VOLATILES IN MC-3000 BITUMINOUS PAVING MIXTURES

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Very little information is available documenting the rate at which hydrocarbons evaporate from pavements made with liquid asphalt binders. It is probable that the cutter used in a rapid-cure (RC) liquid evaporates quickly and cleanly leaving the original asphalt cement in the pavement mix. The trade assumes a medium-cure liquid (MC) acts in the same manner as an RC with the only difference being that the MC requires a little longer to evaporate. The cutter used in MC binders typically has the volatility of kerosene/fuel oil. Such material alone evaporates in a few days to a few weeks, but when mixed with an asphalt cement, may not evaporate for years. This difference is of some importance when estimating the potential reduction in atmospheric hydrocarbon obtainable by banning cut backs.

The rate of evaporation could be monitored by either of two general approaches. One would be through measurement of the level of hydrocarbons immediately above the pavement. After the first few days, the concentration would be so low that available equipment would not be sufficiently sensitive to make adequate measurements. The second approach would be measurements of the material remaining in the pavement over a period of time.

Traditionally, the quantity of binder material in the pavement is measured by removing the binder from the aggregate with a solvent. The solvent and dissolved binder are separated from the aggregate by centrifuging or vacuum. Loss of fines from the aggregate affects the measurement. If the binder is an asphalt cement, recovery of the asphalt from the solution is possible by the Abson process. If the binder is a liquid containing volatile solvents, such material would be lost in the asphalt recovery. As this study was an attempt to look at the rate of loss of the one to two percent of volatile cutter in the pavement mix, standard extraction tests would not suffice.

The composition of cut back asphalts is determined by the AASHO T78 distillation test. Again, the accuracy of the test is not sufficient when investigating the rate of loss of the solvent. To improve the accuracy, a test was developed that avoided both extraction and low-quality volume measurements. This test is, in principle, a distillation test of the binder carried out without prior separation of the binder and aggregate. Connecticut aggregates are relatively unaffected by temperatures to 460°C and, if present, should not interfere with the distillation process.

The standard AASHO T-78 method utilizes a 200 ml sample of bituminous material in a 500 ml flask. The quantity of mix required to provide a sample of 200 ml of binder would be approximately 2500 grams and would occupy a volume of 1000 ml. This would require the substitution of a much larger distillation flask. As all glassware used in the T-78 test method is precisely dimensioned, substitutions would void the method. The change in volume would also affect the rate of heating specified.

Procedure

The procedure used consisted of placing 200 to 300 grams of mix in a 165-mm diameter porcelain evaporating dish and weighing precisely. The dish was placed in a constant-temperature oven for 15 minutes and then reweighed. The cycle was repeated at progressively higher temperatures. Differences in the weight before and after each cycle provided an accurate accounting of what portion of the material was volatile at each temperature. The temperatures used were those reported in T-78 (110, 225, 260, 316, 360°C). As heating was carried out in the presence of air, some difficulty was anticipated in dissolving the residue to determine the binder content. Raising the temperature to 460°C solved this problem as the remainder of the binder also evaporated. Thus the procedure not only determined what portion of the binder was volatile at each temperature, but also found the binder content.

If the original goal of measuring the loss of volatiles with time was to be carried out, a means of accelerated aging must be employed. Combinations of heat and air have been widely used to simulate aging. Research by the California Department of Highways indicates that four hours of the thin film rolling test represents five years on the pavement. Unfortunately, such correlations have been based on physical characteristics such as hardness or viscosity rather than chemical composition. Efforts to relate chemical composition to artificial aging would require a period of time equal to the calendar period to be simulated.

In order to expedite the measurement of volatile changes, it was decided to use the natural aging which has already occurred on the highways and avoid simulating aging. To do this, locations were selected where the age and class of the surfacing could be documented. Samples were collected from class 8 pavements of ages of a few minutes to ten years. The sources of the binders in the various mixes were not traced, as some changes could be expected over a ten-year period even if from one source. For comparison purposes, a small number of other materials was included.

Results

The volatiles data for the ten years of pavements are shown in Figures 1-7. Each point represents the average of three tests and each test is for pavement from a different location. The year of construction of mix is plotted along the x axis increasing from left to right. The vertical scales are percent of total mix. The percents are accumulative in that the value plotted for any temperature includes losses at all lower temperatures. The binder totally evaporated for all samples at 460°C. Regardless of age, the mixes averaged 7-1/2 percent binder, Fig. 6. This is below the original value at the time of placement, as some material evaporated over the years. For most of the temperatures represented by the curves, the volatiles remaining in the pavement and represented by those driven off during the test are relatively constant for the first five years. During the second five years the volatiles decrease gradually. An aberration is apparent in Figure 1. The decline with age was very sharp with no material volatile at 110°C remaining at ten years. Material evaporating at 110°C would be very light kerosene. At the low-age end of this curve, the amount of material remaining was also low. The implication is that the cutter used in the MC-3000 starting in 1978 contained less of the higher-volatile material than in prior years. The difference is not apparent at 225°C and above.

