DIELECTRIC MEASUREMENTS
OF
ASPHALT CONTENT

FINAL REPORT

August 1967

Prepared by

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in cooperation with

U. S. DEPARTMENT OF TRANSPORTATION
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SUMMARY

DIELECTRIC MEASUREMENTS OF ASPHALT CONTENT

Present methods of measuring asphalt content in asphaltic plant mixes are either time consuming or costly. The differences in dielectric properties of asphalt and aggregates suggest that an inexpensive instrument might be developed which could determine asphalt control by measurements of this difference. Blackwell Electronic Laboratories of Denver and the Department of Highways, State of Colorado, investigated this possibility during fiscal 1966-67.

In the experiments, the dielectric constant of typical asphalt mixes was determined by measuring the change in capacitance of a parallel resonance circuit. The dielectric loss was determined by measuring the voltage of the resonance circuit. Frequencies used were from 50 to 200,000 cycles per second. A variety of combinations of capacitor plates and electrodes were used to obtain optimum output values.

After considerable work, it was tentatively concluded that the dielectric readings were as dependent upon the density of the mix as on the asphalt content. To measure asphalt content it will be necessary to control or measure the density of the sample.

The research work has been extended through fiscal 1967-68 by contract with Blackwell to establish final procedures for measuring both density and asphalt content by means of the electronic device developed under this research project.

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INTRODUCTION: All materials have what are known as dielectric properties. The development of an electronic device that would accurately measure dielectric constants could result in new test methods for measuring the properties of various highway construction materials.

During fiscal 1966-67, a research project was conducted on dielectric measurements that involved DOH Central Materials Laboratory personnel, the Blackwell Electronic Laboratories of Denver, and the DOH Planning and Research Division. The objective was to attempt the development of electronic and mechanical equipment for the measurement of the asphalt content of hot bituminous mixes by dielectric methods and a suitable test method for use in the field. A quick field test method for asphalt content is needed for better quality control.

The Blackwell Electronic Laboratories were to furnish a prototype of the dielectric instrument and the DOH Laboratory was to build suitable mechanical sampling equipment and provide typical specimens of asphalt mixes for experiments.

THEORETICAL BASIS FOR EXPERIMENTS:

Asphalts, petroleum oils, and gilsonite are generally known to be excellent insulators and to possess good dielectric strength, low dielectric constant, and low dielectric loss. The second constitutent of an asphalt mix, the aggregates, exhibit a higher dielectric loss and a larger dielectric constant. The third ingredient, moisture, has a very high dielectric constant, making its presence in the mix readily detectable.

In the experiments, the dielectric constant of typical asphalt mixes was determined by measuring the change in capacitance of a parallel resonance circuit and will be referred to as "C". The dielectric loss was determined by measuring the voltage of the resonance circuit and will be referred to as "Q".

NARRATIVE CONCERNING WORK PERFORMED:

From the initial experiments run at 100,000 CPS (Cycles Per Second), sensitivity as follows was indicated:

C of asphalt	Q of asphalt	C of aggregate	Q of aggregate
2.5 to 2.6	98% of air	3.5 to 5.0	50% to 75% of air

From the data collected thus far, it appears quite possible to measure asphalt content by measuring the "Q" or "C" of a hot, dry asphalt mix. Equipment used to arrive at preliminary dielectric results is illustrated schematically in Figure 1.

The dielectric prototype that evolved from these initial trials consisted of 3 major components:

1. Oscillator (source of power)
2. Sensing elements (sample container and electrode)
3. Readout system (modulator and amplifier)

The tuneable oscillator was capable of an output of 50 to 200,000 cycles per second.

Two types of sample containers and 4 types of electrodes were built in the DOH Laboratory machine shop or purchased from local suppliers. The rectangular container with a side-plate type of capacitor was discarded in favor of the cylindrical type having a center electrode. Further experimentation caused the elimination of all diameters of electrode except the 1 inch size. Sample containers were selected of suitable size with the thought in mind of attaching them to a long handle and striking through the discharge of the pug mill at the hot plant in order to obtain a representative sample. This sample would be of proper size for dielectric measurements and could be used for conventional tests (either reflux or vacuum extractions) without splitting. The various containers and electrodes are shown in Figure 2.

