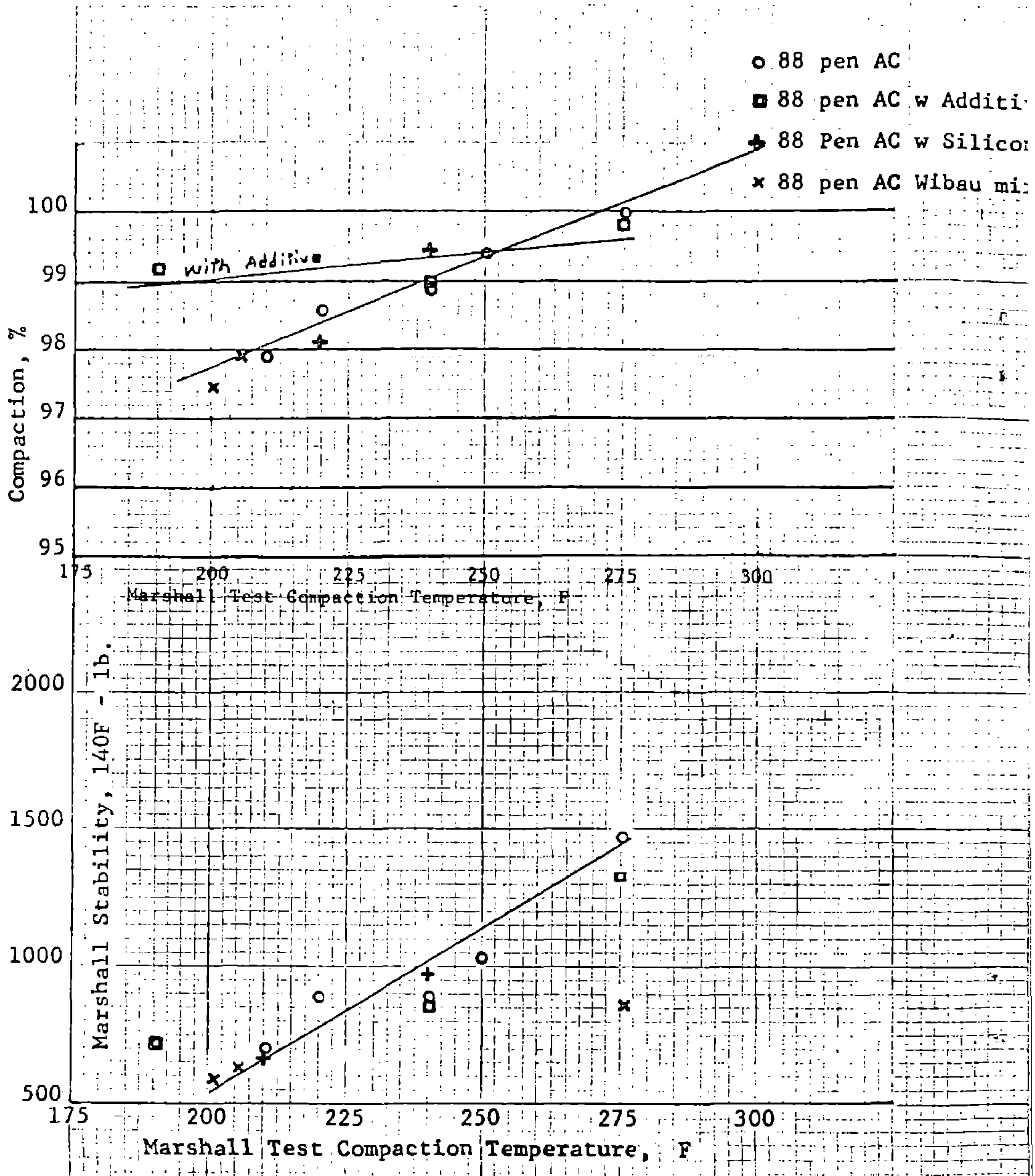


Figure 6: Compaction Temperature versus % Compaction and Marshall Stability Values Dense Graded Granite Aggregate

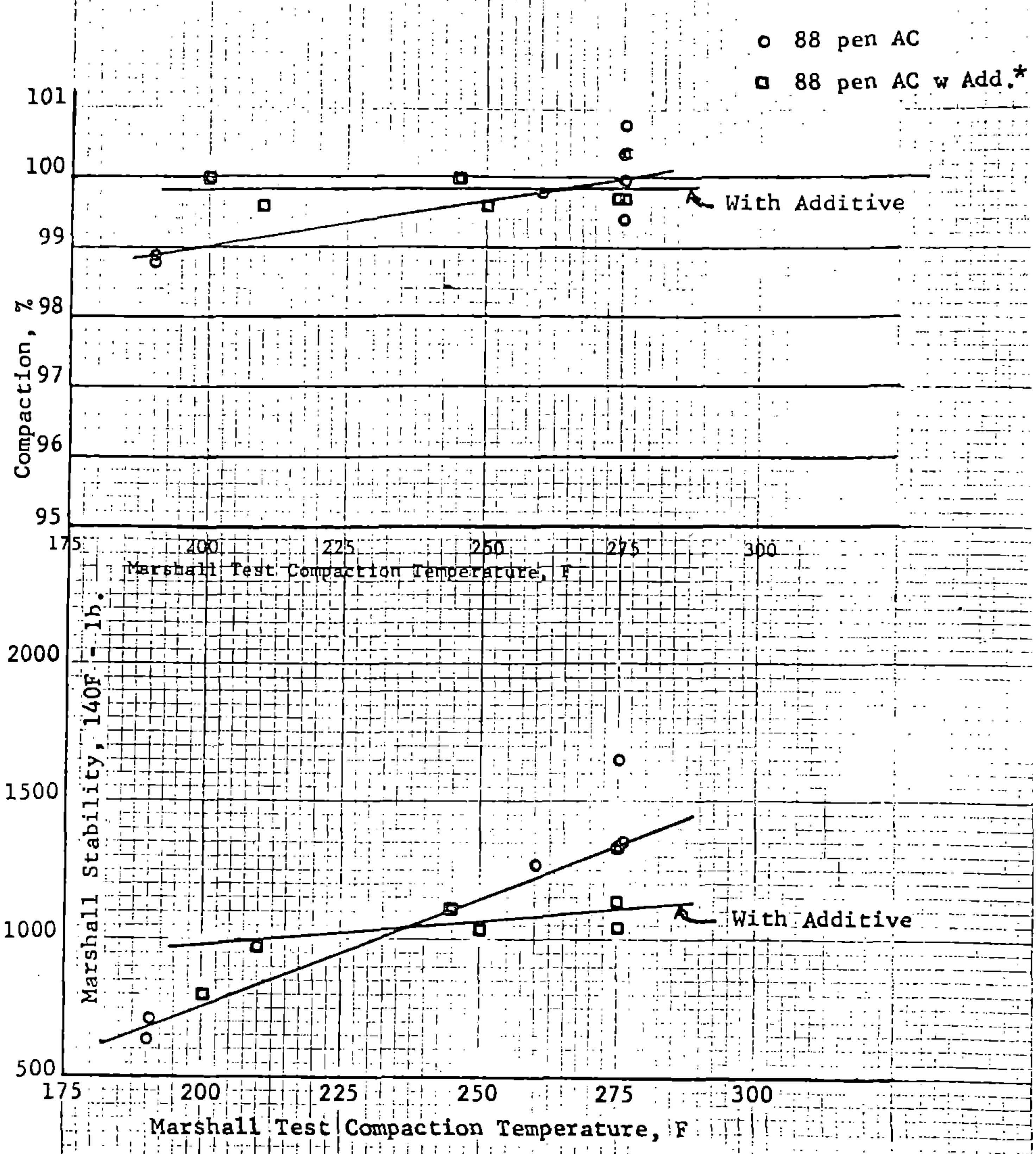


Figure 7: Compaction Temperature versus % Compaction and Marshall Stability Values

Granite Open Graded Mixes

*Tall Oil Pitch-Aluminum Sulfate Additive

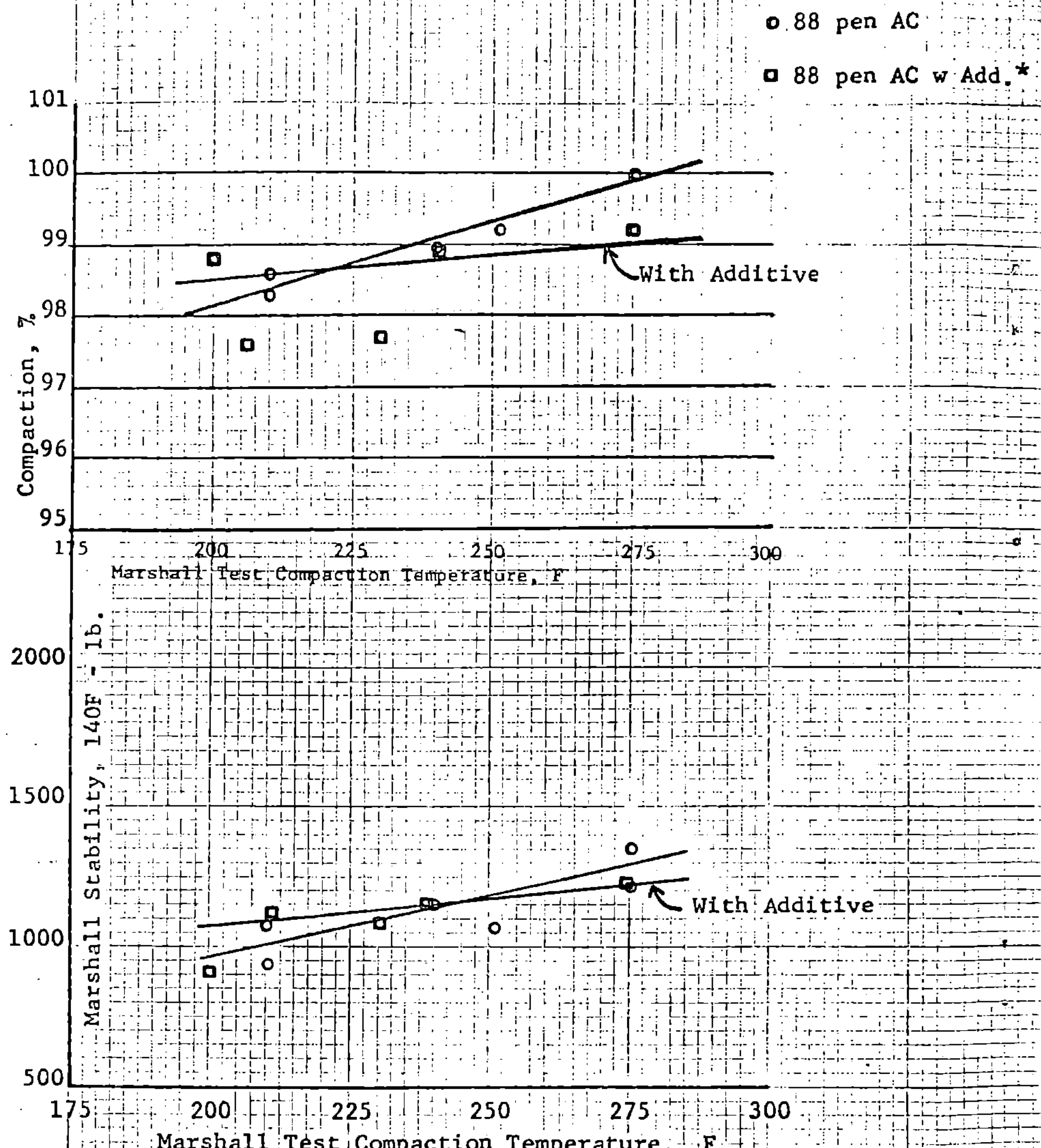


Figure 8: Compaction Temperature versus % Compaction
and Marshall Stability Values