The scatter resulting from testing different mixes from several sources is seen in the first four years where at least two pavements were tested for each year.

It is difficult to follow a single pavement through Figures 1-6. Figure 7 has been prepared to permit ready determination of the change in the rate of evaporation with increased temperatures. The sharp break in all curves at 360°C indicates this temperature can be considered as discriminating between cutter and asphalt cement. The curves for one and five year pavement are essentially identical. That for nine years indicates some loss of volatiles between five and nine years.

The typical MC-3000 used in Connecticut contained ±10 percent cutter. The cutter should evaporate below 360°C; thus the loss to 360° expressed as a percent of the loss to 460°C should represent the percent cutter in the binder at the time of test, Figure 8. The cutter remaining then appears as 18 percent during the first six to eight years.

The cutter content so indicated is high and raises the possibility of some other factor causing change. To put a scale on scatter due to other factors, at one location two samples were taken, one from a sunny area and one from shade. The difference in the results was very small. This implies that differences in natural aging factors are of little importance.

The assumption that all material evaporating below 360°C comes from the cutter can be questioned. Presumably an asphalt cement such as AC-20 has no cutter and should material evaporate below 360°C it must be part of the asphalt cement. Figure 10 presents test results for class 12 mixes when one hour old. At 360°C the average volatiles were 0.8 percent of the total sample. For the MC-3000 material at the same age and temperature the volatiles were 1.4 percent. Deducting the 0.8 found for AC binder from the 1.4 found for MC binder indicates 0.6 percent attributable to the cutter. This corresponds to 7 percent of the binder and would be 80 percent of the cutter present in the original binder prior to making the mix.

Conclusions

The results of the volatile tests are consistent. The test procedure is sensitive and capable of measuring small changes in binder material. At the time of placing, approximately 80 percent of the cutter in the MC-3000 binder remains. The level remains nearly constant for five years. The level of volatile material decreases smoothly during the second five years to one-third at ten years.

LOSSES DURING HEATING TO TEMPERATURE INDICATED

Year of Construction and Location	110°C	225°C	260°C	315°C	360°C	460°C	Total Percent Volatiles*
CLASS 8							
71	.0	.24	.35	.51	.94	7.90	11.94
	.0	.16	.28	.44	.83	7.78	10.71
	.0	.16	.28	.44	.88	7.83	11.22
Ave.	.0	.16	.28	.44	.88	7.84	11.29
72	.08	.23	.44	.60	.92	7.50	12.23
	.04	.24	.44	.60	1.04	9.59	13.68
	.04	.27	.47	.63	1.06	7.53	14.06
Ave.	.04	.25	.44	.60	1.05	7.53	13.32
73	.04	.24	.39	.63	1.22	6.95	17.60
	.0	.23	.43	.74	1.21	6.79	17.71
	.0	.19	.42	.72	1.12	6.76	17.42
Ave.	.0	.22	.41	.72	1.21	6.79	17.58
74	.16	.32	.40	.56	.88	7.72	11.4
#32	.12	.28	.36	.56	.92	7.62	12.04
State Line	.8	.24	.35	.51	.91	7.65	11.86
Ave.	.12	.28	.37	.55	.91	7.67	11.77
75	.12	.31	.47	.66	1.21	7.41	16.3
#195	.12	.43	.59	.98	1.37	7.47	18.32
Coventry	.08	.39	.55	.83	1.42	7.72	18.37
Ave.	.11	.39	.54	.80	1.36	7.50	18.30
76	.12	.35	.42	.66	1.25	7.42	16.84
#44	.12	.40	.48	.71	1.15	7.14	16.11
Willington	.16	.39	.47	.71	1.25	7.33	17.11
Ave.	.11	.38	.45	.70	1.22	7.30	16.69
77	.20	.36	.48	.68	1.19	7.59	14.74
Sun	.12	.36	.48	.68	1.15	7.76	14.87
#2	.10	.29	.38	.70	1.10	7.66	14.38
Ave.	.13	.35	.46	.69	1.15	7.67	14.66
77	.23	.54	.57	.88	1.34	7.46	18.46
Shade	.23	.42	.58	.81	1.31	7.41	17.61
#2	.31	.57	.65	.92	1.38	7.53	18.27
Ave.	.24	.51	.59	.87	1.34	7.46	18.11

* Total percent volatiles in the binder computed as $\frac{\text{Loss to } 360°C}{\text{Loss to } 460°C} \times 100$

LOSSES DURING HEATING TO TEMPERATURE INDICATED (continued)

