c.1

53165 2.50

110.2

FACTORS AFFECTING PRODUCTIVITY OF CENTRAL PLANT CONCRETE MIXERS

Tune Up the Cycle Time - Reduce the Delays

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FOREWORD

The data contained in this report are strictly of a factfinding nature. The commentary is intended for informational and explanatory purposes and should not be considered critical under any circumstances. It is recognized that conditions on individual jobs frequently warrant operational practices which are not conducive to optimum equipment performance or productivity.

The actual field studies were made on typical, active jobs by the Structures and Applied Mechanics Division, Office of Research and Development, Bureau of Public Roads, with the aid of junior engineer personnel in-training, in cooperation with the respective highway departments, contractors, and manufacturers. The data findings reflect plant operations on 20 different projects in widely scattered regions of the continental States. This summary of job performance data has been prepared in response to indications that the information can be of significant value to the highway industry.

FACTORS AFFECTING PRODUCTIVITY OF CENTRAL PLANT CONCRETE MIXERS

Tune Up the Cycle Time and Reduce the Delays

Production rates today of 400 to 500 cubic yards per hour are commonplace for central mix plants equipped with a two drum setup. Such rates are the forerunners of challenge to the mile-a-day paving contractor who intends to sustain his membership in the distinguished performance club. The production rate credentials are steadily going higher. Short period surges are claimed for plant production rates reaching 600 cubic years per hour. Multi-lane slipform pavers are reputedly capable of handling 250 to 300 cubic yards per hour per lane. Certainly no one expects the future to stand still, but it is recognized as equally true that time and continuing experience will determine the realistic production ceiling for the type of construction projects most frequently encountered. Likewise, the part played by specification changes in enhancing the opportunities for expanded developments in central plant mixing equipment needs to be recognized.

Even so, the evidence shows ample room for significant improvements in the management and productivity of many currently operating central plant concrete mixing setups. This fact is born out by operating data from 20 different projects. The focal point of interest in this discussion is centered on the wide range in cycle time characteristics and performance variations encountered for these plants. Some of the changes in cycle time adjustment (which these data indicate are possible on a large percentage of the plants) reflect significant opportunities for increasing the potential capacity of many plants, and stepping up actual production rates.

For the purpose of discussing these opportunities, it is desirable to identify and define for the typical central mix concrete plant, the component time elements of the plant operating cycle. In either the one or two drum setup, the essential time elements composing the cycle are:

1.) charging, 2.) mixing, and 3.) discharging.

Charging time is the interval of time taken for all solid ingredients of the batch to enter the mixing drum. Mixing time is considered to begin when all solid ingredients have entered the drum and to end with discharge of any part of the batch. Discharge time ends when the empty drum has returned to mixing position. Usually there is a lag interval of 1 to 2 seconds between return of the empty drum and start of charging time for ingredients of the next batch.

Figure 1 shows mixer charging time in seconds for each of the 20 plants studied. The sequence is arrayed in ascending order of time from fast to slow charging. These times exclude the charging lag interval from instant empty drum is returned, to the start of aggregate charging. All data have been adjusted to the common denominator of 8 cubic yard batches, by applying batch yardage ratios to the charging time and the concrete discharge flow portion only, of the discharge time. The quickest charging time, shown on the left was between 14 and 15 seconds, while at the far right the slowest charging time is more than double that of the best performance. It is interesting to note that this chart and all of those that follow show a data spread that is reasonably typical of most all types of construction job comparisons.

Figure 2 shows for the same 20 plants, the discharge time for each setup arrayed in ascending sequence from the quickest to the slowest performance. Their ascending order for discharge is not necessarily the same plant sequence as that for charging time. The discharge time shown includes return of the empty drum to mixing position. Again, all data has been adjusted to the common denominator of 8 cubic yard batches. In addition, the "drum return lead time," which actually varies between plants from plus to minus over a surprising range, was adjusted to a reasonably consistent lead time of one to two seconds depending on the drum return speed. Discharge lag time from the start of drum tilt to instant first concrete leaves the mixer, is recognized as a part of mixing time, and therefore excluded from discharge time. The discharge time ranged from a minimum of about 10 seconds to a maximum which again was more than double that of the best performance.

The nonmixing cycle time shown in figure 3 was obtained by matching from figures 1 and 2 the charging and discharging time of each plant respectively, and adding a uniform allowance of 1 second for charging lag. The ascending sequence of the nonmixing cycle time for each plant is significant because the range in this cycle time component reflects for any given mixing time the potential productivity lost because of cycle time differences. Potential productivity as applied here is the production rate of which the plant is capable, without any delays to interrupt the continuous repetition of the plant operating cycle. For example, using a mixing time of 60 seconds, the plant at the far left would be capable without delays of turning out one 8 cubic yard batch from a single drum in 1 minute and 29 seconds while the plant at the opposite end of the sequence would require 1 minute and 49 seconds to turn out the same 8 yard batch from a single drum. These two extremes represent a potential difference in hourly production rates of about 57 cubic yards, at a mixing time of 1 minute.

One more feature in figure 3 merits attention. The shaded area overlaying the data bars for the 20 plants, indicates the nonmixing cycle time which performance has demonstrated to be potentially possible for a well adjusted plant under the right conditions, if top performance for both charging and discharging were to be obtained on the same plant. Such a top flight performance would be 3 seconds better than the best plant time shown at the extreme left.

Figure 4 shows theoretical production potential at 1 minute mixing time for the 20 plants based on the same nonmixing cycle time and the same graphic sequence given in figure 3. The important qualification relative to the production limits shown here is that hypothetically, all delays to the operating cycle have been eliminated. In actual practice this is never realistic for extended intervals. The range in potential of approximately 57 cubic yards per hour as noted earlier is the difference shown here between a high of 322 and a low of 265 cubic yards.

Figure 5 again shows potential production limits for the 20 plants, and retains the same order established in figure 4, but instead of reflecting the 60 second mixing time, plus adjusted charging lag and drum return lead times used in figure 4, the rates shown are based on the actual mixing time, charging lag time[1/] and drum return lead time found during the period that plant performance data were obtained.

Figure 6 is only a decorated version of figure 5, and provides an additional comparison with average actual production rates sustained by each plant for periods of two to three weeks of operation. Major down time of the plants has been excluded. The solid portion of the bar shows actual production adjusted to 8 yard batches while the broken segment shows for each plant respectively, the implied cost of minor delay interruptions to plant operations in terms of potential production lost. The relationship between actual and potential as shown in this chart reflects the job operating efficiency of the plant operations. The extremes in operating efficiency range from a low of 32 percent to a top of nearly 93 percent. The missing plant in the middle was dropped from this chart because data were not available on the plant operating efficiency.

The data in figure 7 is quantitatively identical to figure 6, but the arrangement has been shuffled to indicate the minimum mixing time at which each plant's batchmeter was operating. Also, additional detail is given regarding the general category of minor delays. The potential efficiency identified by the background curves has been redefined from that discussed in preceding charts. In this chart, the gap in any given instance between the top of the bar and the 100 percent curve indicates the extent to which the mechanical potential of that plant as operated falls short of the top potential demonstrated to be possible, based on the best performance encountered for charging and discharging among the group of 20 plants, when "charging lag" and "drum return lead time" are adjusted to the optimum values used in figures 1, 2, and 3. This so-called possible potential is derived from a cycle time composed of 15 seconds charging time, 10 seconds discharging time, and 1 second charging lag. Although the graphic pattern is somewhat erratic, the trend to higher actual production is apparent as mixing time decreases. The plant minor delays have been divided into three categories: (1) routine minor operating delays to plant, (2) lack of batch trucks at plant, and (3) plant holdups due to slow work at the paving site.