Limestone Open Graded Mixes

*Tall Oil Pitch-Aluminum Sulfate Additive

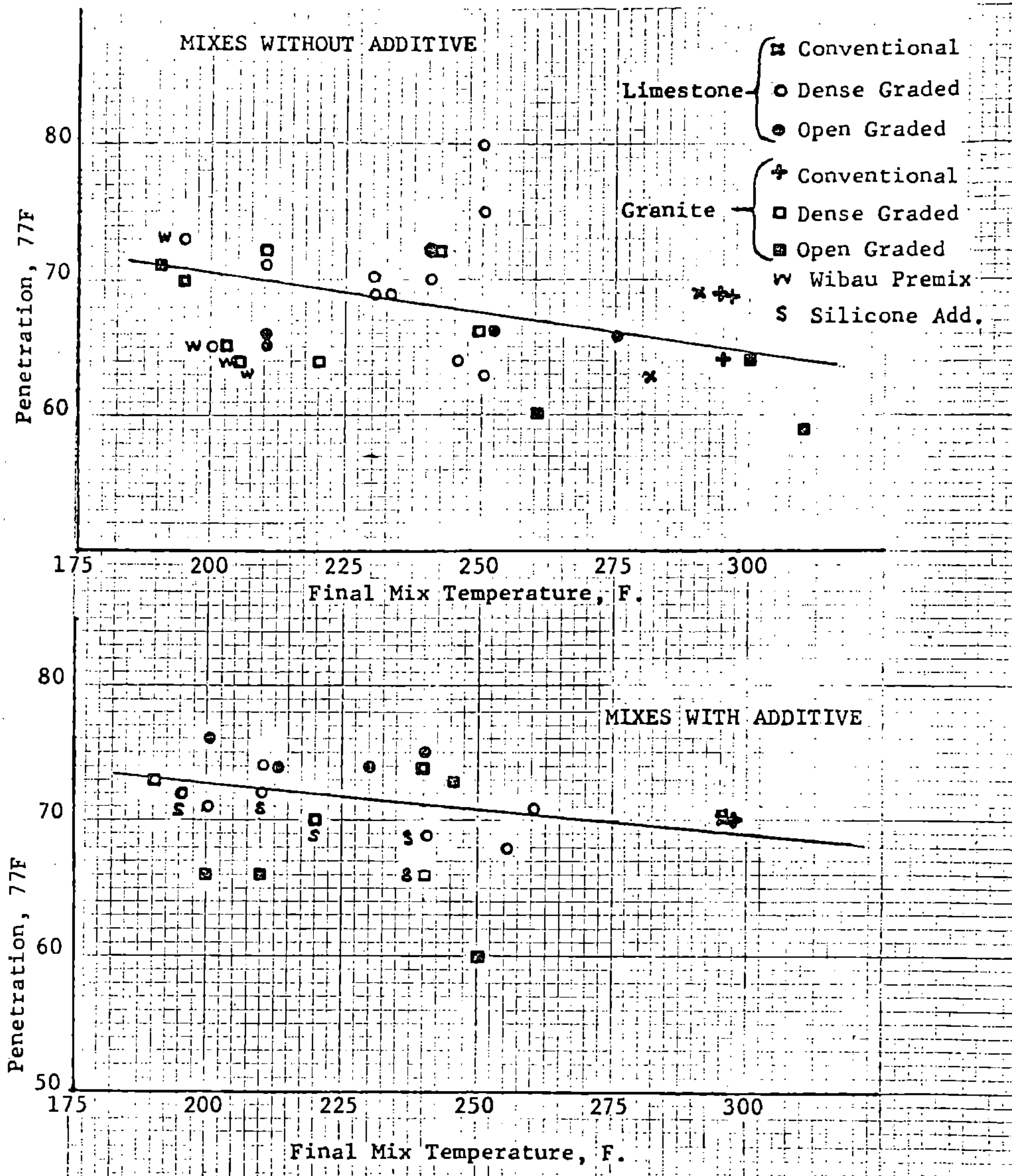


Figure 9: Penetration of Recovered Asphalt Versus Final Mix Temperature

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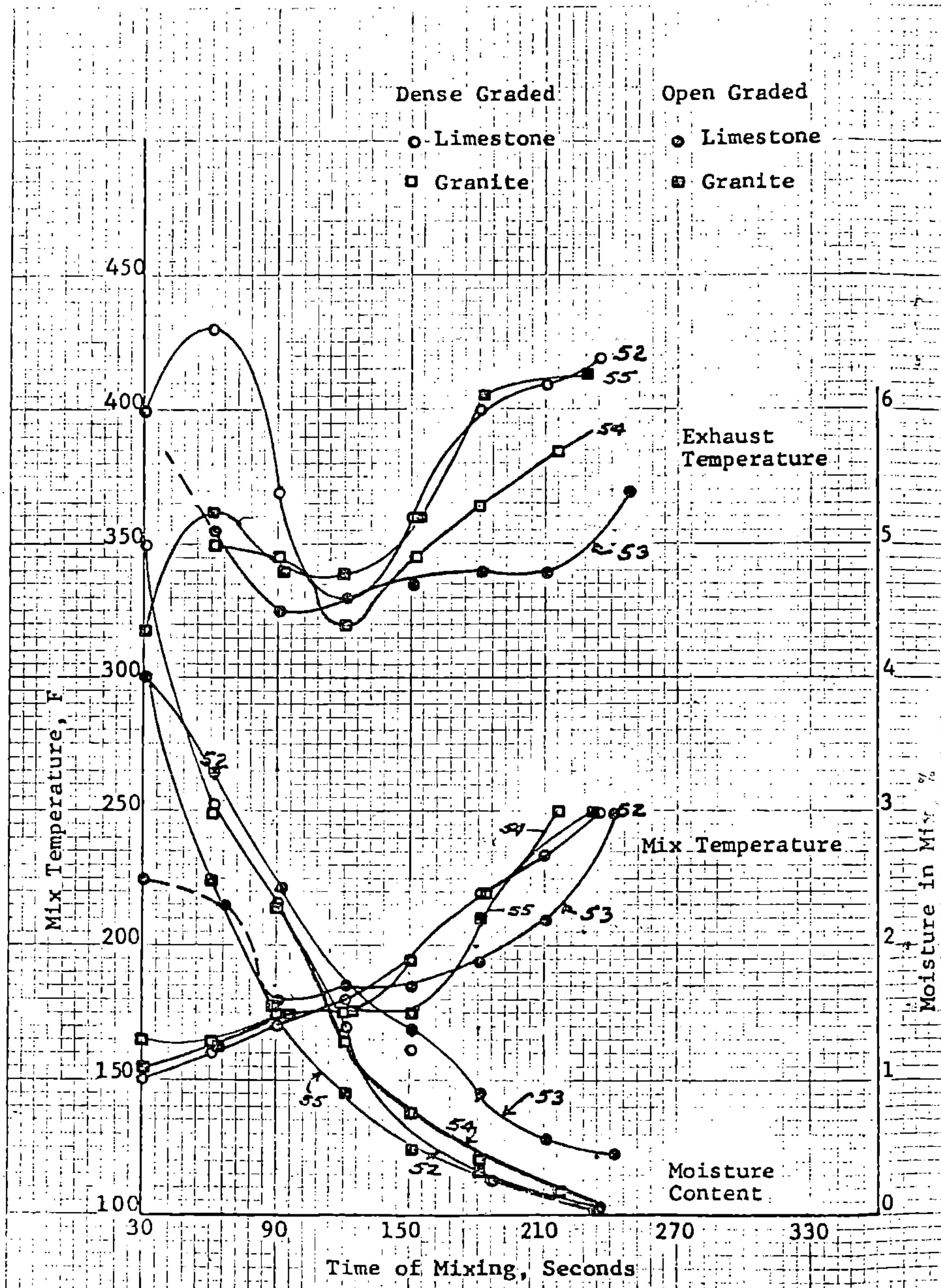

Figure 10: Temperature and Moisture Contents of Supplemental Mix Series

SOURCE: American Oil,
Whiting, Ind.

TABLE 1

ASPHALT CEMENT

Intended Use: Drum Mixer Study Project

Type	85/100		200/250
Tank Number	Lab. Stock		Lab. Stock
PENETRATIONS:			
At 77° F. (100 gms. 5 sec.)	88	87	238
Ductility at 77° F., 5/60 (cm)	150+		150+
Specific gravity at 77° F.	1.025		1.017
Equiv. lbs./gal. at 60° F.	8.57		8.51
Flash point, C.O.C. (° F.)	550+		550+
Loss, 5 hr. ( ) Reg. (X) thin film (%)	0.02		0.30
Penetration after, at 77° F.	52		113
(%) of original	57.8		47.5
Ductility after, at 77° F. (cm)	110+		150+
Solubility in CCl_4 (%)	99.93		99.99
Viscosity, kinematic at 275° F. (cSt)	267		153
Spot Test (Oliensis)	Negative		Negative

Tests on Laboratory Stock Used in Study.

TABLE 2

Test Mix Gradations

	Limestone		Granite	
Aggregate No.	1	2	3	4
	Dense Graded	Open Graded	Dense Graded	Open Graded
3/4" Sieve........	100.0		100.0	
1/2" "	98.9	100.0	96.7	100.0
3/8" "	94.7	80.0	77.1	70.0
No. 4 "	68.9	40.0	62.5	40.0
No. 8 "	50.5	20.0	50.7	20.0
No. 16 "	36.3	11.0	40.9	14.0
No. 30 "	28.9	9.0	28.8	10.0
No. 50 "	23.3	6.0	14.8	8.0
No. 100 "	9.1	5.0	5.1	5.0
No. 200 "	7.1	4.0	2.7	4.0

No. 1 - 50% 1/2" Limestone, 35% Limestone Screenings, 15% Fine Washed Glacial Sand.

No. 2 - 87% 1/2" Limestone, 13% Limestone Screenings Blended and rescreened to give design gradation.

No. 3 - 55% Crushed Granite, 40% Coarse Sand, 5% Fine Sand.

No. 4 - 100% Crushed Granite rescreened to design gradation.

TABLE NO. 3

MOISTURE AND MIX TEMPERATURE TEST DATA

RUNS 35, 36 AND 52

Mix 36				Mix 35		Supplemental Mix 52			
Time Sec.	Temp. (F) Mix	Temp. (F) Exhaust	% H_2O In Mix	Temp. (F) Mix	Temp. (F) Exhaust	Time Sec.	Temp. (F) Mix	Temp. (F) Exhaust	% H_2O In Mix
30	150	440		120	435	30	150	400	
60	160	445		145	430	60	160	430	3.05
90	170	440	3.84	160	425	90	170	370	2.31
120	175	375	2.31	165	415	120	180	330	1.38
150	175	360	1.86	170	400	150	195	360	1.25
180	185	380	0.78	170	400	180	220	400	0.27
210	200	395	0.85	175	410	210	235	420	
240	220	400	0.25	190	430	230	250	440	0.05
270	235	410	0.07	210	450				
300	265	425	0.07	225	460				
330			0.02*	245	475				
338				250	480				

*After Cooling

TABLE NO. 4

SUPPLEMENTAL MOISTURE TESTING RUNS

LIMESTONE AGGREGATE

Run No. 52 Dense Gradation Original Moisture - 5.0%				Run No. 53 Open Gradation Original Moisture - 4.0%			
Time Sec.	Temp. (F) Mix	Temp. (F) Exhaust	% H_2O In Mix	Time Sec.	Temp. (F) Mix	Temp. (F) Exhaust	% H_2O In Mix
30	150	400		30	225		
60	160	430	3.05	60	215	355	3.32
90	170	370	2.31	90	180	325	2.42
120	180	330	1.38	120	180	330	1.86
150	195	360	1.25	150	185	335	1.38
180	220	400	0.27	180	195	338	0.85
210	235	420		210	210	338	0.55
230	250	440	0.05	246	250	420	0.34

GRANITE AGGREGATE

Run No. 54 Dense Gradation Original Moisture - 5.0%				Run No. 55 Open Gradation Original Moisture - 4.0%			
Time Sec.	Temp. (F) Mix	Temp. (F) Exhaust	% H_2O In Mix	Time Sec.	Temp. (F) Mix	Temp. (F) Exhaust	% H_2O In Mix
30	165			30	155	317	
60	165	350	3.03	60	165	362	2.48
90	175	346	2.29	90	175	344	1.55
120	175	320	1.28	120	175	340	0.90
150	195	346	0.75	150	175	360	0.49
180	220	363	0.41	180	210	406	0.37
216	250	385	0.18	234	250	414	0.04

TABLE NO. 5

MOISTURE TESTS

DENSE GRADED MIXES

Limestone Aggregate				Granite Aggregate			
	Mix	% Moisture			Mix	% Moisture	
Mix No.	Temp. (F)	Imm.*	Ext.**	Mix No.	Temp. (F)	Imm.*	Ext.**
1	230		0.04	8	240		0.09
2	250		0.02	9	250		0.06
3	250		0.02	10	210	0.09	0.15
4	240		0.02	14	220	0.03	0.02
5	210	0.11	0.12	38T	240		0.05
6	195	0.63	0.20	39T	190	0.19	0.13
7	230		0.10	45S	240	0.03	0.02
11	208	0.11	0.03	47S	220		0.04
12	250	0.10	0.03	50W	205	0.34	0.08
13	230	0.02	0.02	51W	200	0.31	0.08
17	275		0.04				
33	245		0.06				
35	250		0.02				
37T	260		0.04				
40T	200	0.55	0.21				
41T	255		0.02				
42T	210	0.28	0.15				
43W	195	0.28	0.13				
44S	210	0.15	0.10				
46S	240		0.04				
48S	195	0.60	0.22				
49W	200	0.68	0.15				

* Sampled immediately after mixing.