Year of Construction and Location	110°C	225°C	260°C	315°C	360°C	460°C	Total Percent Volatiles
78							
Sun	.08	.35	.39	.74	1.29	7.56	17.01
#32	.12	.36	.44	.64	1.20	7.46	16.04
Franklin	.19	.36	.48	.71	1.23	7.53	16.32
Ave.	.13	.36	.44	.70	1.24	7.52	16.40
78							
Shade	.0	.36	.67	.83	1.11	7.90	14.00
#32	.0	.27	.52	.76	1.12	7.67	14.58
Franklin	.0	.28	.54	.73	1.08	7.88	13.73
Ave.	.0	.29	.58	.77	1.10	7.82	14.10
79	.20	.36	.48	.64	.91	7.99	11.44
No Traffic	.16	.36	.55	.63	1.07	8.12	13.18
Rocky Neck	.08	.28	.44	.56	.96	8.09	11.88
Ave.	.15	.35	.49	.61	.98	8.07	12.17
79	.08	.28	.44	.59	.95	6.57	14.46
Traffic	.02	.32	.47	.67	1.10	7.42	14.89
Rocky Neck	.04	.31	.47	.62	1.01	7.21	13.98
Ave.	.05	.30	.46	.63	1.02	7.06	14.44
80	.31	.59	.78	1.02	1.49	7.32	20.32
#156	.32	.52	.76	1.00	1.52	7.29	20.32
Old Lyme	.24	.55	.75	1.02	1.45	7.50	19.37
Ave.	.29	.55	.76	1.01	1.49	7.37	20.30
80							
Shade	.0	.28	.60	.88	1.32	7.77	17.01
#207	.12	.48	.83	1.15	1.59	8.15	19.51
Windham	.04	.39	.79	1.10	1.58	7.92	19.90
Ave.	.06	.38	.74	1.01	1.50	7.94	19.50
80							
Sun	.12	.44	.60	.84	1.23	7.52	16.40
#207	.08	.35	.63	.96	1.33	7.40	17.99
Windham	.04	.35	.55	.79	1.21	7.31	16.67
Ave.	.08	.37	.60	.86	1.24	7.41	17.02
81							
Hain	.12	.44	.63	.87	1.27	7.22	17.58
On Truck	.04	.40	.63	.83	1.27	7.14	17.78
6 min.	.08	.39	.62	.81	1.28	7.29	17.55
Ave.	.08	.41	.63	.84	1.27	7.22	17.66

LOSSES DURING HEATING TO TEMPERATURE INDICATED (continued)

Year of Construction and Location	110°C	225°C	260°C	315°C	360°C	460°C	Total Percent Volatiles
CLASS 12							
81							
#97	.0	.11	.19	.38	.75	7.52	10.00
Sprague	.0	.08	.19	.31	.85	7.43	11.40
1 hr.	.0	.08	.20	.44	.88	7.27	12.09
Ave.	.0	.09	.19	.37	.83	7.41	11.63
81							
Hain	.0	.16	.28	.40	.71	7.73	9.23
On Truck	.0	.19	.24	.44	.75	7.44	10.11
6 min.	.0	.16	.28	.43	.71	7.51	9.47
Ave.	.0	.17	.25	.42	.73	7.56	9.60
81	.008	.20	.24	.44	.89	7.66	10.48
#97	.0	.20	.28	.36	.89	7.98	11.11
Sprague	.0	.12	.20	.36	.76	7.63	9.48
Ave.	.0	.17	.24	.38	.86	7.76	10.35