[1/] The only exception to this was on two of the plants where for unorthodox causes, charging lag time was excessive beyond the limits of orthodox and reasonable practice. Reasonable allowances for charging lag time were substituted in each case.

There are several interesting and significant points which deserve attention in this chart.

(1) The observed production potential of these plants was short on the average, by nearly 13 percent of the attainable potential indicated by the curves. This is equivalent to about 40 cubic yards per hour.

(2) Minor delays to plant operations caused these plants to fall short of their observed production potential, as is, by 30 percent on the average. The previously noted 13 percent added to this 30 percent means that their average performance was more than 40 percent short of attainable potential.

(3) Eighteen of the cited 30 percent minor delays to plant operations were caused by lack of hauling units at the plant, while holdups due to slow work at the paving site accounted for 3 percent, and other minor plant operating delays accounted for the remaining 9 percent.

(4) The nine plants having the fewest delays from lack of hauling units at the plant had an average loss of 6.2 percent from this cause, while their average loss from other minor plant operating delays was 7.5 percent.

(5) In contrast to the above, the ten plants having the most delays from lack of hauling units at the plant had an average loss of 28.2 percent from this cause, while their average loss from other minor plant operating delays was 11.1 percent.

This seemingly illogical trend in the comparative 7.5 and 11.1 percent loss from minor plant operating delays noted above, follows a familiar pattern for typical job performance. Jobs which generate the faster tempo of performance seem to breed fewer delays in general. This seeming paradox is a classic characteristic of high levels in job performance.

The heavy proportion of plant delays incurred from lack of hauling units, so often encountered on many jobs, focuses attention on a major stumbling block in our continuing quest for improved operating efficiency and lower construction costs for highway pavements.

Figure 8 illustrates in a rough way the relation between waits at the plant by hauling units versus plant waits for hauling units. The significant fact about this relationship is that neither one of these waits is seldom if ever reduced to zero, in practice. Even with an abundant supply of hauling units, there are inevitably brief instances when there are none available at the plant. However, purely from the economic standpoint of operating costs for equipment and labor it is interesting to examine the point of economic balance for plant waits versus hauling unit waits. For a $300,000 plant setup including auxiliary equipment, assume the hourly operating costs including labor to be $150 per hour. If the hourly operating cost per hauling unit, including driver, is $15 per hour the cost ratio of waiting time per batch becomes 1:10. This means that the hauling unit can afford to wait on the plant 10 times as long per batch on the average, as the plant can afford to wait on the hauling unit. Thus, for example, if it were determined for a given job situation, and a given number of haulers, that the plant was waiting for haulers 7 minutes for every 100 batches, the haulers could afford to wait 70 batch truck minutes for the same 100 batches. Expensive specialty haulers such as side dumpers, or agitor type equipment are generally not available as for-hire haulers. Consequently, the contractor must invest a substantial amount of capital in hauling equipment, some of which must stand-by during periods of short haul operations, thus running up the contractor's overhead charges. There are many variations between jobs, including a cash flow basis for the above calculations, which would obviously affect the plant to hauling unit relationship.

Another factor to be considered is the increasing frequency with which project specifications permit the use of ordinary dump trucks as haulers to deliver concrete to the paving site. This has the dual advantage of not only permitting the use of less expensive hauling equipment, but also reduces the contractor's capital investment demands because rental units are much more readily available in the case of ordinary dump trucks than happens for specialty type haulers.

In conclusion, it is evident that where the job situation is conducive to high production operations, and contract provisions permit, central plant mixing setups are currently enjoying a demonstrated popularity. The potential for high production with central plant mixers is apparent from data presented. However, in seeking to utilize this potential to the greatest extent possible, the data shows that attention to good plant adjustment and balanced hauling capacity are highly important on central plant mixers. In many cases, production losses from lack of an adequate supply of hauling units are clearly a calculated management decision, particularly with specialty haulers. However, the available data suggests that ample opportunity exists for improved unit cost economy through greater attention to the problem of waits, along with proper plant adjustment and better control of operating delays.

MIXER CHARGING TIME FOR EIGHT CUBIC YARD BATCHES

Central Plant Concrete Mixer Comparisons
Excludes charging lag interval

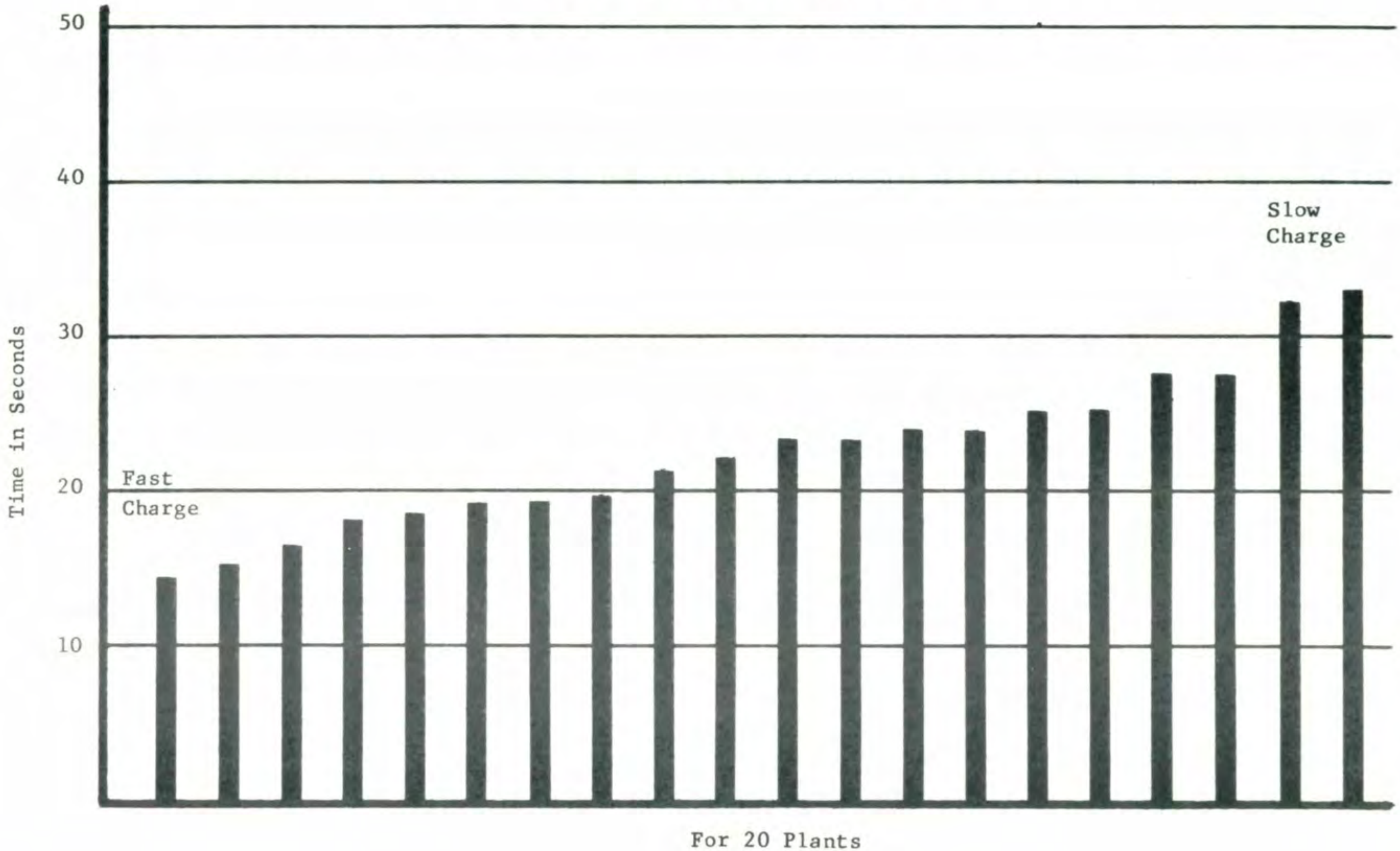

FIGURE 1

MIXER DISCHARGING TIME FOR EIGHT CUBIC YARD BATCHES

Central Plant Concrete Mixer Comparisons
Reflects adjusted drum return lead time
Excludes discharge lag time