** Sampled after quartering samples for extraction and recovery test.

T - Tall Oil Pitch-Aluminum Sulfate Additive

S - Silicone Additive

W - Wibau Premix

TABLE NO. 6

MOISTURE TESTS

OPEN GRADED MIXES

Limestone Aggregate				Granite Aggregate			
	Mix Temp.	% Moisture			Mix Temp.	% Moisture	
Mix No.	(F)	Imm.*	Ext.**	Mix No.	(F)	Imm.*	Ext.**
15	210	0.24	0.17	18	310		0.01
16	252	0.09	0.04	19	260	0.02	
20	210	0.29	0.16	21	300		0.02
23	240	0.15		22	190	0.19	0.04
25T	212	0.43	0.37	24	195	0.20	0.11
26T	230	0.21	0.12	27T	200	0.07	0.10
29T	200	0.30	0.08	28T	245	0.05	0.10
30T	240		0.10	31T	210	0.24	0.06
				32T	250		0.03

* Sampled immediately after mixing.

** Sampled after quartering sample for extraction and recovery test.

T - Tall Oil Pitch-Aluminum Sulfate Additive

TABLE NO. 10

RECOVERED ASPHALT PENETRATIONS

LIMESTONE AGGREGATE

Dense Graded			Open Graded		
Mix No.	Mix Temp. (F)	Recovered Asphalt Pen. @ 77F	Mix No.	Mix Temp. (F)	Recovered Asphalt Pen. @ 77F
A	280	63	C	295	69
E	290	69	15	210	66
G-T	295	70	16	252	66
1	230	70	20	210	65
2	250	75	23	240	72
3	250	80	34	240	70
4	240	167	25-T	212	74
5	210	71	26-T	230	74
6	195	160	29-T	200	76
7	230	69	30-T	240	75
11	208	146			
12	250	138			
13	230	69			
17	275	66			
33	245	64			
35	250	63			
37-T	260	71			
40-T	200	71			
41-T	255	68			
42-T	210	74			
43-W	195	73			
44-S	210	72			
46-S	240	69			
48-S	195	72			
49-W	200	65			
H	290	168			

T - Tall Oil Pitch-Aluminum Sulfate Additive
S - Silicone Additive
W - Wibau Premix

TABLE NO. 11

RECOVERED ASPHALT PENETRATIONS

GRANITE AGGREGATE

Dense Graded			Open Graded		
Mix No.	Mix Temp. (F)	Recovered Asphalt Pen. @ 77F	Mix No.	Mix Temp. (F)	Recovered Asphalt Pen. @ 77F
B	295	64	D	292	69
8	240	72	18	310	59
9	250	66	19	260	60
10	210	72	21	300	64
14	220	64	22	190	71
38T	240	74	24	195	70
39T	190	73	27T	200	66
45S	240	66	28T	245	73
F-T	295	70	31T	210	66
47S	220	70	32T	250	60
50W	205	64			
51W	200	65			

T - Tall Oil Pitch-Aluminum Sulfate Additive

S - Silicone Additive

W - Wibau Premix

TABLE NO. 12

RETAINED WET STRENGTH OF COMPACTED MIXES

Asphalt Pen.	Aggregate	Grading	Special Conditions	No. of Tests	% Ret. Strength
88	Limestone	Dense	None	5	101.7
238	"	"	"	4	93.4
88	"	"	Tall Oil	2	93.2
88	"	"	Silicone	3	88.7
88	"	"	Conventional	2	103.3
238	"	"	"	1	83.8
88	"	"	Wibau	1	86.3
88	"	Open	None	3	87.1
88	"	"	Tall Oil	2	81.1
88	"	"	Conventional	1	101.9
88	Granite	Dense	None	4	101.2
88	"	"	Tall Oil	2	110.7
88	"	"	Silicone	2	111.9
88	"	"	Conventional	2	92.8
88	"	"	Wibau	1	103.5
88	Granite	Open	None	3	80.7
88	"	"	Tall Oil	2	85.9
88	"	"	Conventional	1	93.9

APPENDIX II

TABLE I

DRUM MIXER: LABORATORY TEST DESIGN

TYPE AGGREGATE	ADDITIVES	GRADATION	INITIAL MOISTURE CONTENT	MIX TEMPERATURE	GRADE ASPHALT (PENETRATION)
A. DRUM MIXER					
Limestone	No	Dense	5%	200 to 220° F.	85 to 100
					200 to 250
				230 to 250° F.	85 to 100
					200 to 250
		Open	4%	200 to 220° F.	85 to 100
				230 to 250° F.	85 to 100
Limestone	Yes	Dense	5%	200 to 220° F.	85 to 100
				230 to 250° F.	85 to 100
		Open	4%	200 to 220° F.	85 to 100
				230 to 250° F.	85 to 100
Gravel	No	Dense	5%	200 to 220° F.	85 to 100
				230 to 250° F.	85 to 100
		Open	4%	200 to 220° F.	85 to 100
				230 to 250° F.	85 to 100
Gravel	Yes	Dense	5%	200 to 220° F.	85 to 100
				230 to 250° F.	85 to 100
		Open	4%	200 to 220° F.	85 to 100
				230 to 250° F.	85 to 100
B. STANDARD HOT MIX CONTROL					
Limestone	No	Dense	N/A	300° F.	85 to 100
					200 to 250
		Open	N/A	300° F.	85 to 100
Limestone	Yes	Dense	N/A		85 to 100
Gravel	No	Dense	N/A	300° F.	85 to 100
		Open	N/A	300° F.	85 to 100
Gravel	Yes	Dense	N/A		85 to 100

TABLE II

DRUM MIXER TESTS LABORATORY OPERATING PROCEDURE

1. Run gradations on stock aggregates, compute blend, blend and rescreen for each batch.

2. Weigh 10,500 grams of aggregate blend into a 3-gallon pail. Add 525 grams of water (5% moisture).

3. Seal container and allow wetted aggregate to set overnight for maximum moisture absorption.

4. Rotate dryer and ignite burner. Heat dryer shell to 250° F. as measured externally at the middle of the drum.

5. Take a 500 gram sample of aggregate for a moisture test.

6. Charge aggregate to the drum mixer. Be certain the flight clockwise from the asphalt addition point (as viewed from the charging hatch) is covered with aggregate.

7. Add asphalt heated to 275° F. to cold aggregate in the drum mixer. Use special container provided which allows an even dispersion of asphalt over the wet aggregate.

8. Close the mixer charging hatch.

9. Turn on the combustion blower.

10. Turn on the exhaust fan, adjust to 1/4" vacuum or less in the exhaust pipe.

11. Ignite the burner and start stop watches simultaneously. Adjust until gas metering orifice pressure drop reads 1 inch W.C. Read and enter gas pressure readings. Do Not Rotate Drum.

12. At 30 seconds start drum rotating and take the initial set of eadings. Take data indicated in the log sheet.

13. Take readings at 30 second intervals.

14. When the desired material temperature is attained, shut the burner off immediately and note the time.

15. Quickly shut off the combustion fan, the exhaust fan and the drum drive.

16. Open the discharge hatch and check the material temperature with a reliable hand thermometer (mercury thermometer). Record this temperature.

TABLE II - Cont'd.

17. Remove aggregate - asphalt mix.

18. Weigh amount of mix recovered. Record gross and tare weights.

19. Sample and analyze mix.

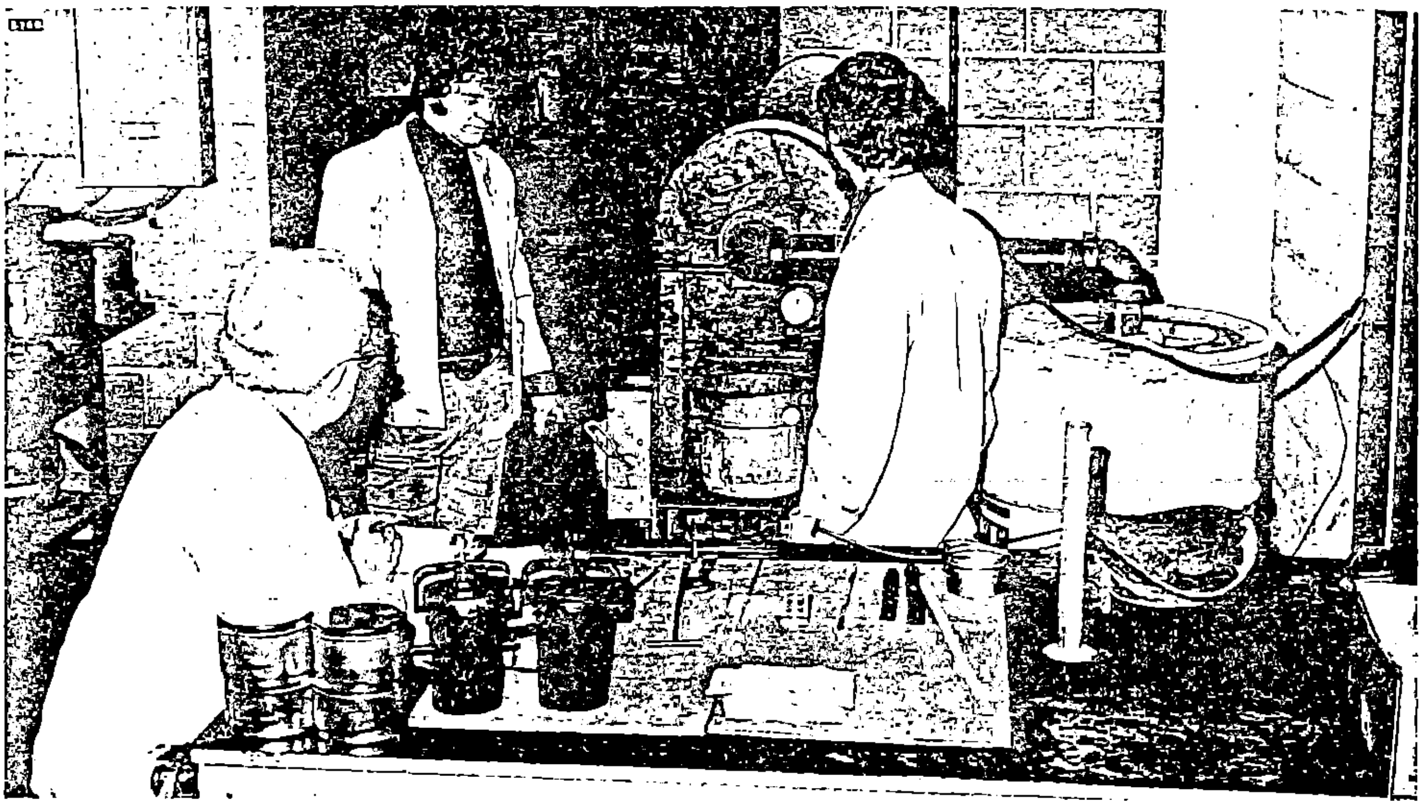

ILLUSTRATION #1:
THE BARBER-GREENE LABORATORY DRUM MIX SYSTEM WAS INSTALLED AT THE CHICAGO TESTING LABORATORY FACILITIES, NORTHBROOK, ILLINOIS.