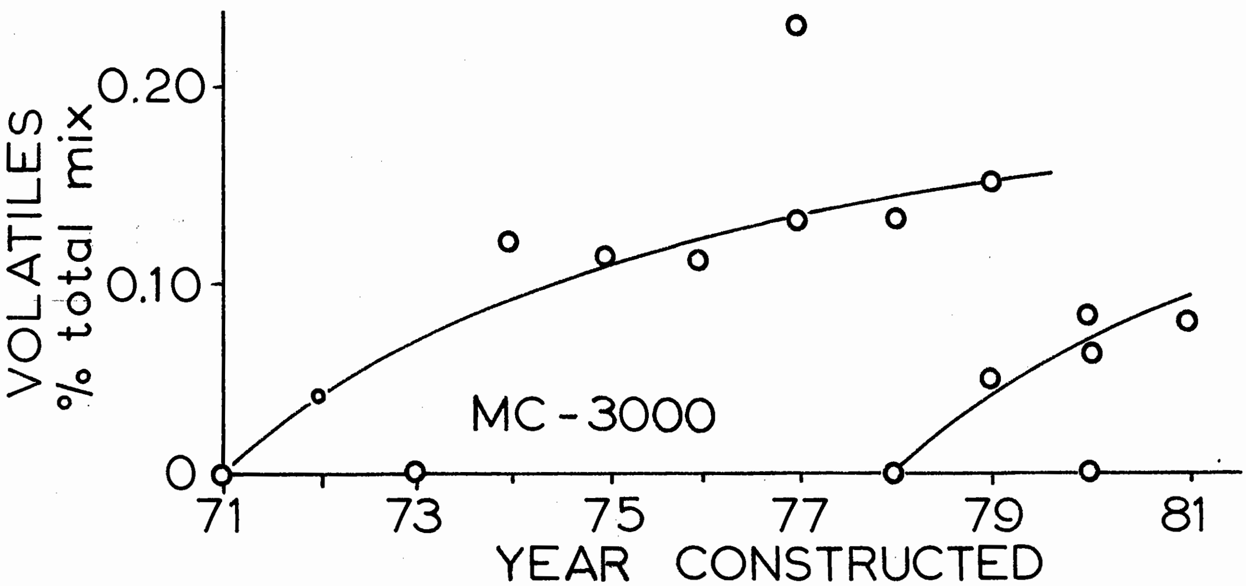

FIG. 1 VOLATILES TO 110°C VERSUS AGE

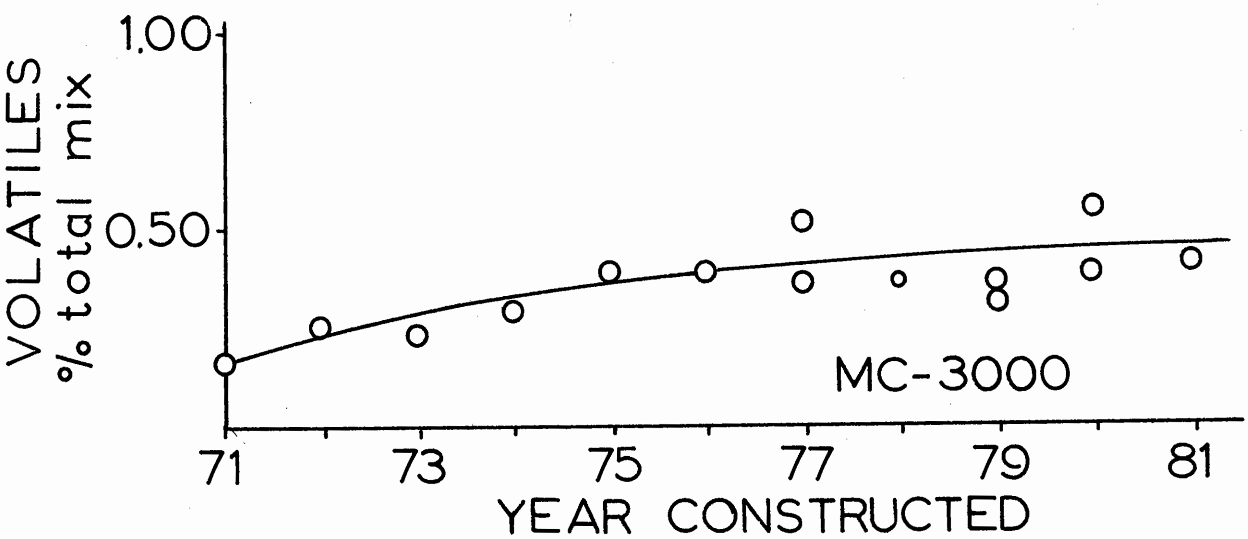

FIG. 2 VOLATILES TO 225°C VERSUS AGE

