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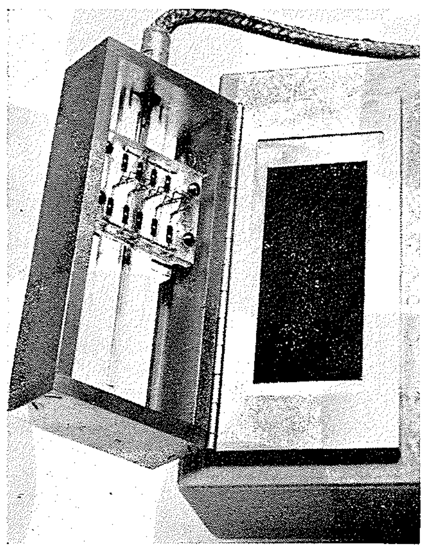
By P. M. JONES

A comparison of a more sophisticated spark-gap tester with the one specified in the ASTM Method of Test for Failure Endpoint in Accelerated and Outdoor Weathering of Bituminous Materials (D 1670) shows that the latter instrument requires no further complication.

In any study of the physical degradation of asphalt coatings during natural or accelerated weathering tests, some means of detecting and recording failures must be available. Electrometric methods suggested by Strieter (1)[1] and later modified by Weetman (2) were the first attempts to augment visual examinations. This procedure was improved by the spark-gap tester described by Boenau and Baum (3). Together with a method of evaluating failure by the photographic technique of Hunter, Gzemski, and Laskaris (4), these comprise the tentative ASTM Method of Test D 1670-59 T.[2]

NRC Instrument

Several years ago, before ASTM Method D 1670 was published, attempts were made at the National Research Council of Canada to construct a spark-gap tester. Some of the specified components were not readily available, and attempts were made to construct an apparatus with other materials. Several difficulties were encountered, so that it was not possible to achieve the specified values of voltage and current. The metal chassis caused breakdown of the resistors, and no reliable means of measuring the voltage was available. A compromise was reached in an apparatus that operated at the specified current and at the highest voltage possible without causing breakdown by internal shorting. This particular arrangement, however, resulted in some burning of the asphalt during the test. Since these experiences cast some doubt on the suitability of the design, an apparatus was constructed to operate on slightly different principles. A comparison of this new NRC design with a properly constructed apparatus as specified in the present ASTM method confirms the adequacy of the ASTM standard apparatus.



The probe unit is shown before the photographic paper is placed on the asphalt panel to record the failure detected by the probes when they pass over the panel.

Fig. 1.—NRC spark-gap apparatus.

The following features were included in the NRC instrument:

1. A more even waveform than that produced by the automobile coil in the conventional apparatus;
2. A spark having a very low current, so as to eliminate any burning of the asphalt;
3. A constant high voltage;
4. A multiple-segment probe unit rather than a single probe.

The single probe detects only one failure and could miss one or more failure points when detecting a stronger one. The multiple probe unit has 9 segments, each isolated from the others by a 1-megohm resistor. The probes are $\frac{3}{16}$ in. long. Since the ASTM Method specifies a lucite counting grid having $\frac{3}{16}$-in. squares with only one flaw in each square required for failure, it was

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[1] The boldface numbers in parentheses refer to the list of references appended to this paper.

[2] ASTM Method of Test for Failure Endpoint in Accelerated and Outdoor Weathering of Bituminous Materials (D 1670-59 T), 1961 Book of ASTM Standards, Part 4, p. 1227.