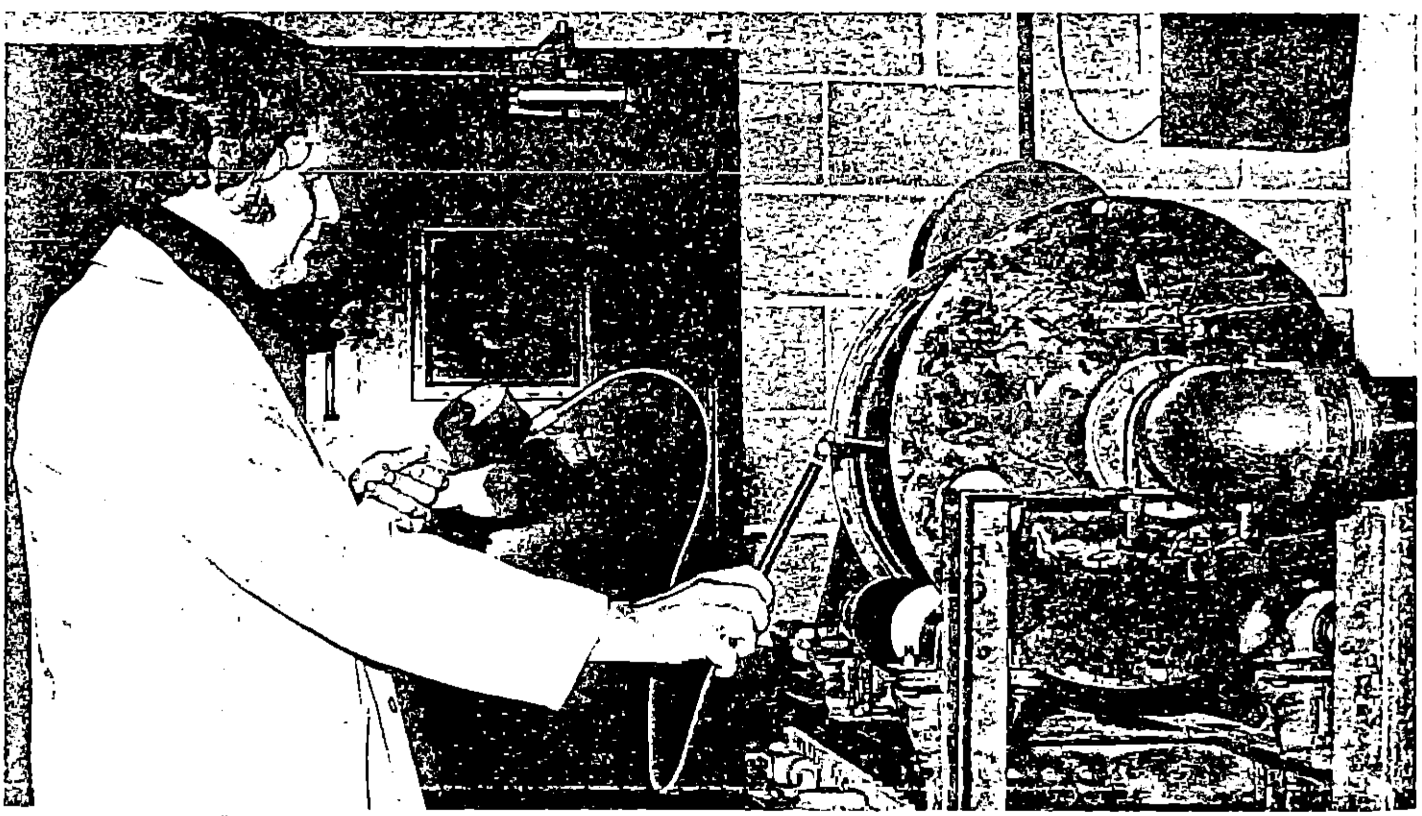

ILLUSTRATION #2:
THE DRUM MIXER WAS CAREFULLY PREHEATED TO A CONSISTENT SHELL TEMPERATURE BEFORE CHARGING A NEW BATCH.

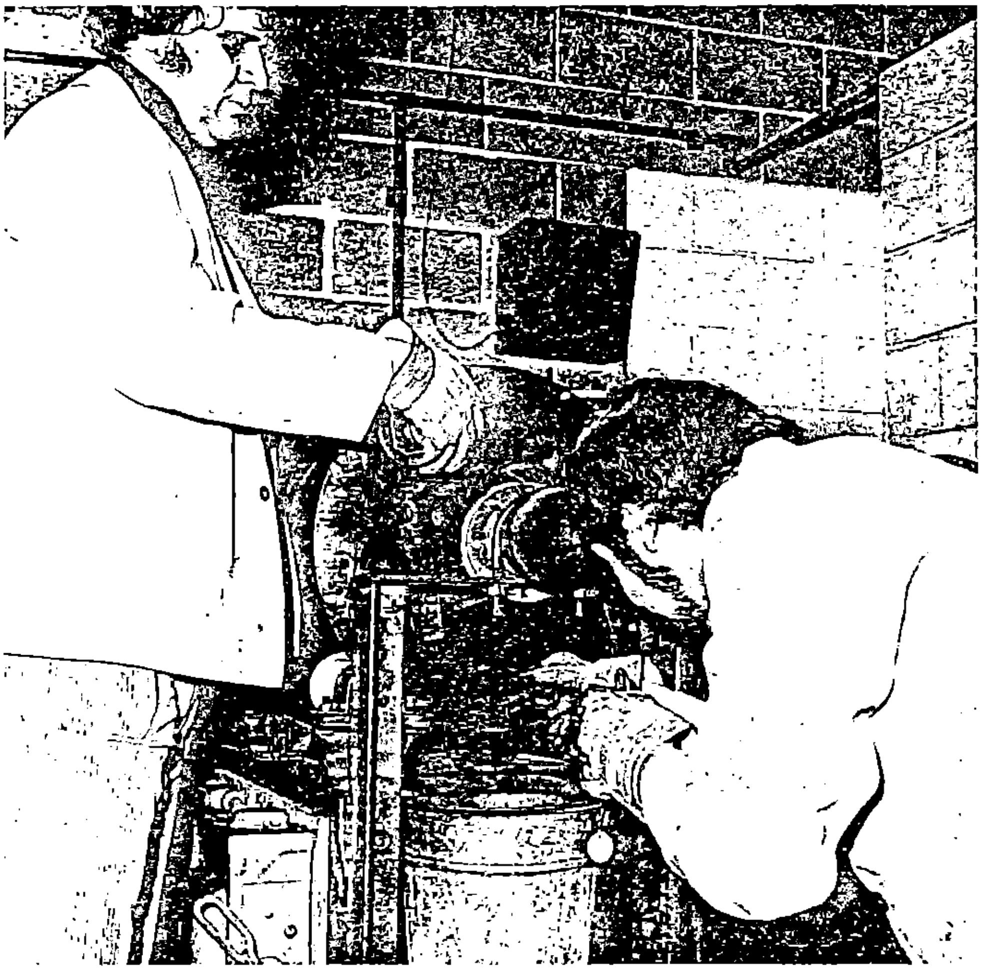

ILLUSTRATION #3:
EACH BATCH WAS COMPLETELY REMOVED, WEIGHED AND SAMPLED.

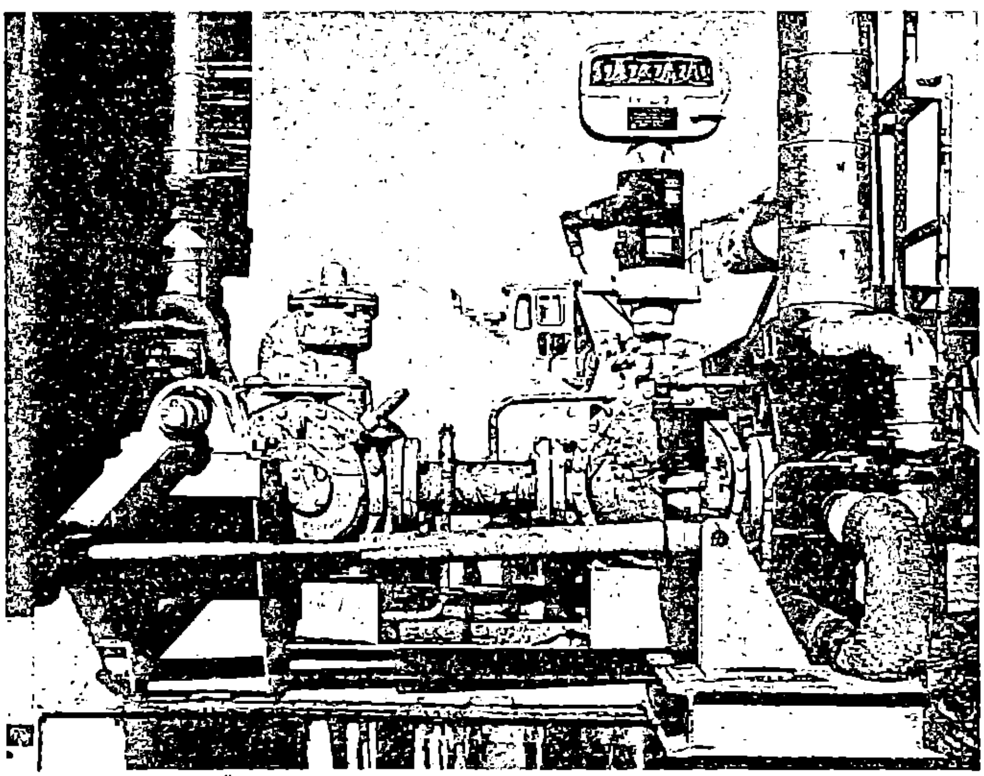

ILLUSTRATION #4:
KEY TO SUCCESSFUL DRUM MIXER OPERATION IS A CONTINUOUSLY MONITORED ASPHALT SYSTEM.

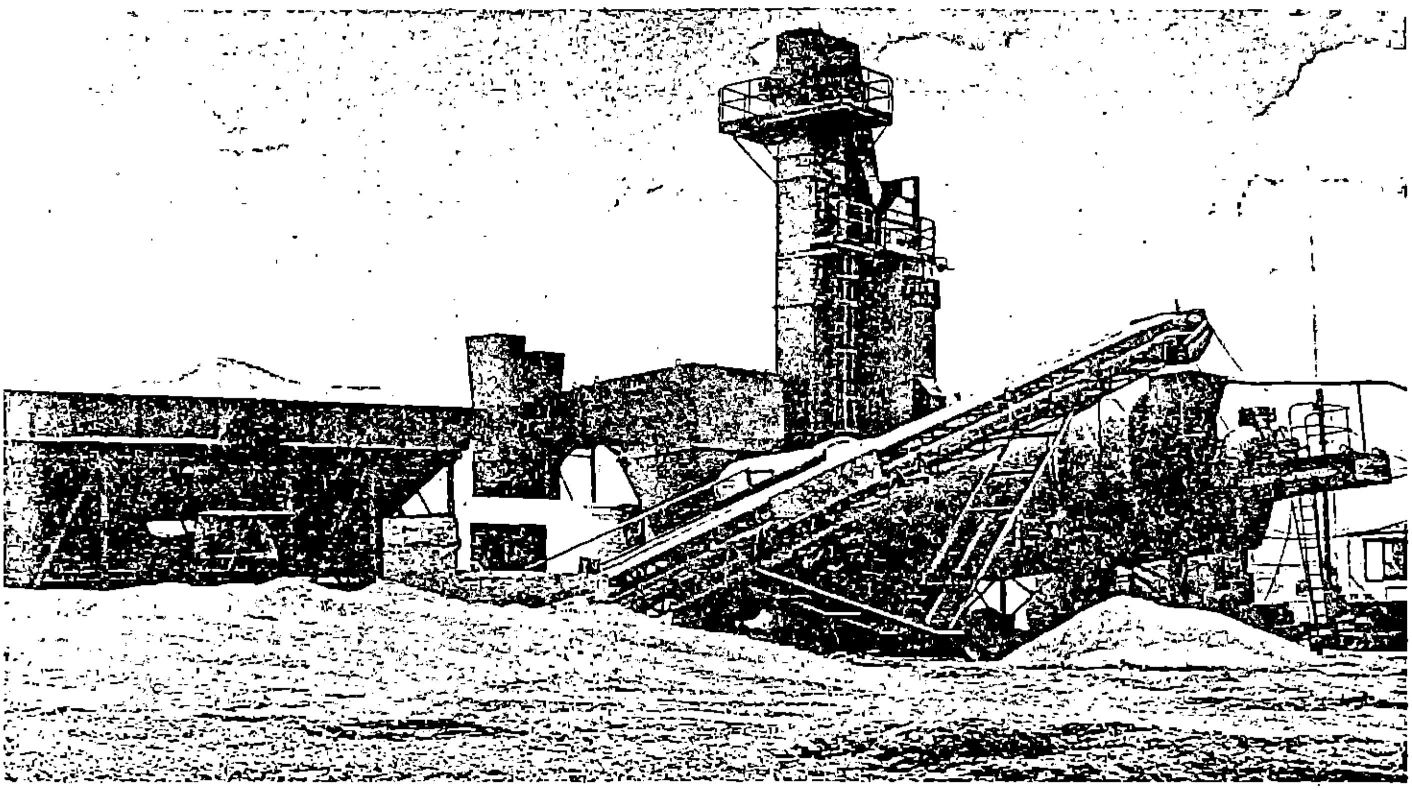

ILLUSTRATION #5:
A TYPICAL DRUM MIXER INSTALLATION, COMPLETE WITH A HOT MIX ELEVATOR AND SURGE SILO SYSTEM.