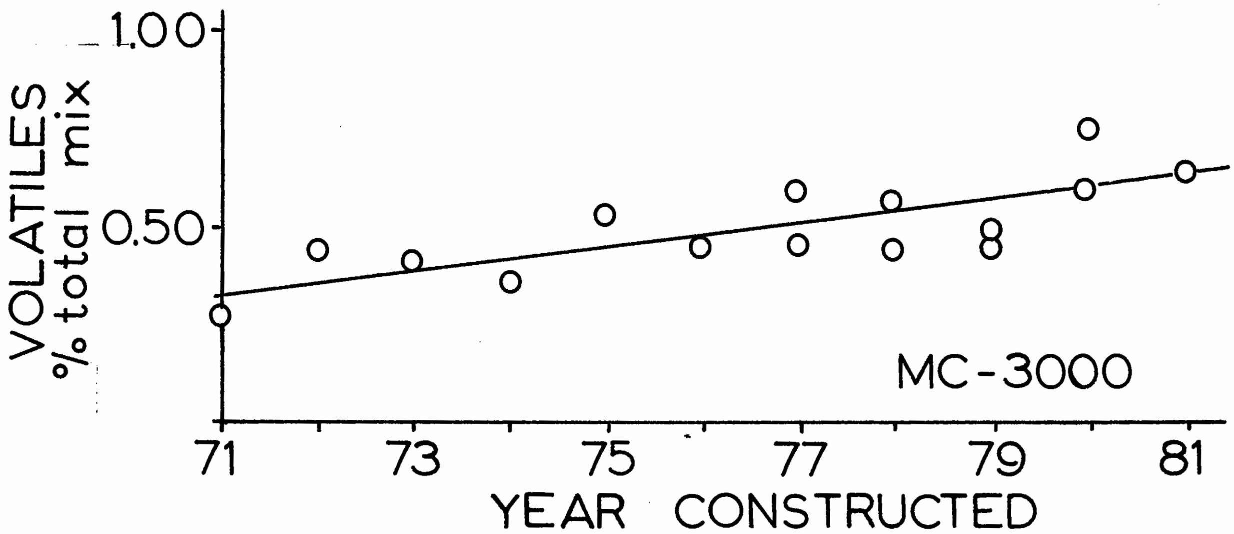

FIG. 3 VOLATILES TO 260°C VERSUS AGE

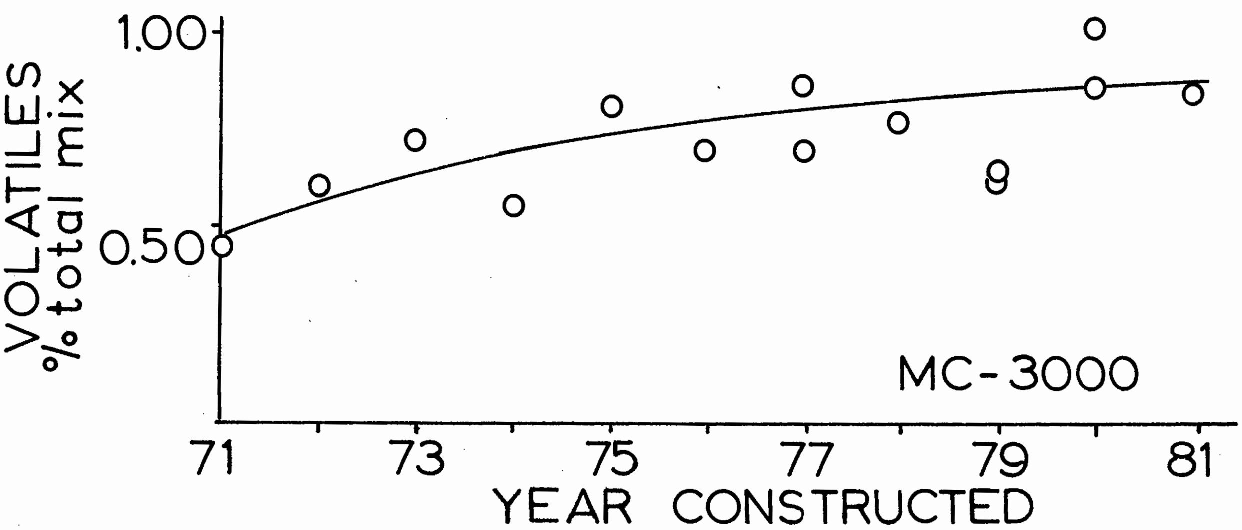

FIG. [illegible] ILES TO 315°C VERSUS AGE