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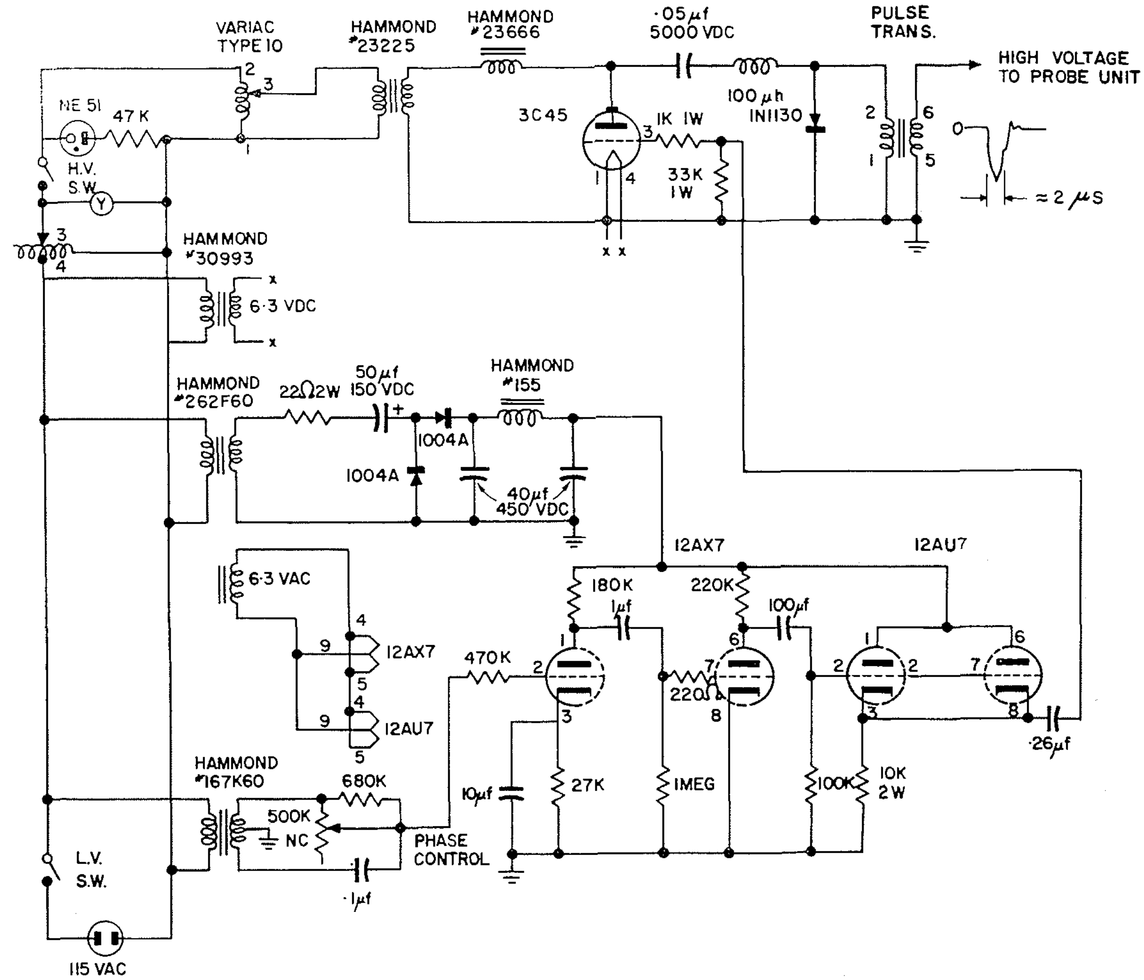

Fig. 2.—Electrical circuit diagram for NRC spark-gap apparatus.

thought that the accuracy of the method would be considerably improved. The NRC probe unit is shown in Fig. 1. The circuit diagram is shown in Fig. 2.

A filament transformer at the lower left-hand side has its primary winding connected to the 110-v 60-cycle line. The secondary winding feeds a phase-shift network that consists essentially of a resistance in series with a capacitance. By varying the resistance a phase shift of approximately −180 deg can be produced at the junction of the resistance and capacitance. The voltage is constant at this point and is fed through a 470,000-ohm grid-limiting resistor to the first grid of a 12AX7 tube. Grid-limiting action clips a portion of the positive-going grid voltage. The output at this stage is fed to the second half of the 12AX7, which is operated at zero bias. There is sufficient grid swing to produce cut-off, and the resulting plate voltage is a square wave. A 100 $\mu\mu$f capacitor and a 100,000-ohm resistor differentiates the square wave and feeds a 12AU7 cathode follower. The positive-going pulse provides trigger for a thyratron tube (type 3C 45).

This thyratron tube is supplied with a sinusoidal plate voltage from a high-voltage transformer through a choke coil. Load on the thyratron is the primary of a pulse transformer connected to the plate through a 0.05 μf capacitor and a 100 μH coil. Across the primary of the pulse transformer a IN1130 silicon diode is placed to eliminate any of the positive pulses.

By controlling the phase shift, the thyratron is triggered when the plate voltage reaches a maximum. With each trigger pulse on the thyratron the 0.05 μf condenser is discharged through the primary of the pulse transformer and a single high-voltage pulse is produced on the secondary.

The magnitude of this output pulse is controlled by the variable tap on the primary of the high-voltage transformer.

In the operation of the equipment the line voltage is set at 120 v and the high-voltage transformer is adjusted to produce an output voltage of 12,000 v. The voltage wave lasts for about 2 μsec and the peak current during this time is 12 milliamp. As this peak current lasts for only 2 μsec and recurs 60 times per second, the average current is 1.4 μamp.

ASTM Instrument

After ASTM Method D 1670-59 T was issued, the components for the test-

TABLE I.—CHARACTERISTICS OF ASPHALTS.

Asphalt	Description	Softening Point,[a] deg Fahr	Penetration[b] at 32 F	77 F	115 F	Specific Gravity[c] at 77 F	Ductility[d]	Flash Point,[e] deg Fahr
No. 1	South American	217.6	13.7	18.8	29.7	1.0184	2.8	565
No. 2	Western Canadian blend	230.9	12.0	14.7	26.5	1.0268	1.8	530
No. 3	Western Canadian blend	221.2	12.2	15.3	26.2	1.0180	1.6	540

[a] ASTM D 36 - 26, Test for Softening Point of Bituminous Materials.
[b] ASTM D 5 - 59T, Penetration of Bituminous Materials.
[c] ASTM D 71 - 52, Test for Specific Gravity of Asphalts and Tar Pitches.
[d] ASTM D 113 - 44, Test for Ductility of Bituminous Materials.
[e] ASTM D 92 - 57, Test for Flash Point by Cleveland Open Cup.

ing apparatus and the measuring apparatus became available. A plastic laminate chassis eliminated some of the breakdown problems, and with an electrostatic voltmeter it was possible to measure and to adjust the voltage. The ASTM apparatus was adjusted to give an output of 8000 v and 180 μamp.