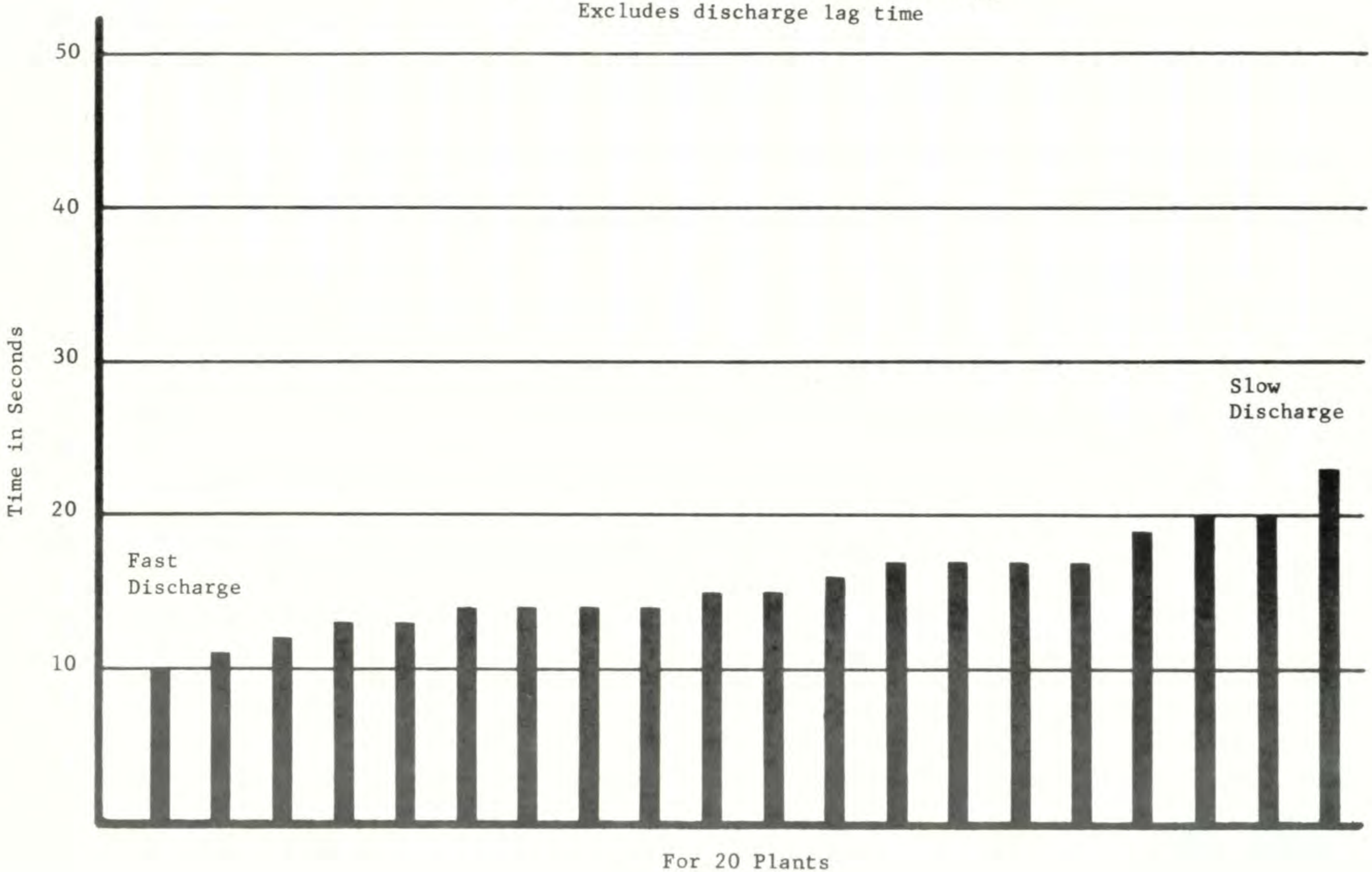

FIGURE 2

TOTAL NON-MIXING CYCLE TIME FOR EIGHT CUBIC YARD BATCHES

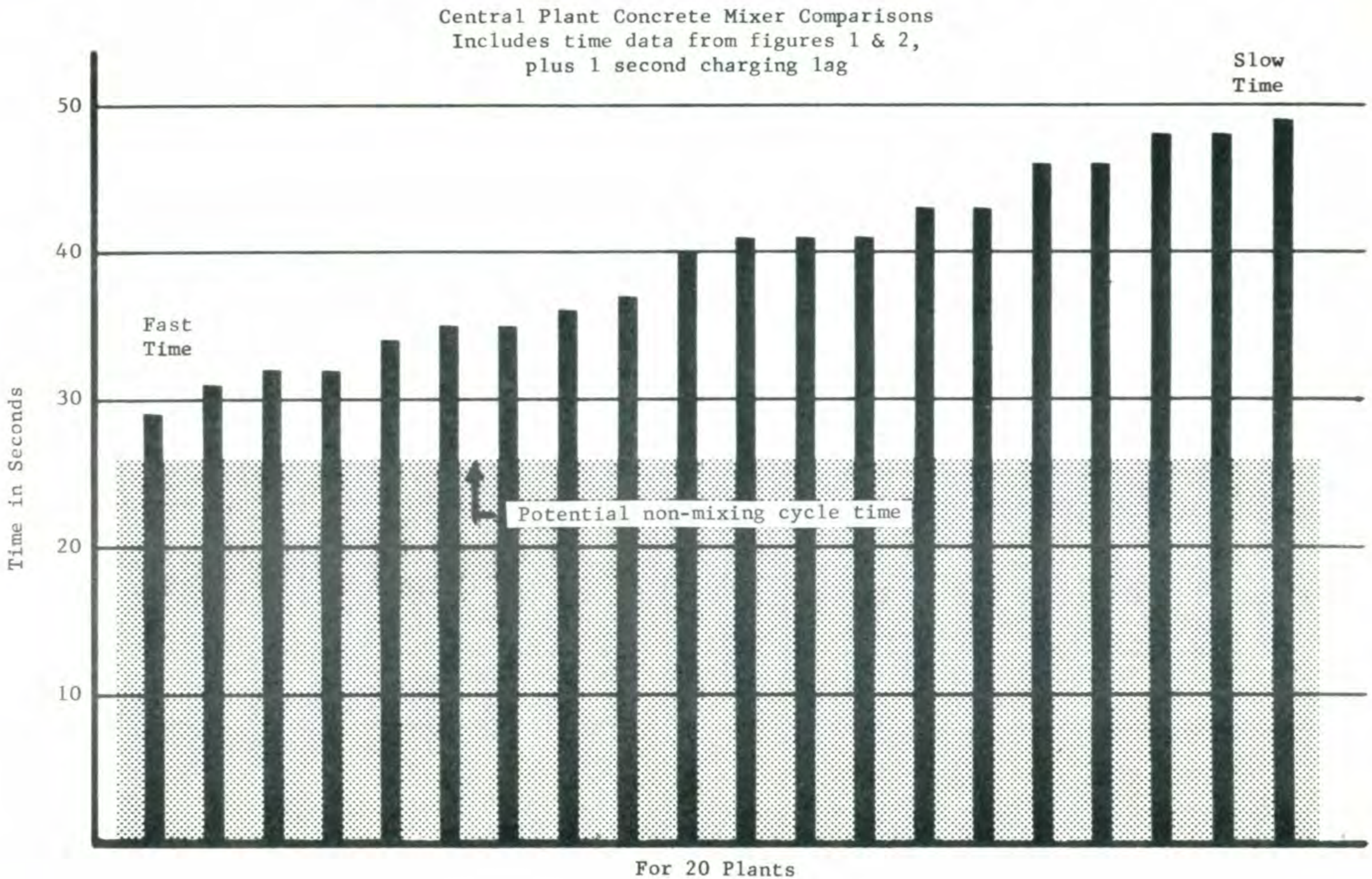

FIGURE 3

PRODUCTION LIMITS FOR 60 SECONDS MIXING TIME, EIGHT YARD BATCHES

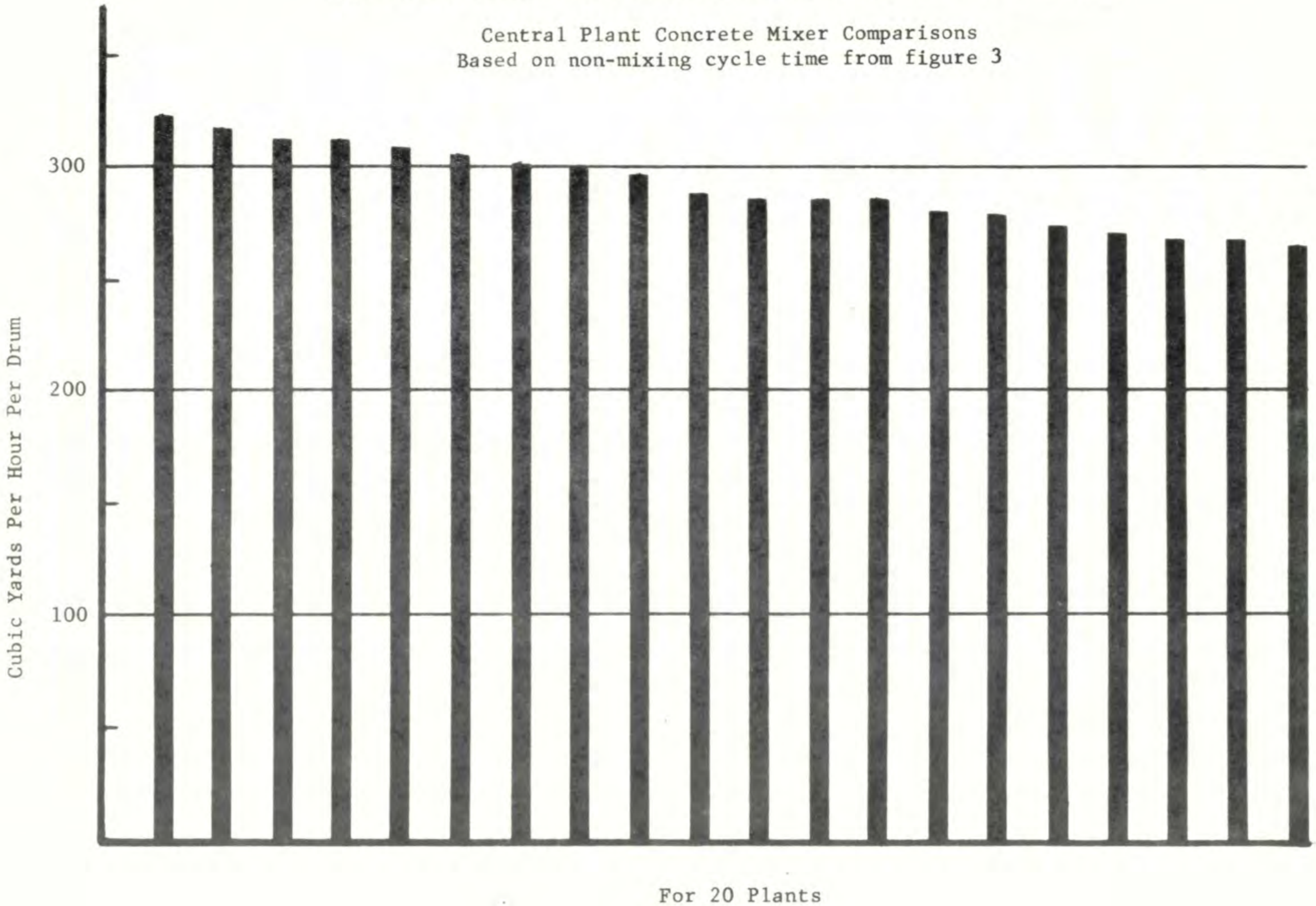

FIGURE 4