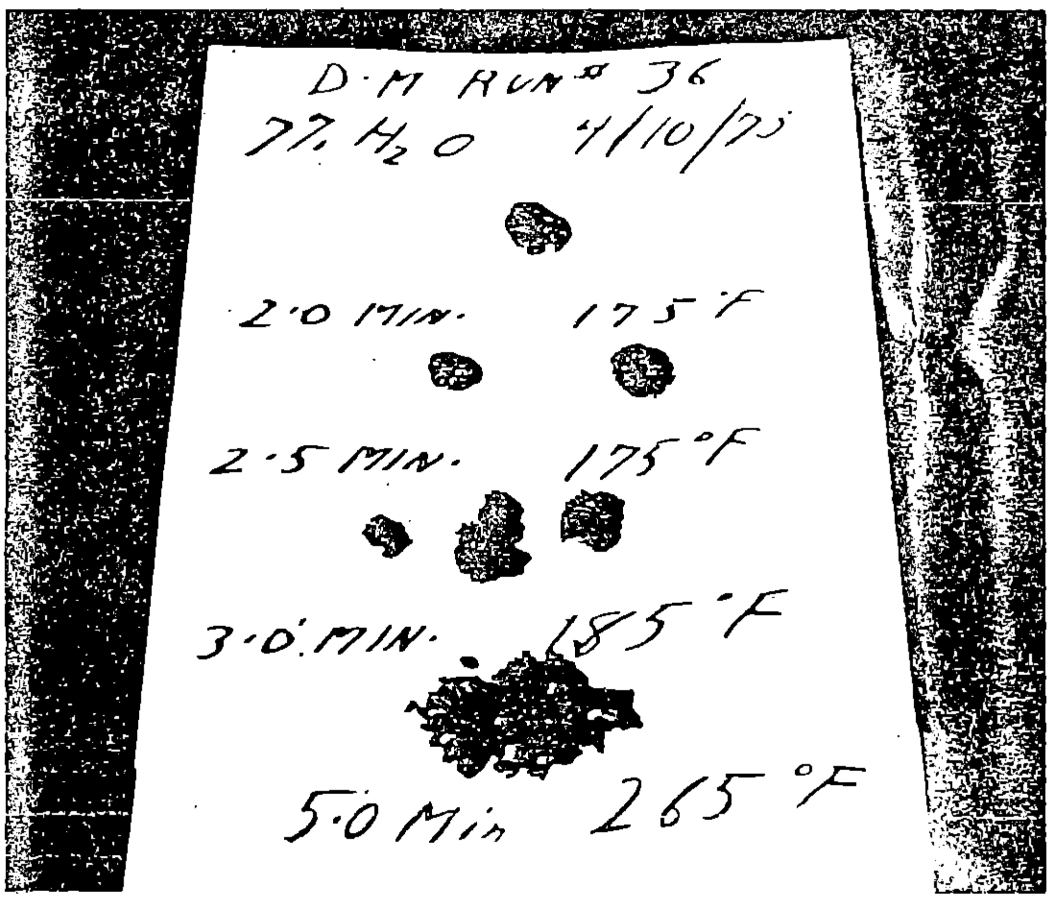

ILLUSTRATION #6:
DETERIORATION OF DUST-ASPHALT BALLS WITH TEMPERATURE AND EVOLUTION OF WATER.

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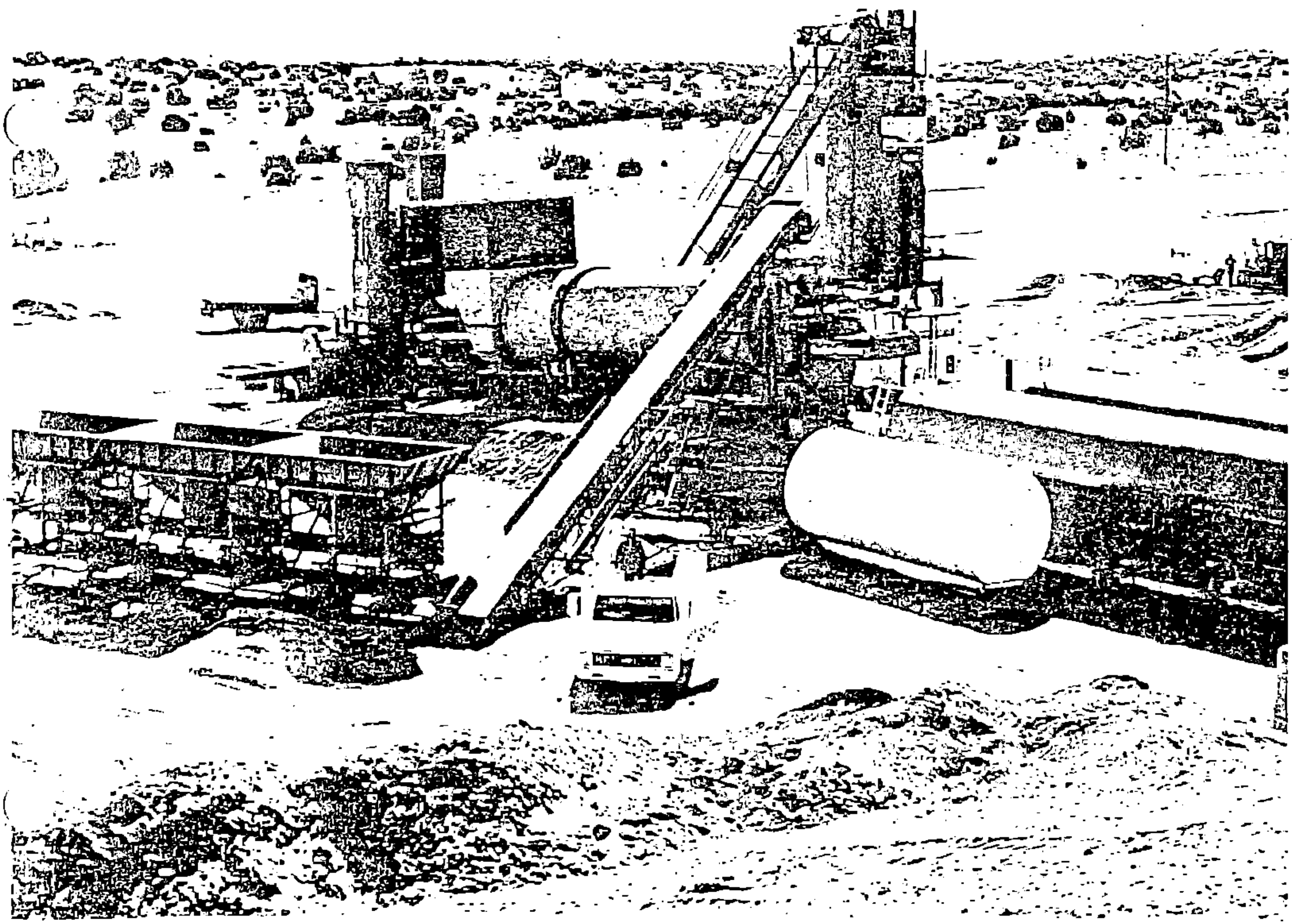
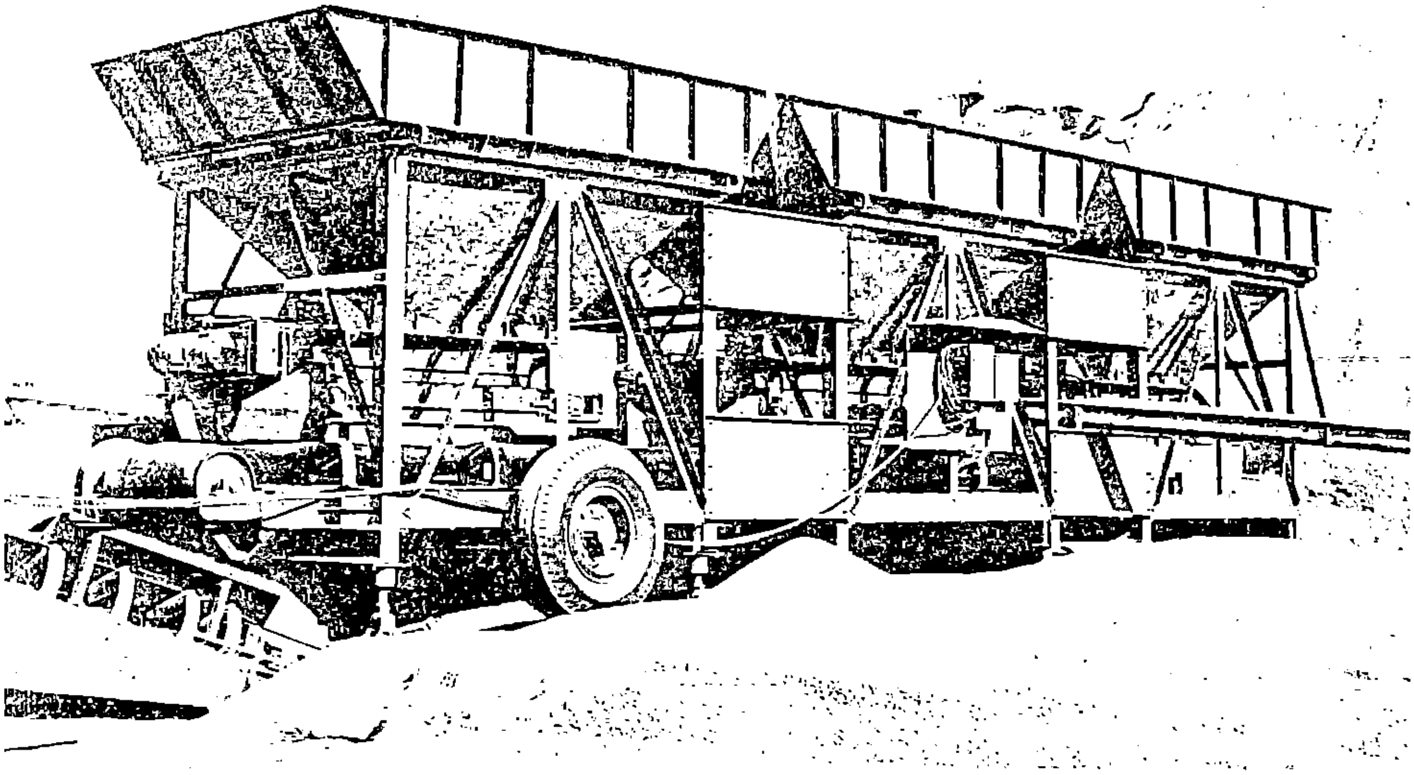
BARBER-GREENE MIXING PLANT LINE

DRUM MIX PLANTS

The typical Drum Mix Plant consists of a highly accurate cold feed system with both total and proportional control, an asphalt metering system that is interlocked with the aggregate system, and a dryer drum that combines the drying and mixing functions. The Drum Mix Plant shown is a Barber-Greene Model DM-75.