Figure 3 shows the 1 inch electrode and the first 3 samples used to establish electrical parameters for the readout system. These specimens are 100% asphalt, a typical sand asphalt mix containing 6.0% asphalt, and 100% dry aggregate of the same type in the 6.0% mix. Figure 4 illustrates mechanical press made by DOH forces to insert the electrode into the sample, a sample of dry aggregate being tested (1) and the original electronic equipment (labeled 2, 3, and 4 in the photo) was supplied by Blackwell to establish readout parameters. Figure 5 shows a schematic of the electronic equipment.

Frequencies of from 80,000 CPS through 120,000 CPS were decided upon as being optimum. Further testing revealed a range of 10 millivolts between the pure asphalt and the dry aggregate samples and a 4 millivolt difference between the 6.0% asphalt mix and the dry aggregate. This 10 millivolt difference was considered to be too small for the desired accuracy (±0.02% asphalt content).

Part of this range (or sensitivity) problem was solved by subsequent research into the types of coils to use. Special powedered metal coils were made up and tied into the dielectric circuitry. The system then yielded a full 1 volt difference between samples containing 5.0% and 7.0% asphalt when used on the typical samples composed by DOH forces.

When testing 6 additional samples of asphalt mix, it became apparent that the dielectric loss should be measured at a fixed capacitance. This capacitance should be obtained by inserting the electrode into the sample until a definite reading was reached. The dielectric loss would then be read when this capacitance was reached. Figure 6 shows the prototype dielectric device and the press used. Figure 7 shows a schematic drawing of the prototype circuitry. A problem then arose concerning the effect of the operator's hand on the readings as the electrode was being inserted. The press was then modified with a threaded shaft, spring, and wheel arrangement whereby the insertion could be done without the readings being affected by the operator's hand. Considerable delay was encountered at this time because of the unforeseen closing of the Central Laboratory machine shop and the necessity of having to let bids on modifications of the dielectric mechanism.

As experimentation continued on asphalt mix samples from various sources and of varying gradations, it became apparent that the method of preparing the samples had a great effect on the results. In the beginning, the specimens were heated, poured loosely into the containers from a static height of 4 inches, and the excess material was struck off with a straightedge. Samples prepared differently had poor correlation. After considerable work it was tentatively concluded that the dielectric readings were dependent upon the density of the mix rather than the asphalt content. The response of the readout was sensitive to the density resulting from the lubrication of the aggregate particles (coated with asphalt) being dropped into the container from the same height. Apparently, the higher the asphalt content, the more dense the sample resulting in a proportional increase in the dielectric reading.

An attempt was made to measure the asphalt content with the samples compacted to a uniform density. This was found to be quite difficult using the tools at hand. The results of tests are shown on Table 1. This method shows promise but lacks the sensitivity desired when the samples are compacted to approximately 125 pounds per cubic foot.

However, achieving a density of about 140 pcf for this particular material would eliminate much of the air voids and, in Blackwell's estimation, yield better range and sensitivity. At this high density, the electrodes would have to be inserted beforehand and the mix compacted around them. Therefore, the press previously described has been abandoned in favor of a larger mold with two capacitor plates installed in the bottom. (See Figure 8.) Experiments planned using this configuration are briefly described in a later portion of this report.

Since the dielectric device showed sensitivity to the density of the mix, it was decided to capitalize on these findings by building a surface parallel plate sensor and experimenting in the area of asphalt density tests. This dielectric density device is illustrated in Figure 9. The results of first attempts are listed on Table 2. As noted, the readings are arbitrary numbers and have nothing to do with asphalt content. What they show is the sensitivity of the device to bulk density.

When using the parallel plate surface density sensor in the field, it shorted out when laid on the hot asphalt surface covered with the thin film of water from the steel wheel roller. However, this problem was overcome by simply wiping the surface with a cloth. A significant drop in the reading of the device was noted after each pass of the roller. It is believed this change in reading can be interpreted in terms of specific gravity. However, further modifications in the instrumentation are needed. The device will then be calibrated on asphalt slabs of known density such as those used for calibrating the nuclear asphalt density probes.

CONCLUSIONS:

Electronic and mechanical equipment were developed to measure the dielectric properties of aggregate and asphalt. While this method showed promise of being able to determine the asphalt content of a given mix during preliminary evaluation, further investigation indicated insufficient range of the instrument for the accuracy desired and an inordinate sensitivity to the density of the sample. This research project has been extended through fiscal 1967-68. One more effort to determine asphalt content will be made using dielectric methods. Asphalt mixes having asphalt contents of 5.0, 6.0, and 7.0% will be compacted to 140 pcf in 3 six inch diameter molds containing two parallel electrodes. Dielectric measurements will be made on the material in these molds. The range and sensitivity will again be checked using this new approach to sample preparation. Concurrent with the asphalt content work, project forces will continue investigating the possibilities of the use of dielectric measurements for asphalt density in the field. This method shows promise of becoming an inexpensive and nondestructive test method.