PRODUCTION LIMITS FOR MIXING TIME ACTUALLY USED, EIGHT YARD BATCHES

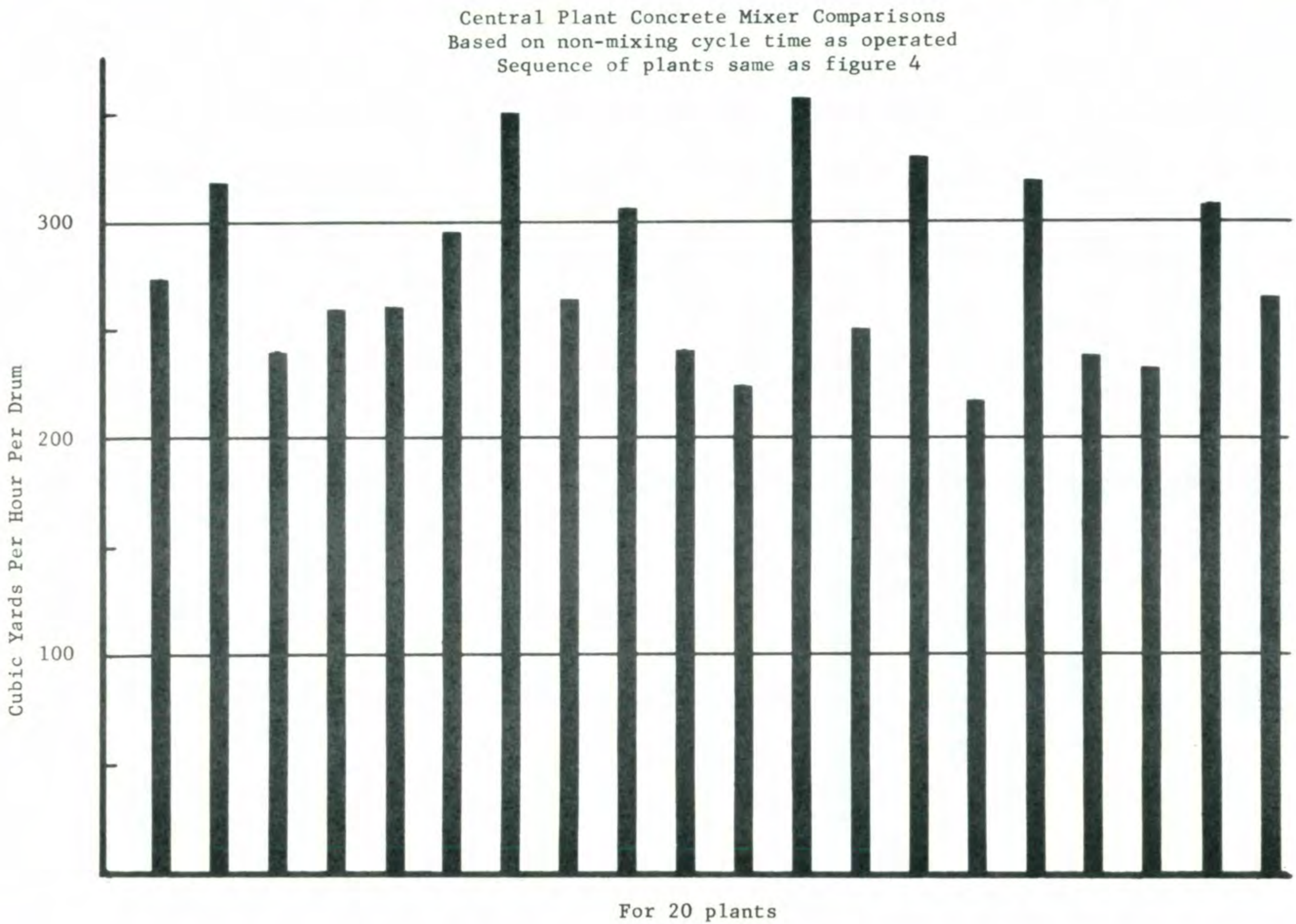

FIGURE 5

ACTUAL PRODUCTION SUSTAINED VS UPPER LIMITS AT MIXING TIME ACTUALLY USED

Central Plant Concrete Mixer Comparisons
Based on non-mixing time as operated, for 8 yard batch
Sequence of plants same as figure 5