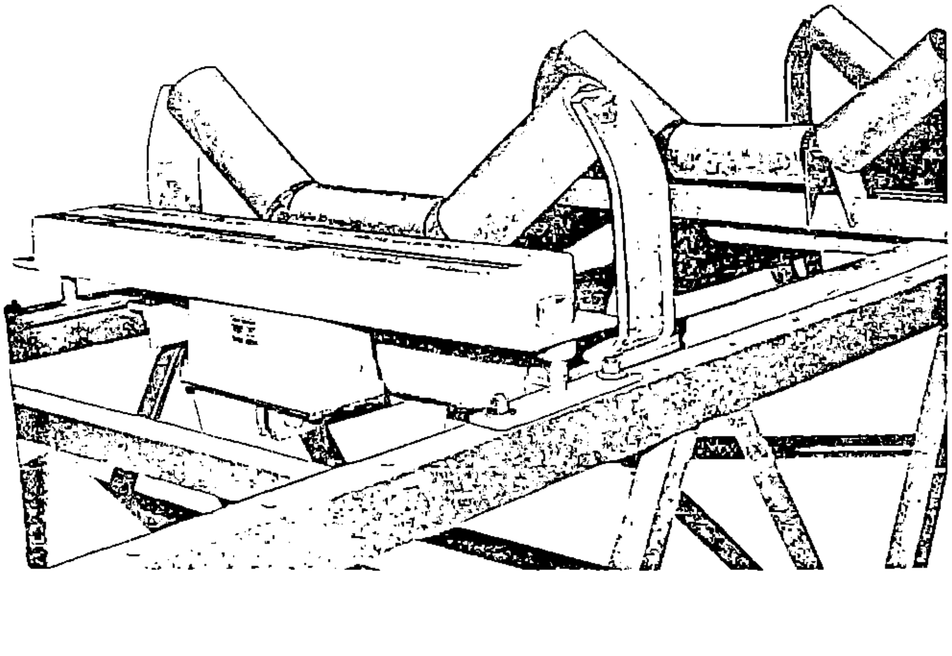
THE AGGREGATE SYSTEM



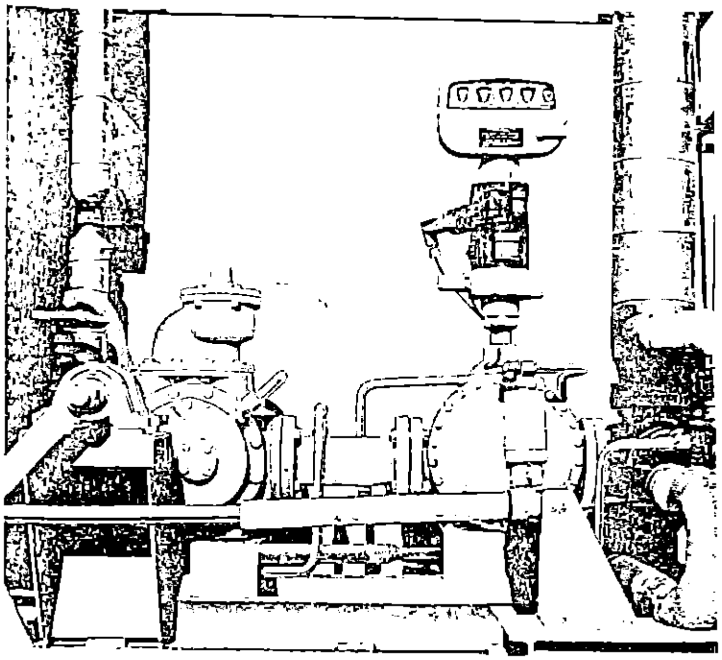
The cold feed unit is the heart of the gradation control system on a drum mix plant. Under each bin is a belt feeder powered by a variable speed electric motor. All of these feeders discharge onto a single gathering belt. The system is designed so that the proportion of each aggregate size can be individually varied and the total amount of aggregate fed into the plant can be increased or decreased without affecting the proportions, thus providing both total and proportional control.

THE WEIGH BELT SYSTEM

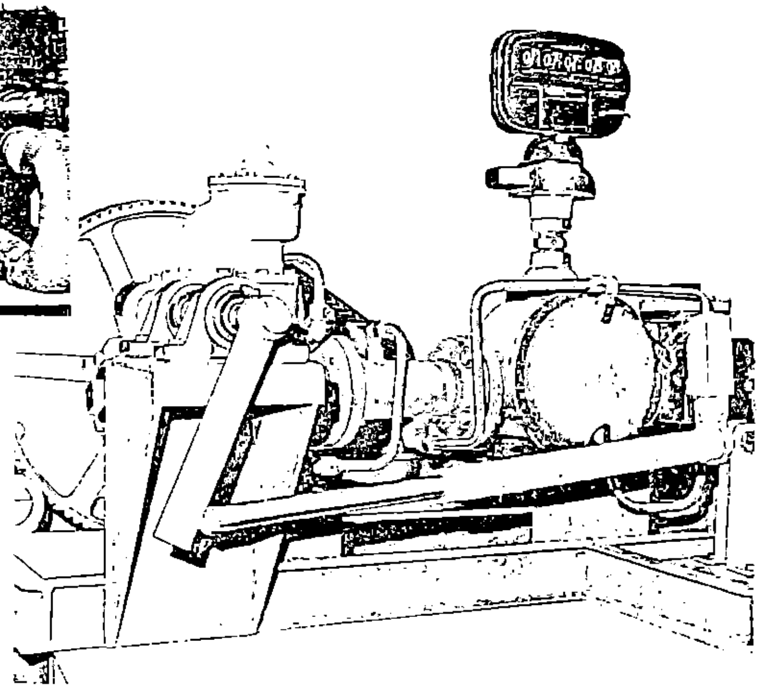
A gravimetric weigh bridge and speed sensor assembly is mounted on the portable inclined feed conveyor.



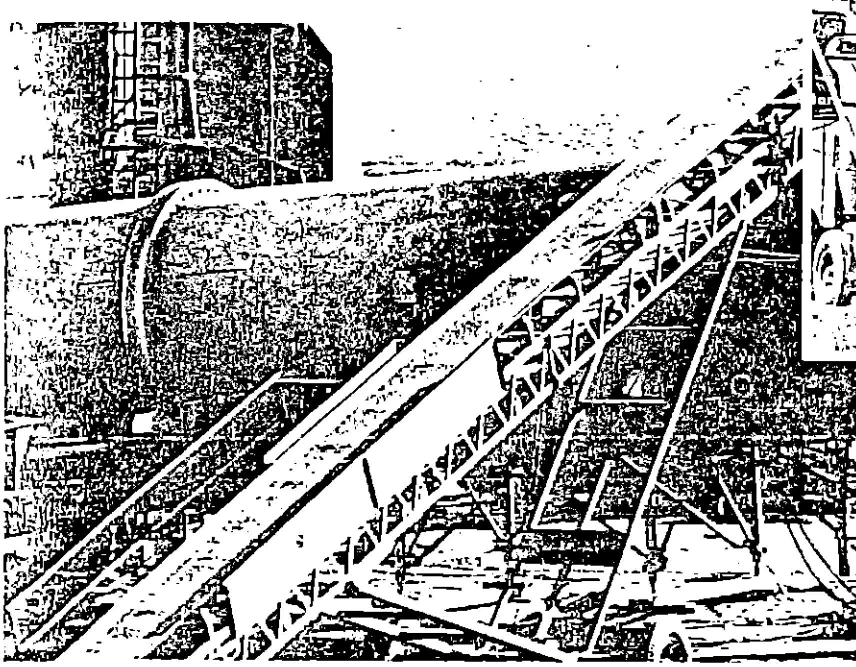
THE ASPHALT SYSTEM

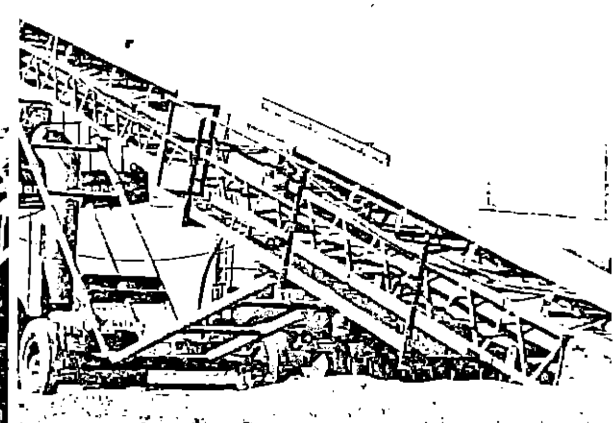


The key to a successful drum mix operation is a continuously monitored asphalt system. On Barber-Greene plants the delivered asphalt quantity is metered and self regulated to the amount required. Without this self regulating feedback control proper proportioning of the quantity of asphalt delivered cannot be assured.



A motor driven worm gear actuator varies delivered asphalt to obtain amount required.

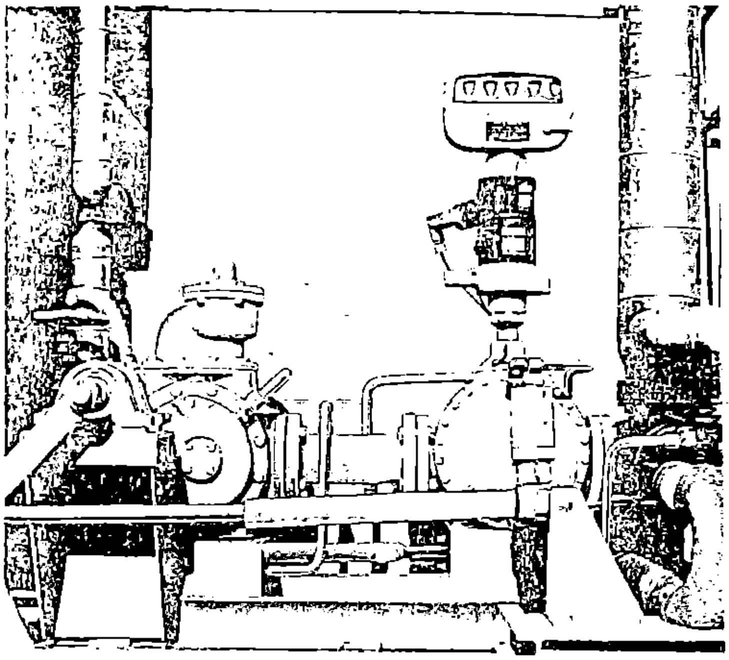




A walkway is provided to facilitate inspection and maintenance of the weigh bridge assembly.

Windguards, gravity take-up (not shown) and self-aligning features improve the reliability and ease of calibration of the weigh bridge assembly.

THE ASPHALT SYSTEM



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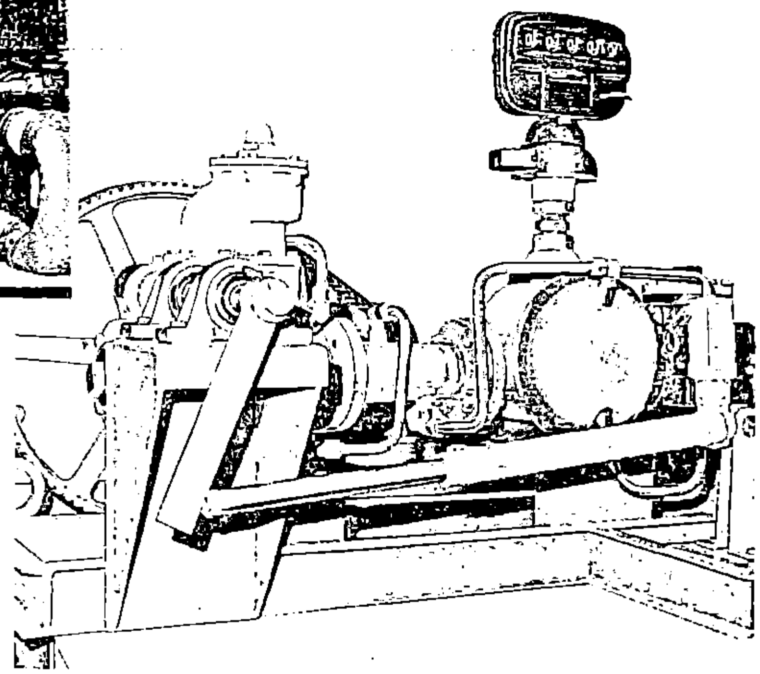