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Work planned concerning the surface density sensor is outlined as follows:

1. Various plate sizes and shapes will be tried to determine depth of penetration of the dielectric field, optimum area to be tested, and the practical overall size of the sensor.
2. The prototype density device will be calibrated on the DOH asphalt concrete standards used for nuclear device calibration.
3. Field trials will determine the practical aspects of dielectric density tests in establishing roller patterns and obtaining final percentages of relative compaction tests.
4. Correlation between the dielectric, nuclear, and conventional tests will be determined.

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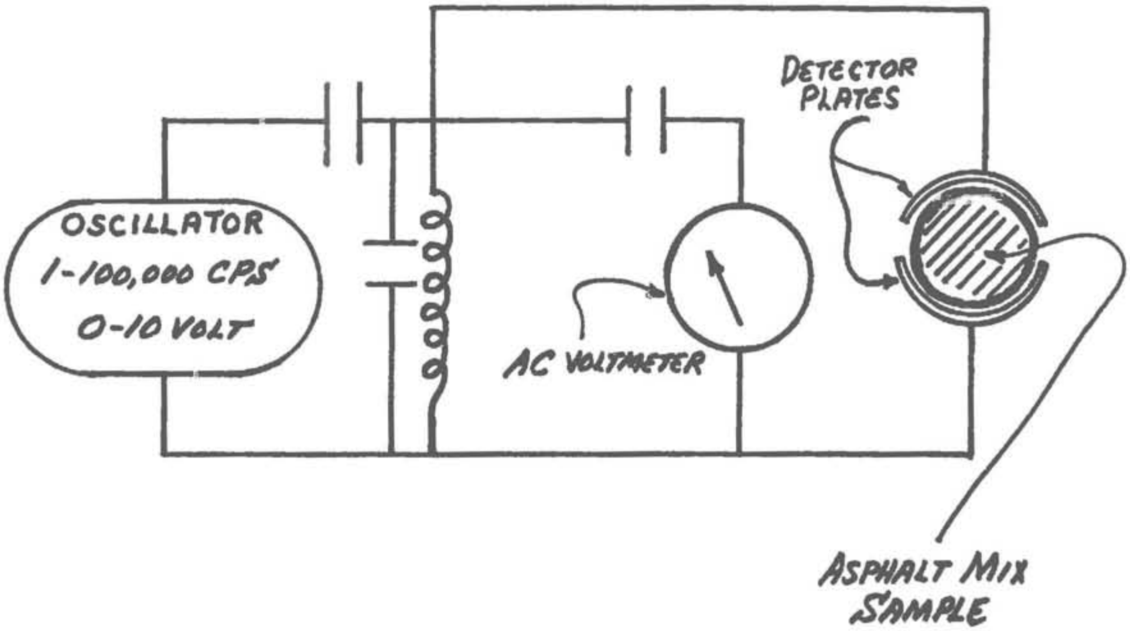