A comparison of the two testers was made to answer the following questions:

1. Does the high current of the ASTM apparatus produce burning?
2. Does the single probe give inaccurate results?
3. Does the lower voltage selected for the ASTM tester result in different values for asphalt durability?

Testing

To compare results from the two instruments, asphalt panels were subjected to an accelerated weathering test. Three asphalts were exposed as films $2\frac{1}{4}$ by $5\frac{1}{2}$ in. by 25 mils thick on $2\frac{3}{4}$ by 6-in. aluminum sheet. These asphalts and their measured physical characteristics are listed in Table I. The panels were prepared by the hydraulic press method (5). Glass fabric coated with Teflon was used instead of the specified dextrin-coated paper to prevent adhesion of the asphalt to the press. Four sets of panels of each asphalt were prepared. The first set was tested with the conventional ASTM instrument; the second set was tested with the modified or NRC instrument; the third set was first tested with the NRC instrument and then with the ASTM instrument; and the fourth set was tested with the ASTM instrument and then with the NRC instrument. Each set consisted of four individual panels exposed in the same single-arc Weather-Ometer at different times (6). The Weather-Ometer was operated in accordance with ASTM Method D 529 - 59 T[3] using cycle A. Since it was not possible to cool the de-ionized water, a water temperature of 55 F was used.

During exposure the specimens were rotated in accordance with the rotation plan in ASTM Method D 529 - 59 T and tested every 5 cycles. The failures were counted on the spark photographs using a 260-square grid.

The results for certain selected numbers of cycles are given in Table II and the numbers of cycles to produce 10 per cent failure of the asphalts are summarized in Table III.

Conclusion

The two testers gave similar values for an arbitrary failure point when this point was for extensive areas of failure. No evidence was found of asphalt burning by the higher current of the ASTM tester. The multiple-probe unit detects more failures in initial exposure, but differences are small when a 10 per cent failure point is used. The NRC tester indicates slightly more failures, but this does not result in any appreciable lowering of the durability rating. The refinements in the electrical performance of the NRC apparatus are achieved at the expense of an increased number of components and much more complicated circuitry. They do not lead to any marked improvement over the results obtained with the much simpler ASTM apparatus.

Acknowledgment:

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TABLE II.—EFFECT OF TESTING PROCEDURE ON RECORDED PERCENTAGE FAILURE OF ASPHALTS.

Asphalt No. 1 — Failure, per cent, Number of Cycles

Test Panel	Testing Equipment	10	30	60	90	120	130	140	145	150
No. 1	ASTM	1.5	1.0	1.0	1.5	2.0	2.0	2.0	4.0	13.0
No. 2	NRC	1.5	1.5	1.5	2.0	2.0	2.5	4.5	14.0	32.5
No. 3	NRC	1.5	1.5	1.0	1.5	2.0	2.0	3.0	10.0	26.5
	ASTM	2.0	2.0	2.0	2.0	2.0	2.0	3.0	10.0	24.0
No. 4	ASTM	1.0	1.0	1.0	1.0	1.0	1.0	2.5	6.0	20.5
	NRC	1.0	1.0	1.0	1.0	1.0	1.0	3.0	10.0	28.5

Asphalt No. 2 — Number of Cycles

Test Panel	Testing Equipment	10	30	60	90	100	110
No. 1	ASTM	2.5	2.5	2.5	7.5	10.0	28.5
No. 2	NRC	1.5	1.5	1.5	6.0	11.0	31.0
No. 3	NRC	2.0	2.0	2.0	5.0	11.0	31.5
	ASTM	2.0	2.0	2.0	5.0	8.0	26.0
No. 4	ASTM	5.0	5.0	5.0	13.0	18.0	34.5
	NRC	4.5	4.5	5.0	16.0	23.0	44.0

Asphalt No. 3 — Number of Cycles

Test Panel	Testing Equipment	10	25	30	35	40
No. 1	ASTM	2.5	2.5	3.0	9.0	25.0
No. 2	NRC	5.5	6.0	8.5	14.0	34.0
No. 3	NRC	1.0	1.0	1.5	9.5	30.0
	ASTM	1.5	1.5	3.0	14.5	27.0
No. 4	ASTM	2.0	2.0	3.0	12.0	38.1
	NRC	2.0	2.0	3.0	12.5	46.0

TABLE III.—DURABILITY IN DAYS (51-9 CYCLE) OF THE ASPHALTS 10 PER CENT FAILURE LEVEL.

Test Panel	Testing Equipment	Asphalt No. 1	Asphalt No. 2	Asphalt No. 3
No. 1	ASTM	150	100	40
No. 2	NRC	145	100	35
No. 3	NRC	150	100	40
	ASTM	150	110	35
No. 4	ASTM	150	90	35
	NRC	150	90	35

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