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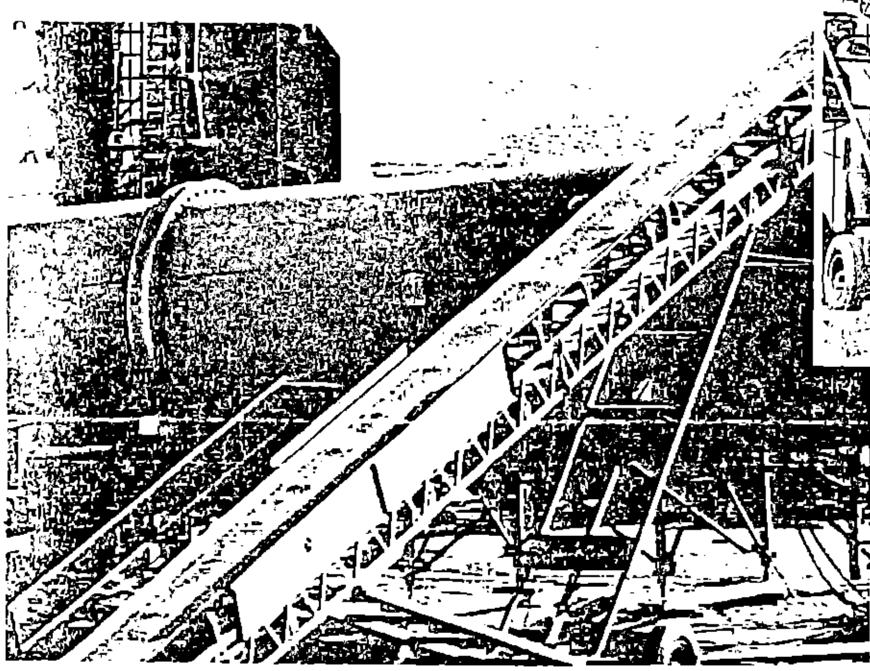
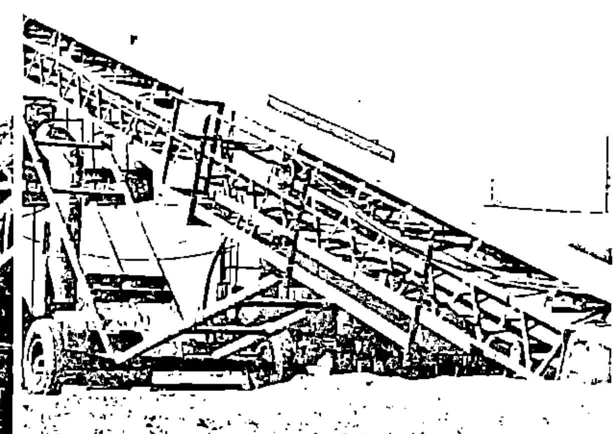
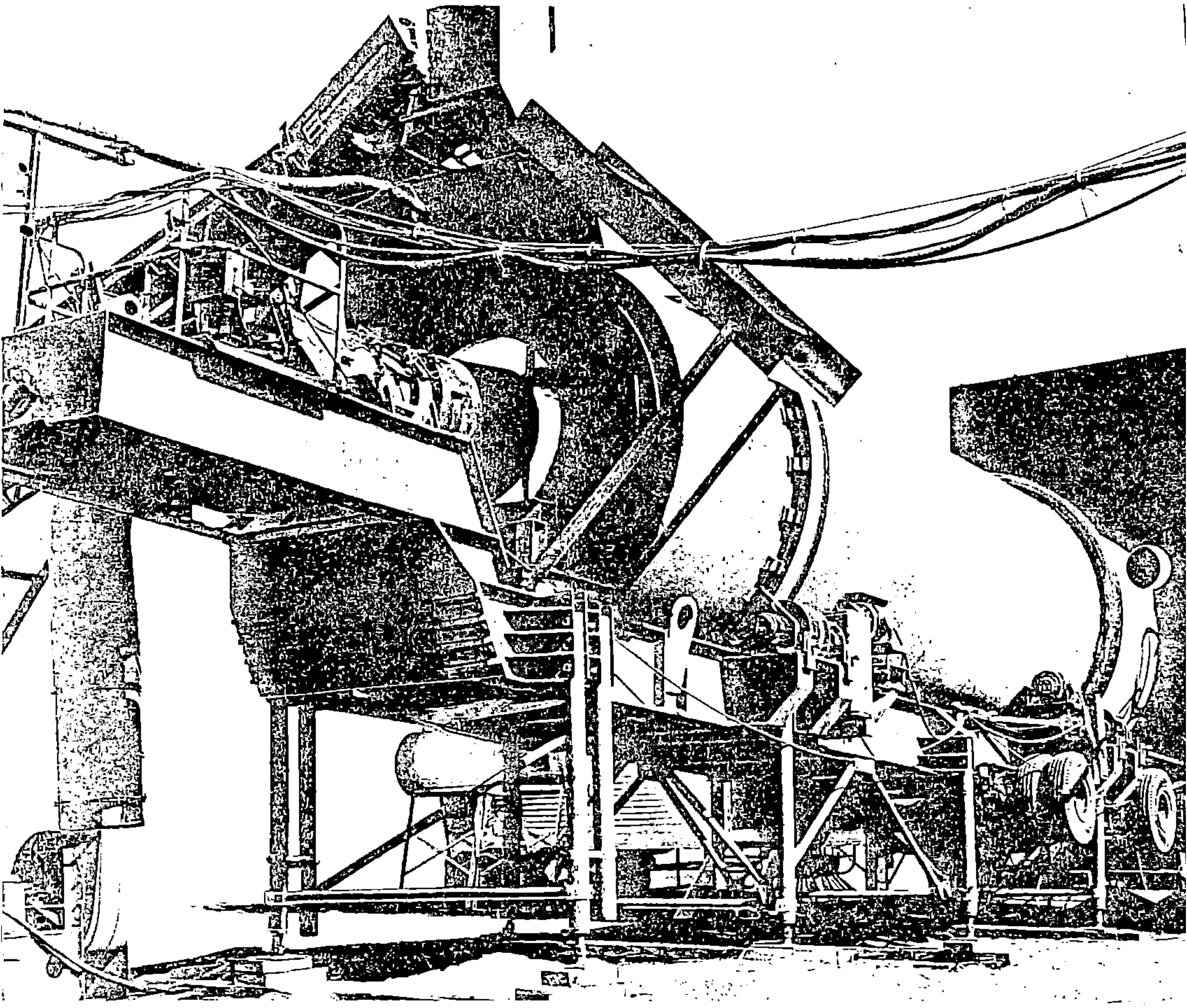




A walkway is provided to facilitate inspection and maintenance of the weigh bridge assembly.

Windguards, gravity take-up (not shown) and self-aligning features improve the reliability and ease of calibration of the weigh bridge assembly.

THE DRUM MIX UNIT

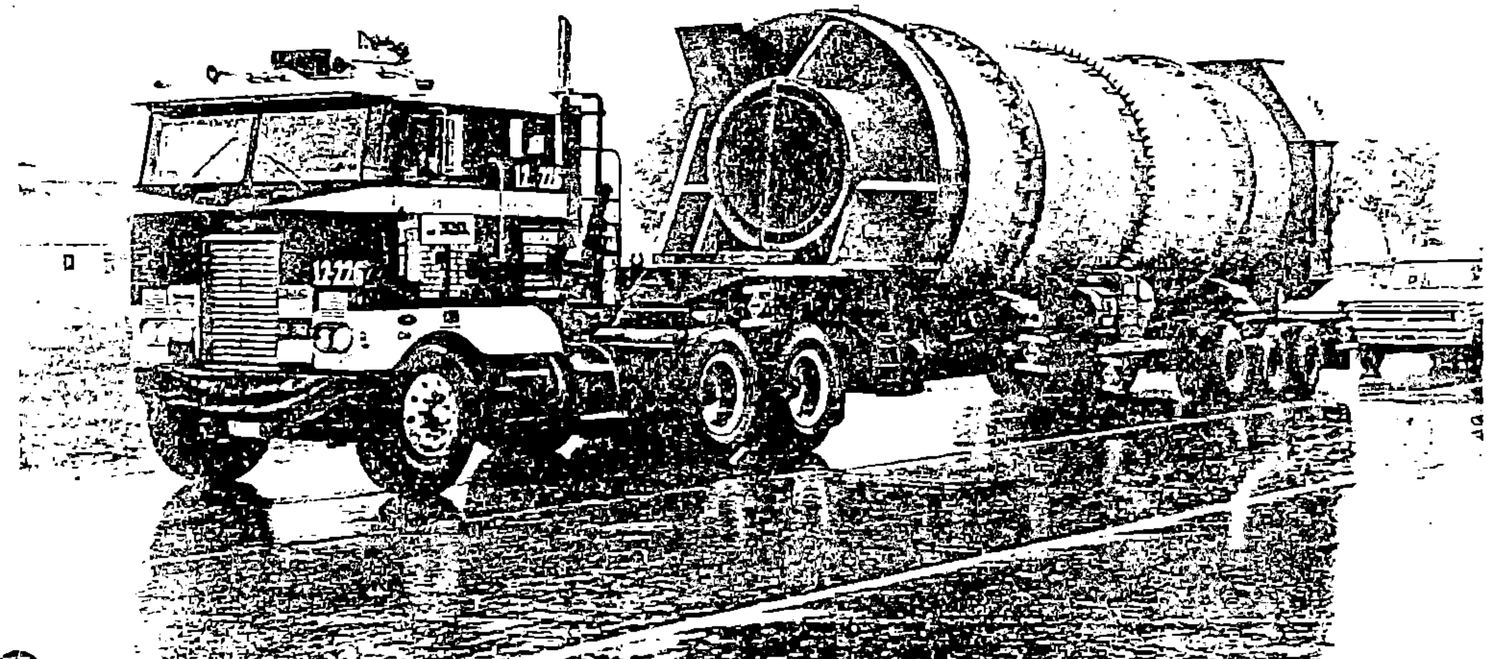


The drum mixer itself is a standard unit almost identical to the standard dryers used in other asphalt plants. The burner, however, is mounted on the charging end instead of the discharge end. This makes it a parallel flow dryer, in which the material travels in the direction of the flame, instead of a counterflow type, in which the material travels toward the burner, becoming hotter as it reaches the discharge point. This change provides maximum heat during initial coating of the aggregate particles so that evaporating moisture can protect the asphalt from the harmful effects of heat and flame. Drying and mixing continue through the length of the drum.

LABORATORY TESTING

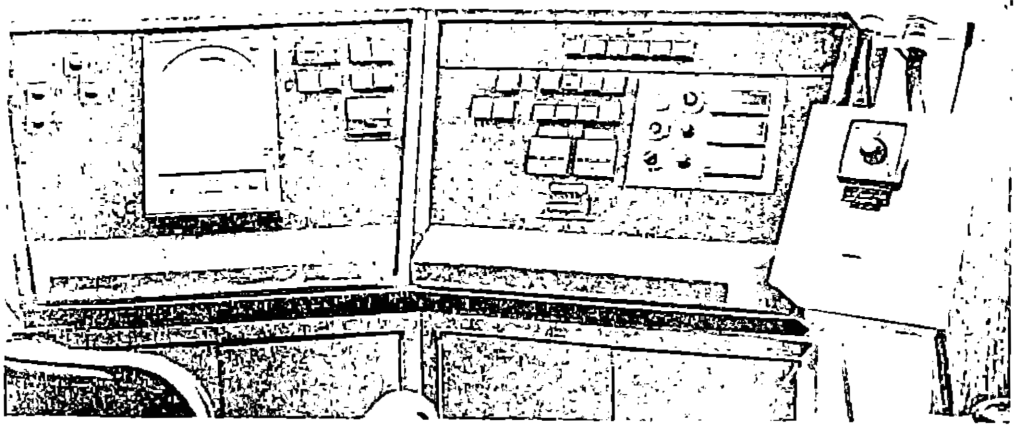
Careful laboratory evaluation of the Drum Mix Process allowed Barber-Greene to confirm the ability of the mixing drum to simultaneously perform the drying and mixing functions as effectively as a separate dryer and mixer.

PORTABILITY

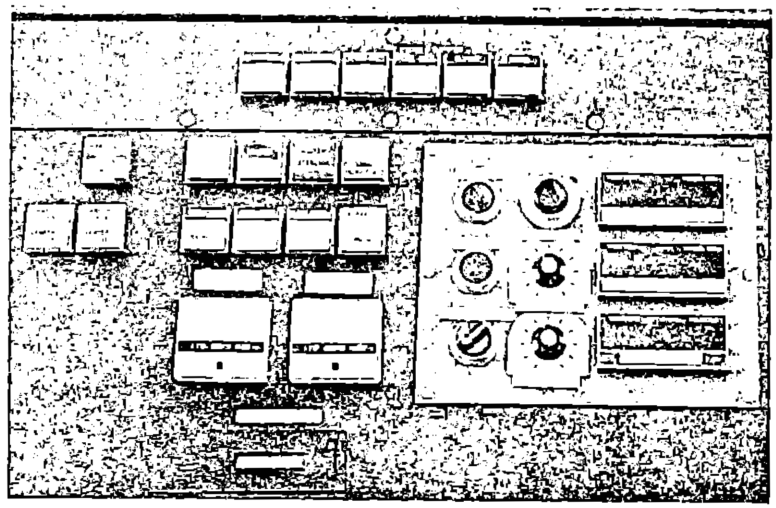


Barber-Greene Drum Mix units are designed for highway travel. Unit shown is a model DM-70.