FIGURE 1

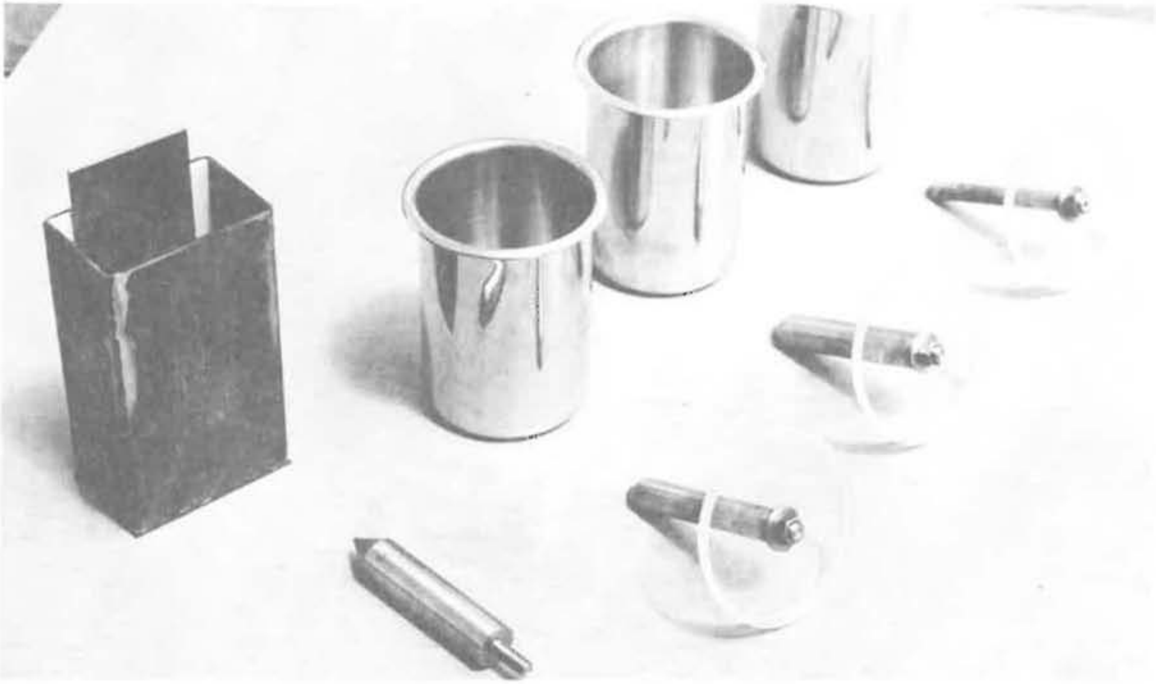


FIGURE 2

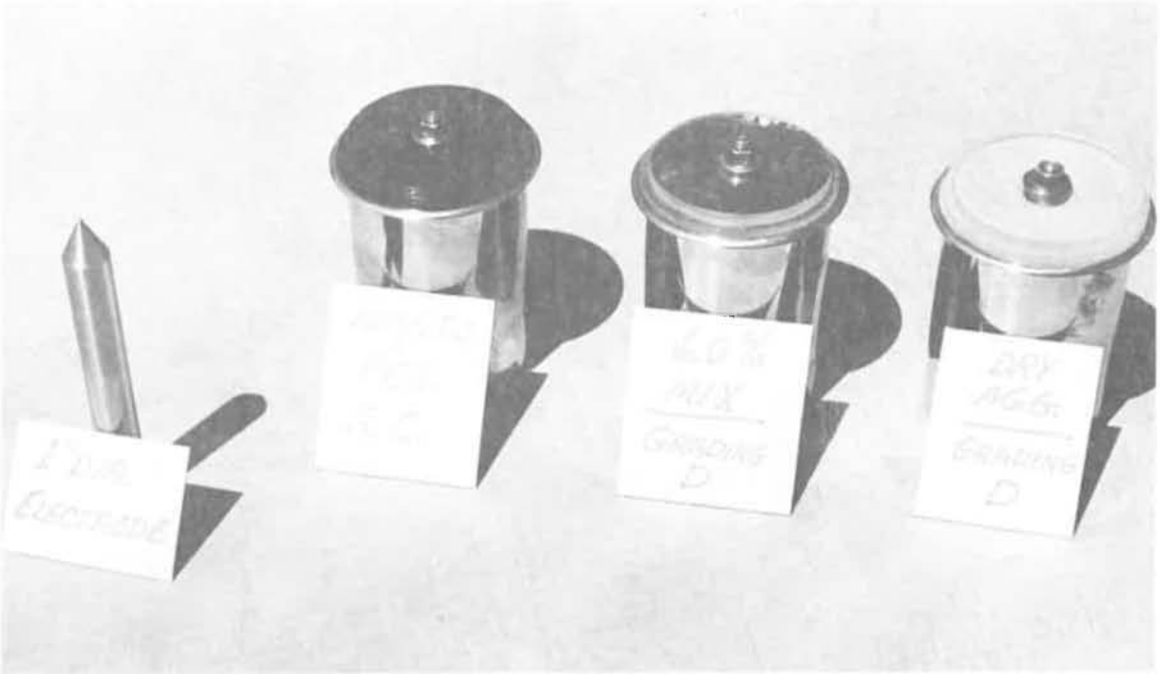