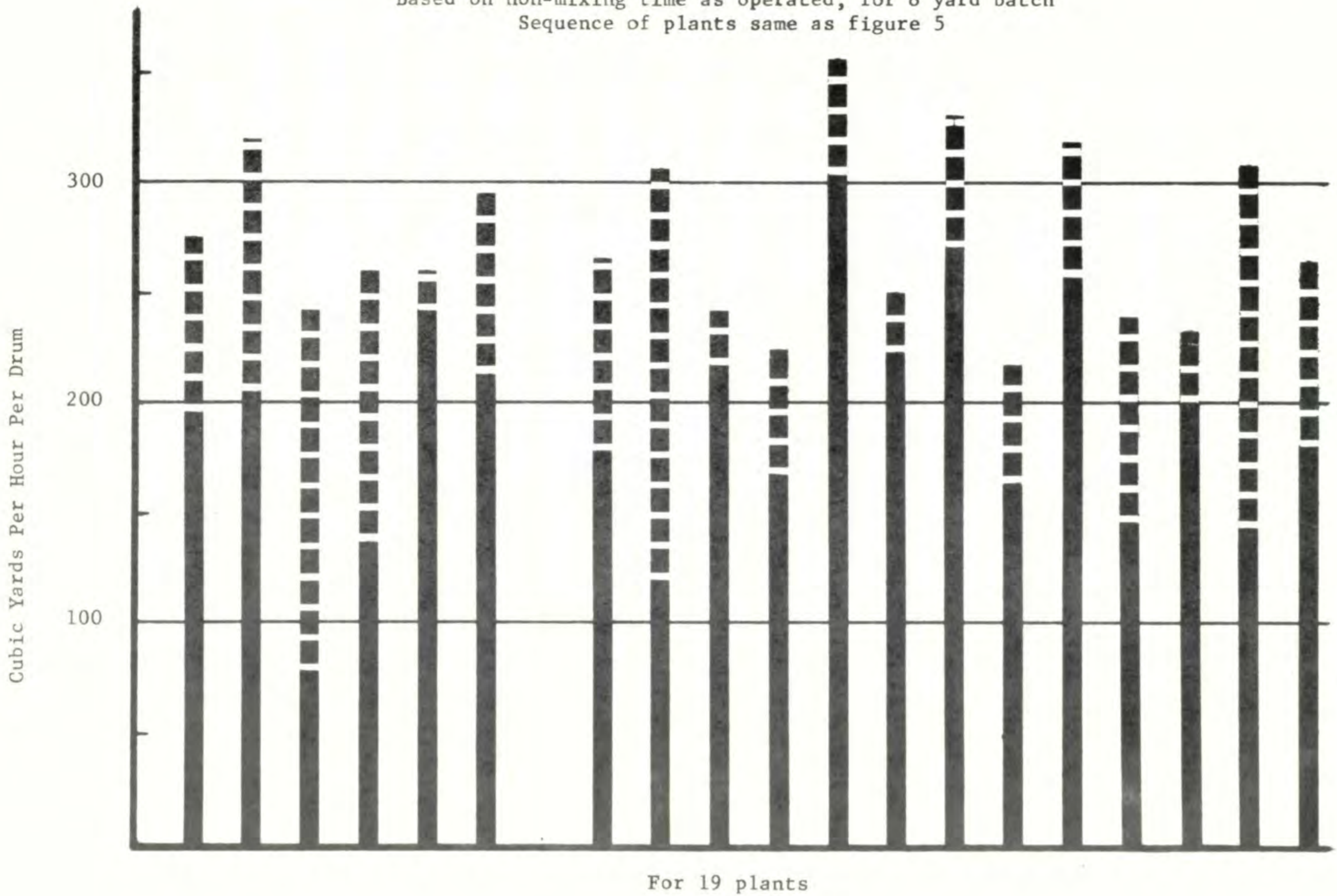

FIGURE 6

PRODUCTION EFFICIENCY AND HOW IT WAS LOST

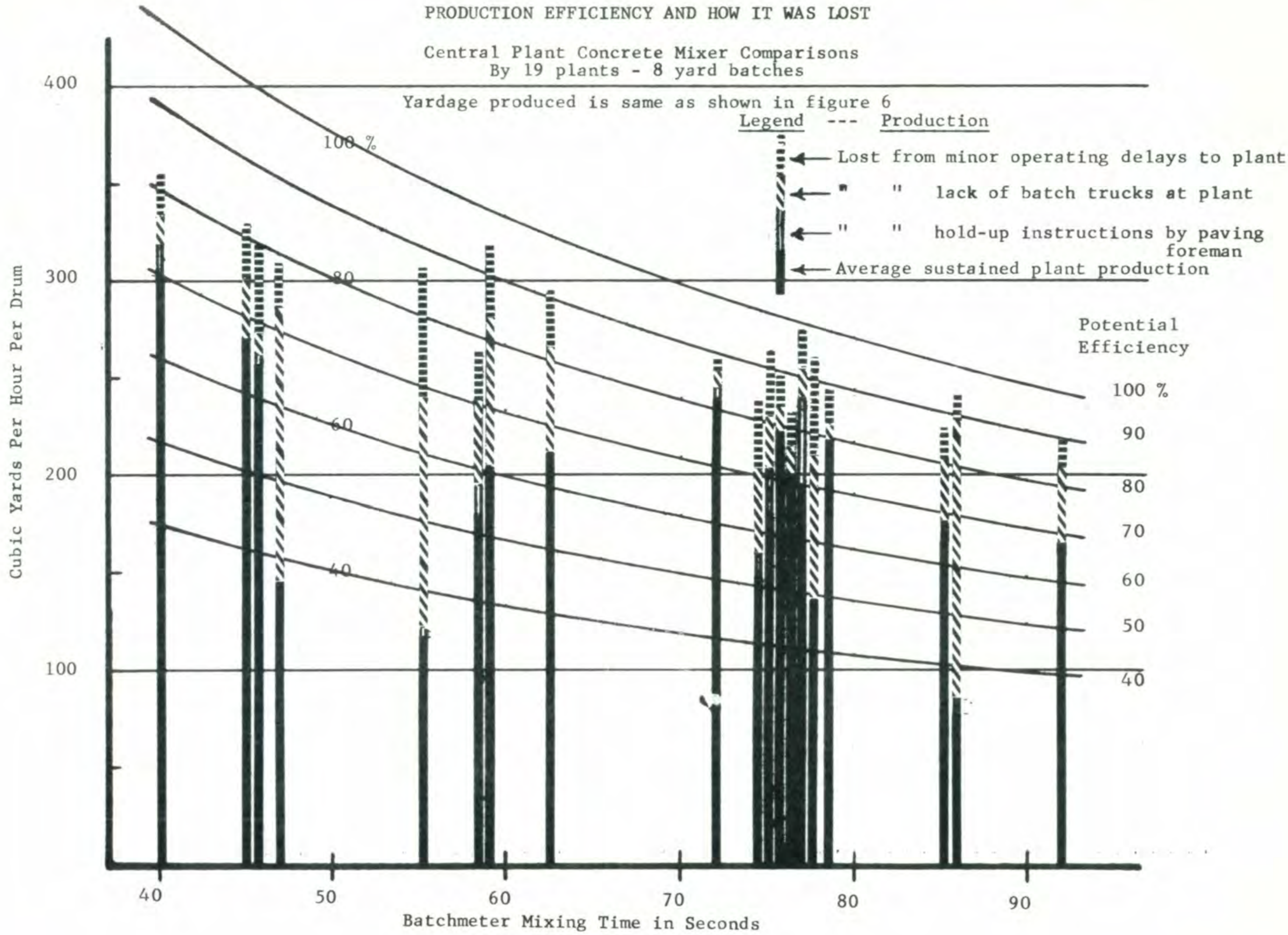

FIGURE 7

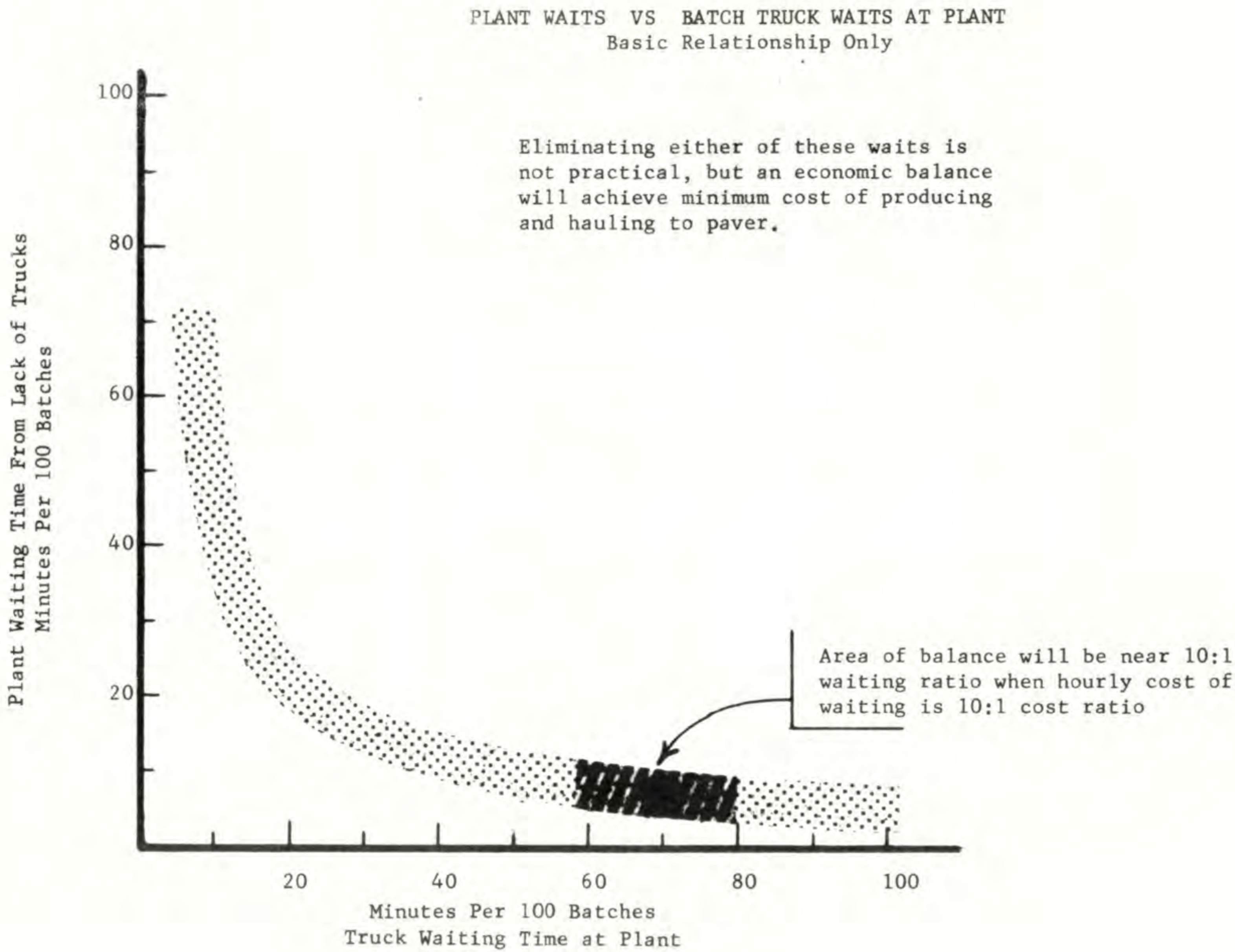
PLANT WAITS VS BATCH TRUCK WAITS AT PLANT
Basic Relationship Only
Eliminating either of these waits is not practical, but an economic balance will achieve minimum cost of producing and hauling to paver.
Area of balance will be near 10:1 waiting ratio when hourly cost of waiting is 10:1 cost ratio
Plant Waiting Time From Lack of Trucks
Minutes Per 100 Batches
100
80
60
40
20
20
40
60
80
100
Minutes Per 100 Batches
Truck Waiting Time at Plant

FIGURE 8

COMPARATIVE PLANT CYCLE TIME CONSTANTS FOR CENTRAL PLANT CONCRETE MIXERS

Unless otherwise noted, all data are time in hundredths of minutes, and are on the basis of "no-delay" cycles. Time entries for items 1 thru 14 are cumulative from instant the empty "drum returned" to mixing position.