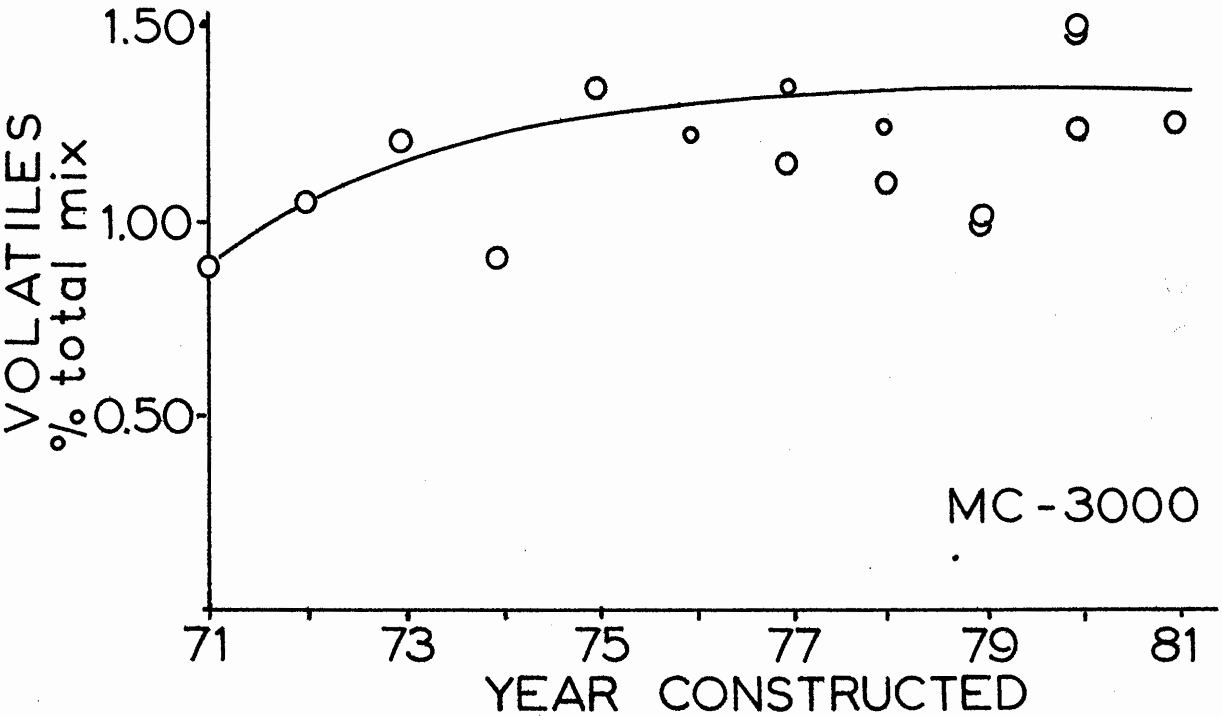

FIG. 5 VOLATILES TO 360°C VERSUS AGE

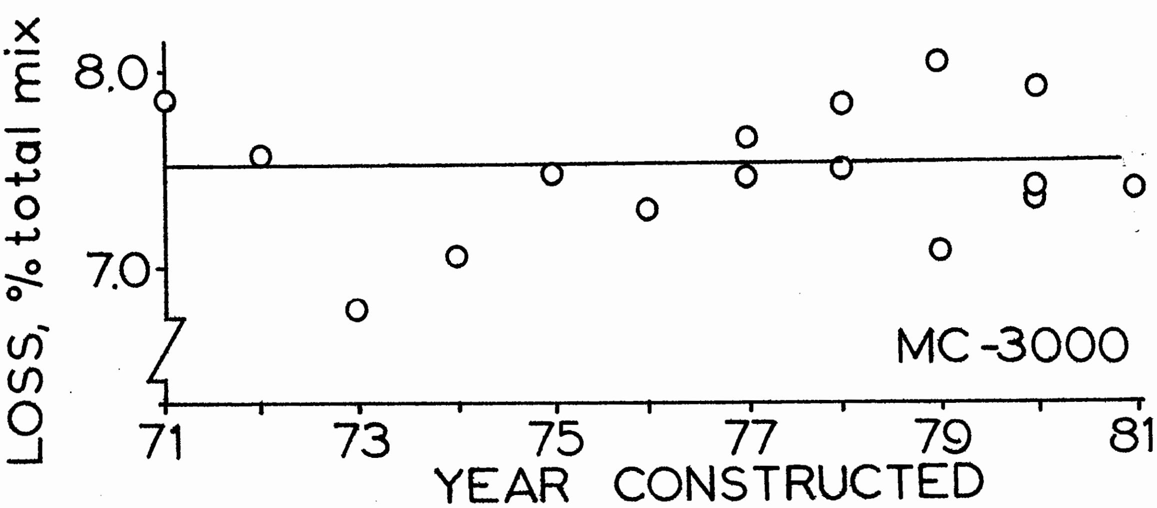