THE CONTROLS

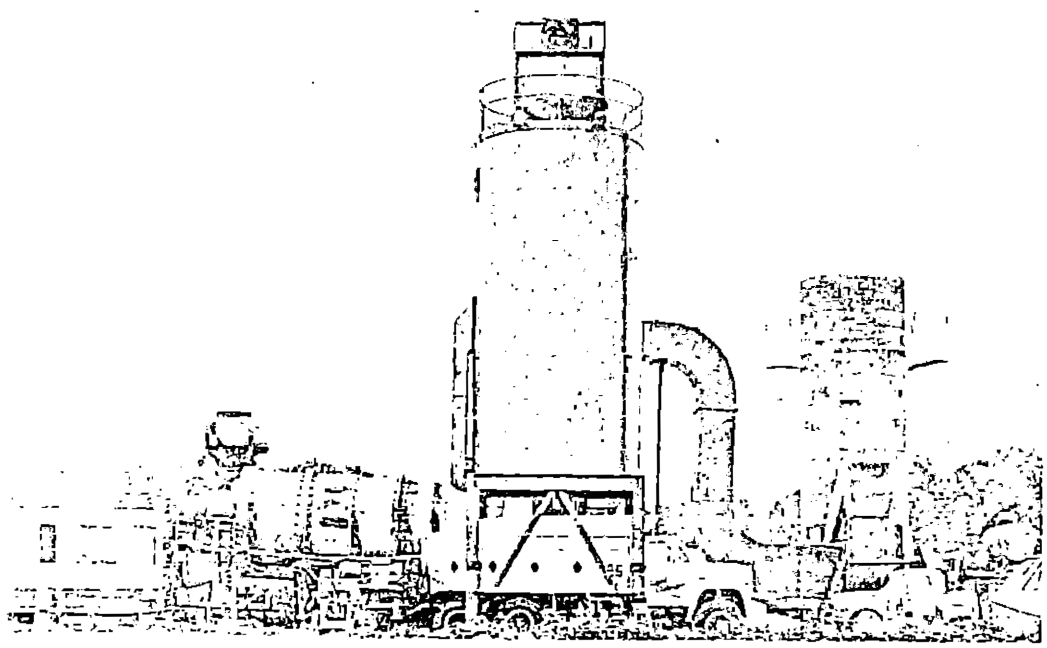


The Barber-Greene control system for the drum mix plant is simple but efficient. The left panel contains the cold feed and burner controls. The start/stop station and proportioning controls are in the right panel. Controls for the surge silo are attached to the right panel.



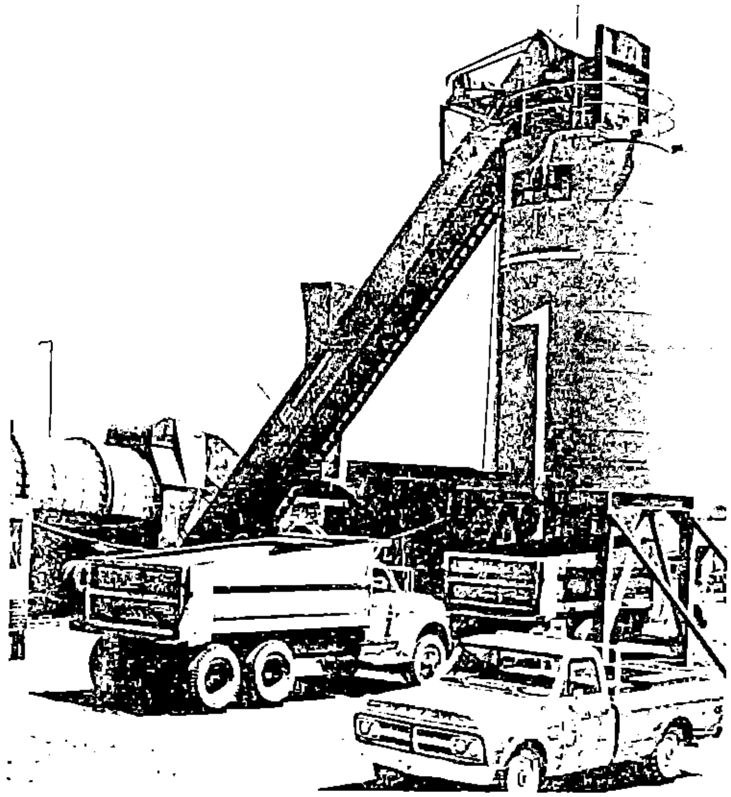
Closeup view of asphalt proportioning controls, digital read-out of required asphalt feed and delivered asphalt and aggregate feed. This control assures desired proportioning of aggregate and asphalt at all times. Simple dial adjustment provides compensation for variations in asphalt density and moisture content of aggregate.

FIELD EXPERIENCE



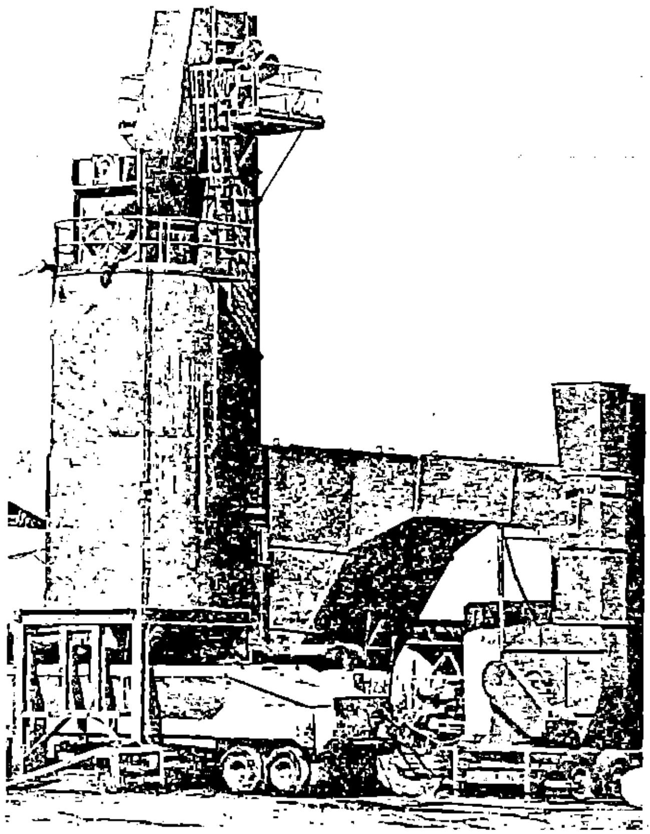
A DM-70 plant operating in Iowa with a wet scrubber system, which meets the state emission specifications.

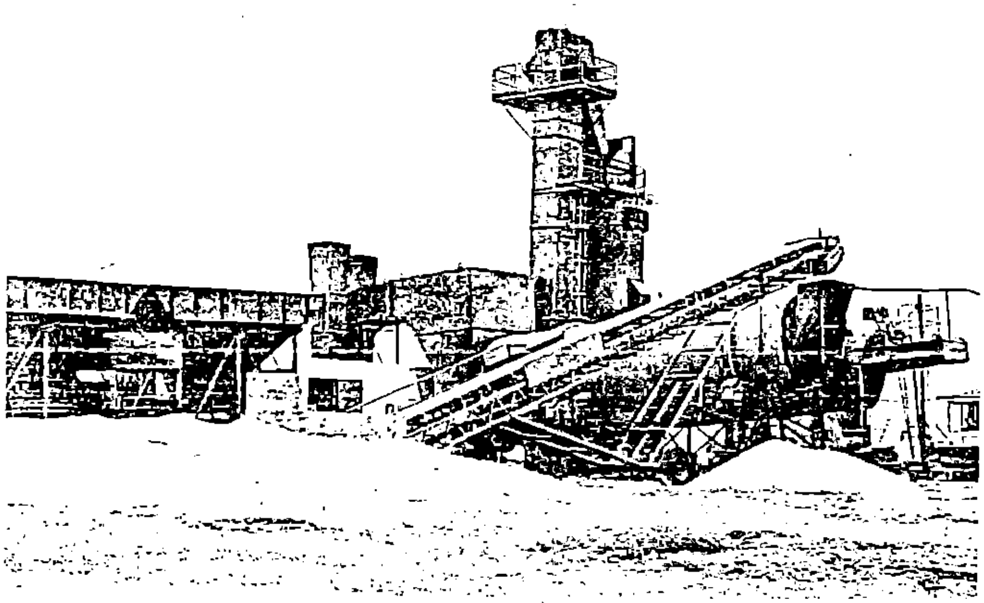
SURGE STORAGE



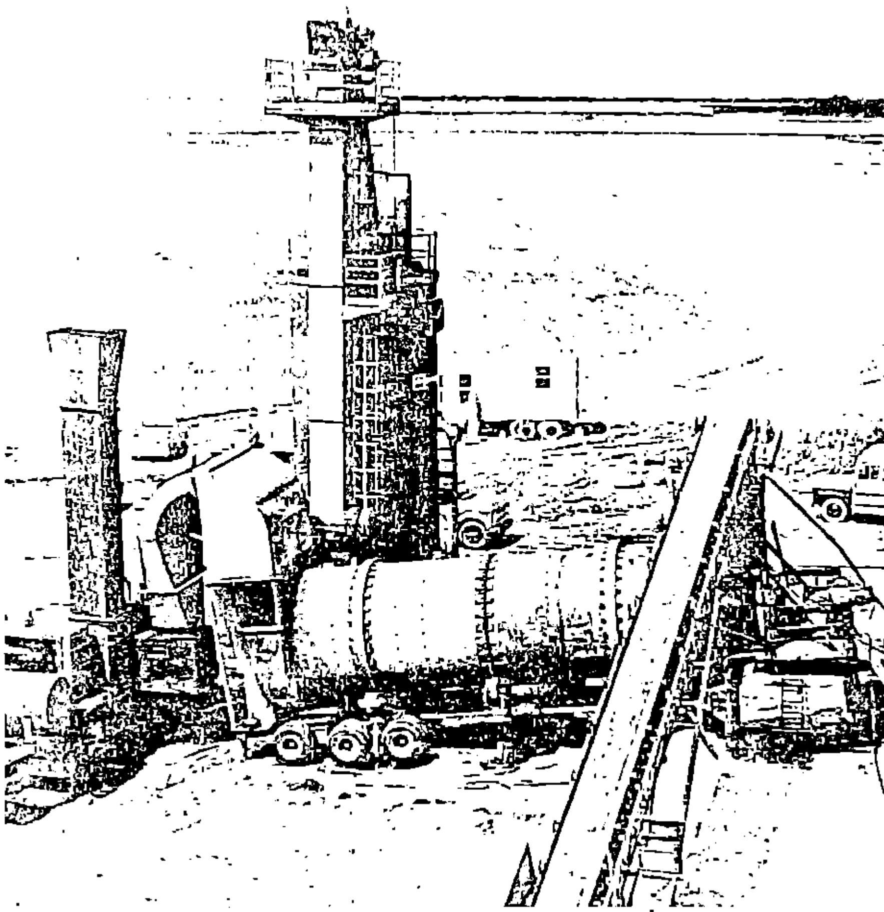
Surge systems are available with slat conveyors.

Hot mix elevators can also be supplied with surge systems.

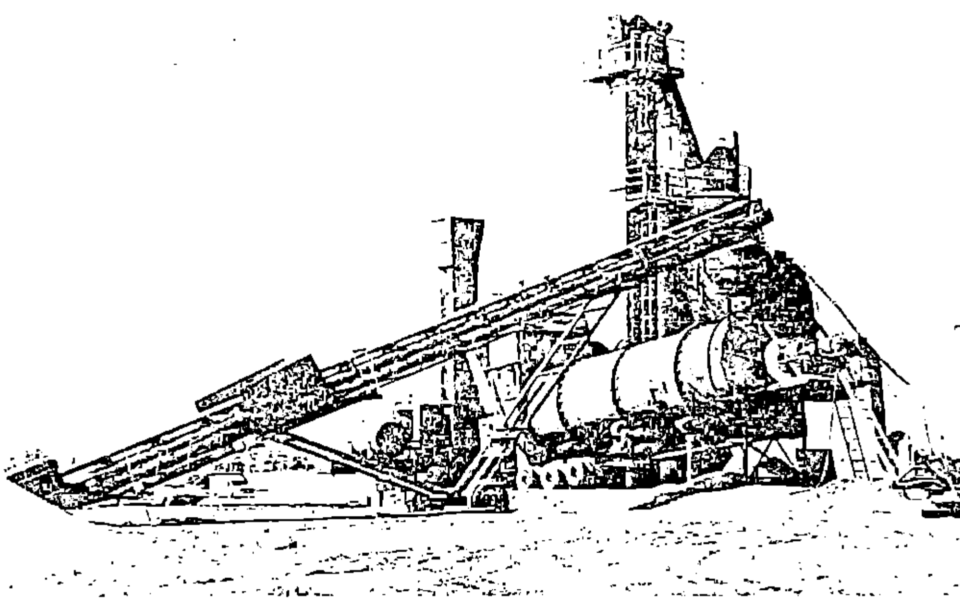




A DM-75 plant in Idaho.



A DM-70 plant operating in Minnesota.



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