Item No.	Data Constant	JOB																				
		A	B	C	G	H	I	J	K	M	N	P	Q	R	S	T	U	V	W	X	Y	Z
1	Water charging lag	0	1	0	-1	3	4	4	1	0	6	1	3	2	7	2	-	-	17	3	3	-2
2	Aggregate charging lag	5	6	3	3	3	4	4	2	0	3	3	5	0	1	3	70	0	19	5	5	0
3	Cement charging lag	7	-	3	6	4	4	4	1	0	7	5	10	8	6	5	74	-	23	6	6	4
4	Aggregate all in	34	59	35	49	29	43	31	37	47	28	60	45	32	35	32	102	35	45	39	43	43
5	Water all in	38	42	26	34	43	37	31	20	48	39	50	44	34	39	37	-	-	44	40	33	35
6	Cement all in	29	-	32	33	13	43	19	24	46	31	57	30	28	32	25	-	-	46	33	41	40
7	Sand, begin weigh	15	42	1/-	56	11	39	20	36	48	1/-	1/-	22	1/-	1/-	-	1/-	1/-	2/65	1/-	40	39
8	Sand, end weigh	32	55	-	77	48	71	29	50	108	-	-	32	-	-	-	-	-	108	-	60	49
9	Aggregate, begin weigh	32	42	38	56	5	39	20	18	48	20	61	29	29	28	-	100	20	46	33	40	39
10	Aggregate, end weigh	73	67	62	72	48	59	33	54	86	75	71	48	-	69	-	160	67	65	104	62	51
11	Cement, begin weigh	32	42	41	48	15	39	17	28	48	35	59	30	30	35	-	-	43	46	33	40	39
12	Cement, end weigh	99	75	89	94	32	-	29	96	97	70	81	50	51	72	-	-	81	73	79	65	53
13	Water, begin measure	50	43	43	56	-	39	-	21	-	50	57	44	-	46	-	-	60	-	47	-	39
14	Water, end measure	124	128	109	85	3/-	93	3/-	80	3/-	64	83	124	3/-	93	3/-	-	67	3/-	109	3/-	58
15	Belt travel time 4/	10	26	4	8	12	13	10	12	8	7	10	16	10	9	10	8	15	10	6	11	9
16	Discharge lag 5/	0	3	4	4	0	3	3	4	2	3	4	3	2	4	5	4	3	3	2	3	3
17	Discharge complete (after start tilt)	10	21	22	24	24	26	26	23	15	19	24	18	26	31	28	21	26	25	17	14	17
18	Drum starts return (after start tilt)	13	16	24	22	-	22	24	21	14	15	25	18	23	27	23	21	25	25	15	21	17
19	Drum returned (after start tilt)	28	27	30	33	24	30	31	32	24	22	32	23	36	33	33	28	29	33	19	27	27
20	Non-mix cycle total (Item 4+19-16)	62	83	61	78	53	70	59	65	69	47	88	65	66	64	60	126	61	75	56	67	67
21	Belt travel speed, ft./min.	583	515	558	770	650	568	530	515	598	714	807	533	491	286	-	-	445	608	548	-	705
22	Belt load, lbs./ft.	140	120	114	72	67	134	181	147	90	127	58	130	137	236	-	-	214	167	115	-	95
23	Batch weight, lbs./100 (Except H_2O and cement)	236	327	204	254	113	238	259	244	220	255	269	260	261	230	191	269	267	262	234	247	237
24	Mixing drum RPM	10.0	9.4	10.8	9.1	21.7	10.6	10.5	10.9	9.1	-	-	-	-	-	-	-	-	11.4	10.4	-	9.0
25	Batch size - cu. yds.	7.5	10.0	6.5	8.0	6/3.5	7.5	8.0	7.5	6.8	8.0	8.5	8.0	8.0	7.5	6.0	8.5	8.6	8.5	8.5	7.5	7.5

1/ Sand weighing time included with total shown for aggregates.
2/ Includes weighing time for intermediate (or small coarse) aggregates.
3/ Water metered while charging the mixer.
4/ From instant aggregate leaves scale hopper for belt, until aggregate drops from belt into mixer.
5/ From instant drum tilting starts until concrete starts discharge.
6/ Data in this column is for a plant equipped with two turbine type mixers. This plant is not included in the group comparisons of 20 plants.

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COMPARATIVE LOSSES IN WORKING TIME FROM MINOR DELAYS INCURRED BY CENTRAL PLANT CONCRETE MIXERS

Item No.	Delay cause	Percent of working time lost - By job 4/																				
		A	B	C	G	H	I	J	K	M	N	P	Q	R	S	T	U	V	W	X	Y	Z
1	Lack of cement	0.7	5.6	0.9	2.2	0.8	1.8	2.3	0.6	0.8	-	-	12.4	-	0.4	-	-	-	-	0.5	-	0.3
2	Lack of aggregates or sand	0.2	-	0.3	5.9	-	2.3	-	-	0.9	1.7	-	-	-	-	-	-	3.4	-	1.9	-	-
3	Check cement bins - supply	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	Add water or cement	0.2	0.1	1.2	0.8	-	-	-	2.1	1.5	-	-	-	-	2.0	-	-	1.2	2.4	2.0	-	0.8
5	Holding hopper clogged	-	-	-	-	-	-	-	-	-	-	-	1.5	-	-	-	-	-	-	0.2	-	2.5
6	Adjust batcher scales	-	-	0.1	0.2	-	-	-	-	0.4	-	-	-	0.3	-	-	-	-	-	0.3	-	0.9
7	Cement bin clogged	-	-	-	-	-	-	-	-	-	0.9	-	2.0	-	-	1.5	1.8	-	-	-	-	-
8	Water meter maintenance	-	-	0.6	-	-	1.0	0.2	-	-	-	-	-	-	-	-	-	-	1.6	-	-	1.3
9	Electrical control malfunction	0.4	-	-	-	9.6	-	-	0.2	2.6	-	4.0	-	-	0.4	0.3	-	4.0	8.3	1.0	-	0.5
10	Minor adjustments & inspections	0.1	0.4	0.5	4.2	3.7	4.5	6.5	0.3	0.4	-	-	1.5	2.5	0.4	0.3	-	1.4	3.2	1.4	-	-
11	Operator	0.1	0.1	0.1	0.2	2.2	0.6	0.5	0.2	0.4	-	3.0	1.5	-	0.4	-	2.7	-	3.1	0.3	-	0.5
12	Hauling unit operator	-	-	0.2	-	0.8	0.8	-	0.2	-	0.4	0.8	-	-	-	-	-	-	-	-	-	-
13	Excess mixing time - beyond spec's	-	-	0.6	-	-	0.6	-	0.3	-	-	0.7	-	0.5	-	-	-	-	-	2.0	-	0.3
14	Excess discharge time	-	-	-	1.0	-	0.5	-	-	-	-	-	-	0.1	-	-	-	-	-	-	-	-
15	Other, cleanup, miscellaneous	0.3	0.3	2.2	-	2.9	1.0	0.2	1.0	-	4.1	1.1	3.0	0.6	0.5	1.0	0.5	0.9	0.2	1.1	-	1.0
	Subtotal	2.0	6.5	7.0	14.5	20.0	13.1	9.7	4.9	7.0	7.1	9.6	21.9	4.0	4.1	3.1	5.0	10.9	18.8	11.2	-	8.1
16	Lack of hauling units at plant	3.9	3.6	14.4	18.0	9.6	5.4	18.5	5.3	6.8	5.7	16.6	38.8	4.9	18.1	46.3	59.0	10.6	28.8	24.1	-	9.6
17	Hold - instructions from grade	1.0	-	4.6	6.4	0.8	0.6	-	4.7	-	16.4	5.7	0.5	-	1.3	-	3.6	9.1	-	-	-	-
	Sub total	4.9	3.6	19.0	24.4	10.4	6.0	18.5	10.0	6.8	22.1	22.3	39.3	4.9	19.4	46.3	62.6	19.7	28.8	24.1	-	9.6
18	Manual operation of plant	-	-	-	-	-	-	-	-	-	-	-	-	1.9	1.8	4.0	-	1.8	-	0.5	-	-
	GRAND TOTAL	6.9	10.1	26.0	38.9	30.4	19.1	28.2	14.9	13.8	29.2	31.9	61.2	10.8	25.3	53.4	67.6	32.4	47.6	35.8	-	17.7
	Total available working time hours (TAWT)	122	146	161	61	-	121	151	163	128	132	110	20	114	75	93	58	140	155	109	-	72
	Shutdown percent TAWT 1/	11.2	17.3	14.1	17.2	-	30.7	10.5	17.3	7.8	47.3	31.9	0	27.8	20.0	5.4	14.9	8.2	29.3	35.3	-	3/
	Operating percent TAWT 1/	7.0	6.0	18.3	2/ 16.0	-	3.6	6.6	5.0	1.3	-17.7	7.2	1.9	13.0	7.7	29.1	8.9	4.7	4.0	6.5	-	13.7
	Total major delays - percent of TAWT	18.2	23.3	32.4	33.2	-	34.3	17.1	22.3	9.1	65.0	39.1	1.9	40.8	27.7	34.5	23.8	12.9	33.3	41.8	-	13.7