FIG. 6 LOSS TO 460°C VERSUS AGE

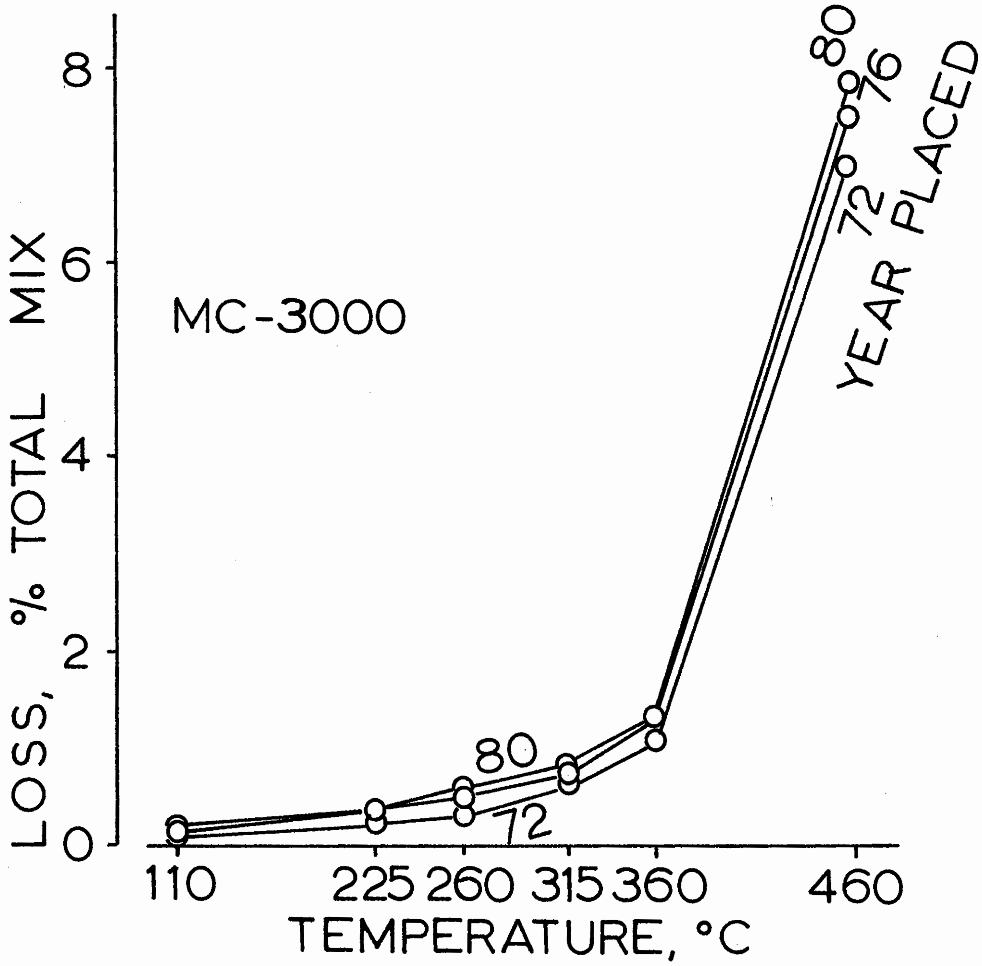

FIG. 7 LOSS VERSUS TEMPERATURE

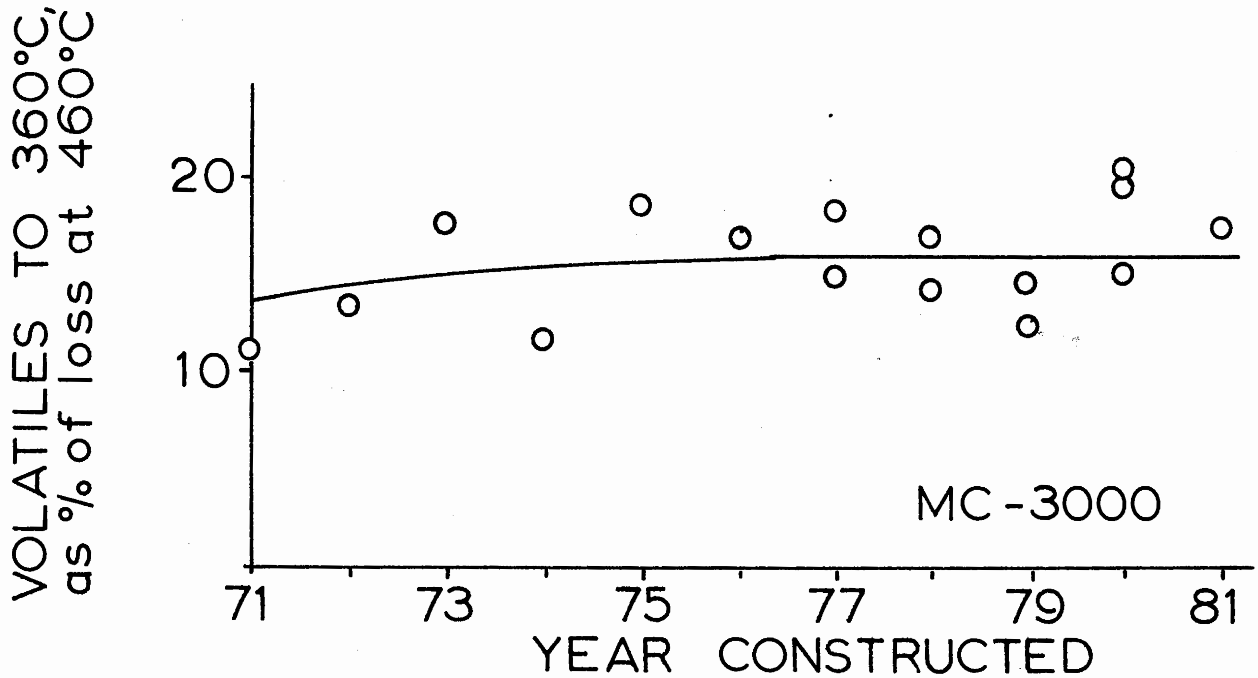

FIG. 8 VOLATILES VERSUS AGE