1/ Percentages are for major delays which are defined as plant down time of 15 minutes or more per occurrence.
2/ Of this 16.0 percent, 12.8 was due to holdups from grade.
3/ Delays of the shutdown type were substantial on this job, but were not summarized due to nature of the operations on this job.
4/ The total time reflected by these percentages excludes major delays, i.e. plant down time of 15 minutes or more per occurrence.

5/15/67

COMPARATIVE PRODUCTION RATES AND PLANT PERFORMANCE DATA FOR CENTRAL PLANT CONCRETE MIXERS

Item No.	Description	JOB																				
		A	B	C	G	H	I	J	K	M	N	P	Q	R	S	T	U	V	W	X	Y	Z
1	Cubic yards per batch	7.5	10.0	6.5	8.0	1/3.5	7.5	8.0	7.5	6.8	8.0	8.5	8.0	8.0	7.5	6.0	8.5	8.6	8.5	8.5	7.5	7.5
	Production, batches per hour:																					
2	Productive time	32.2	29.7	31.1	2/58.2	2/98.9	43.8	2/75.5	44.3	29.5	2/67.7	2/63.5	2/76.7	31.3	27.9	45.2	2/58.9	2/64.6	2/59.6	38.2	-	2/81.3
3	Net available working time	29.9	26.7	23.0	35.6	68.9	35.4	54.2	37.7	25.4	47.9	33.1	29.7	28.0	20.8	21.1	19.1	43.6	31.2	24.7	-	66.9
4	Total available working time 3/	27.6	24.7	18.1	23.7	-	34.3	50.1	35.4	23.1	31.8	29.7	29.1	22.9	18.8	14.6	17.1	41.4	29.5	22.2	-	57.6
	Production, cubic yards per hour:																					
5	Productive time	241	297	202	466	346	329	604	332	201	541	540	613	251	209	275	501	553	506	317	-	609
6	Net available working time	224	267	150	285	241	266	423	283	173	383	281	237	224	156	128	162	374	265	205	-	501
7	Total available working time	207	247	118	190	-	257	401	266	157	254	252	232	183	141	89	145	355	250	184	-	432
8	Mixing time per batch, minutes 4/	1.20	1.31	1.42	1.24	0.67	0.79	1.07	0.71	1.28	1.28	0.98	0.92	1.26	1.53	0.78	0.76	1.25	1.29	1.02	0.67	0.75
9	Batch cycle, minutes, except mixing	0.62	0.71	0.61	0.83	0.53	0.72	0.60	0.65	0.69	0.47	0.88	0.65	0.66	0.64	0.60	1.26	0.61	0.75	0.56	0.67	0.67
10	Batch weighing time, minutes 5/	0.96	0.28	0.77	0.40	0.19	0.42	0.09	0.36	0.61	0.47	0.23	0.79	-	0.58	-	0.60	0.46	0.63	0.70	0.22	0.12
11	Mixer discharge time, minutes 6/	0.28	0.27	0.30	0.44	0.24	0.30	0.31	0.32	0.24	0.22	0.32	0.23	0.36	0.33	0.33	0.28	0.29	0.33	0.19	0.27	0.27
	Belt performance (aggregate charge):																					
12	Speed, feet per minute	583	515	558	7/770	650	568	530	515	598	714	807	533	491	286	-	-	445	608	548	-	705
13	Load, pounds per foot	140	140	114	90	100	134	181	136	90	127	70	130	137	236	-	-	214	167	115	-	95
14	Aggregate charging time, minutes	0.29	0.42	0.32	0.42	0.26	0.38	0.27	0.35	0.47	0.25	0.57	0.40	0.32	0.34	0.29	0.32	0.35	0.26	0.34	0.38	0.43

1/ Data in this column is for a plant equipped with two turbine type mixers.
2/ Data are for two mixers operating with a single batcher.
3/ Major delay time (all normally reflected here) of the job shutdown category is excluded from the above TAWT basis.
6/ On tilting mixers, time is from start of tilt to end of drum return.

4/ Defined as beginning when all aggregate is in the mixing drum and ending when concrete appears from the discharge. Mixing time shown is that allowed by the timer setting and is exclusive of any actually extended mixing time incurred from delays.
5/ From the instant aggregate charging was completed.
7/ This figure not verified.

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COMPARATIVE POTENTIAL FOR IMPROVED PLANT PRODUCTION THRU REDUCTION IN BATCH CHARGING TIME

Item No.	Description	JOB																				
		A	B	C	G	H	I	J	K	M	N	P	Q	R	S	T	U	V	W	X	Y	Z
1	Cycle time per batch - actual (all delays excluded)	1.82	2.02	2.03	2.07	1.20	1.48	1.61	1.36	1.97	1.74	1.86	1.86	1.92	2.17	1.38	2.02	1.86	2.04	1.58	1.34	1.42
2	Item 1 cycle time adjusted to one minute mixing time	1.62	1.71	1.61	1.83	1.53	1.72	1.57	1.69	1.69	1.46	1.88	1.94	1.66	1.64	1.60	1.59	1.61	1.75	1.56	1.67	1.67
3	Cycle time per batch at fastest charging rate 1/, and for one-minute mixing time	1.56	1.60	1.49	2/ 1.66	1.38	1.57	1.55	1.57	1.43	2/ 1.46	1.58	2/ 1.79	1.59	1.53	1.50	2/ 1.54	2/ 1.53	2/ 1.75	1.48	1.52	1.47
4	Percent increase in plant productive potential (based on ratio of potential derived from items 2 and 3)	4	7	8	10	11	10	1	8	18	0	19	8	4	7	7	3	5	0	5	10	14

1/ In other words, the cycle time without delays which would result if aggregate charging time were at the fastest rate per cubic yard obtained among the several plants shown, and with a one-minute mixing time (see job N). Assumes aggregate weighing time would not be a bottleneck to this attainment, where plant is feeding two mixing drums.

2/ This plant would not be able to attain the cycle time shown for item No. 3, with two mixing drums in operation, unless adjustment of the batcher could achieve a reduction in the elapsed time for batch weighing.

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