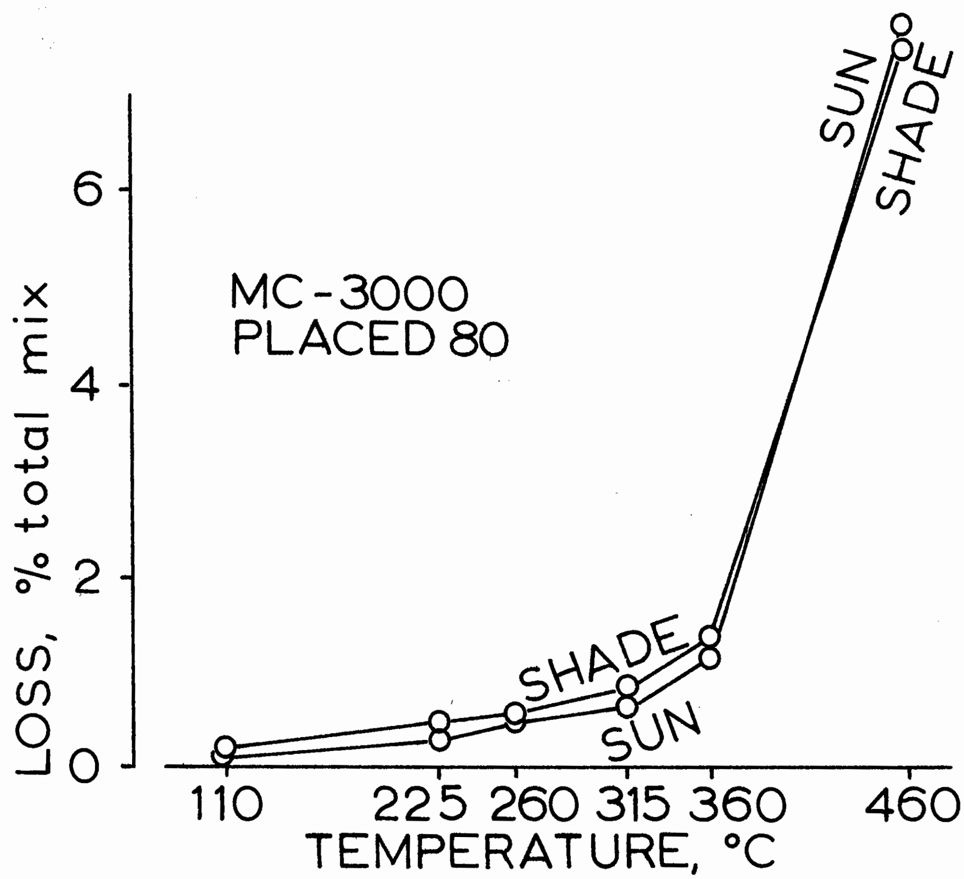

FIG. 9 LOSS VERSUS TEMPERATURE

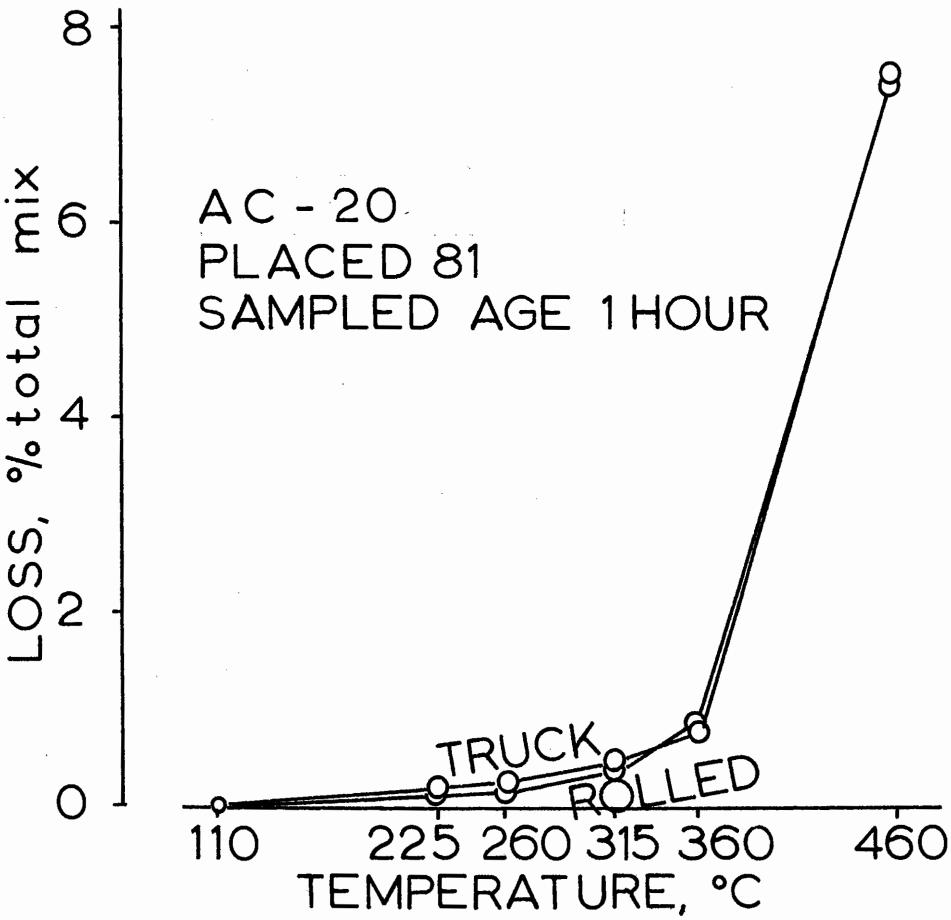

FIG. 10 LOSS VERSUS TEMPERATURE