FIGURE 3

FIGURE 4

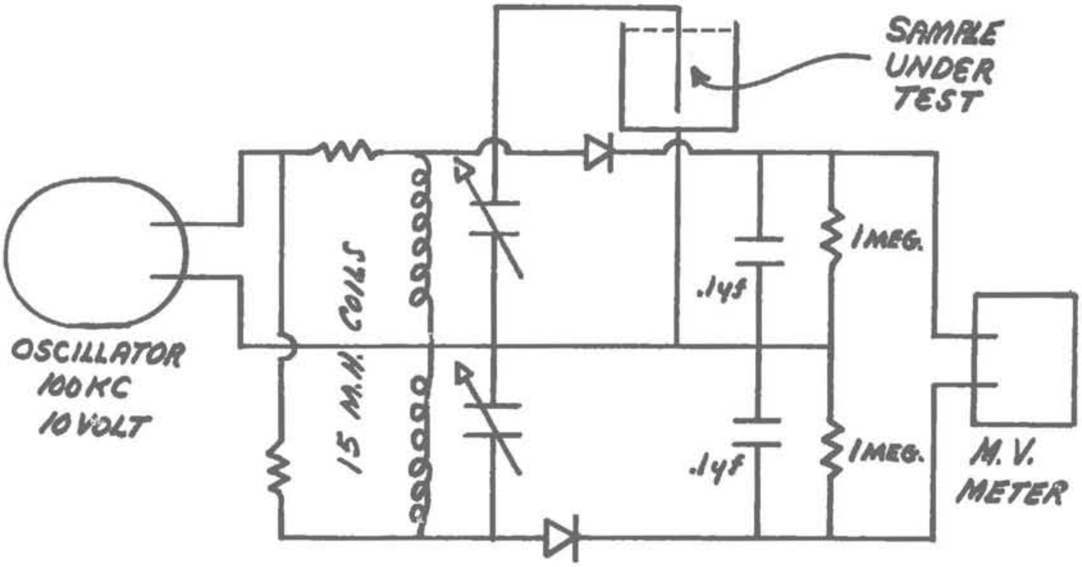


FIGURE 5

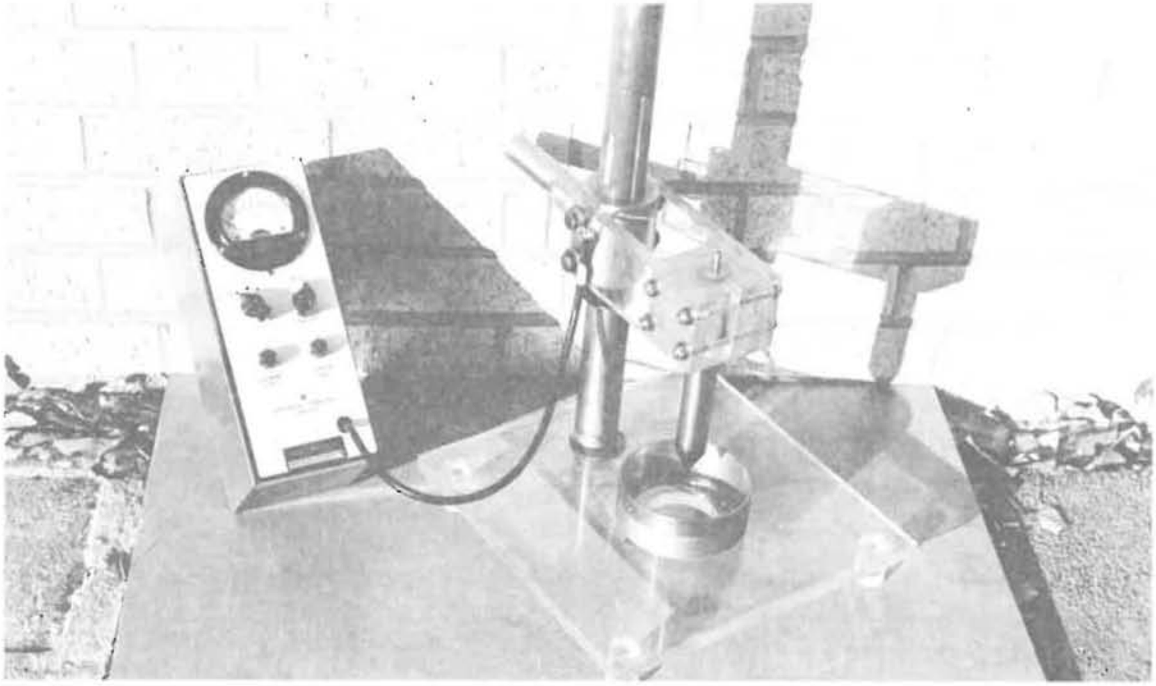
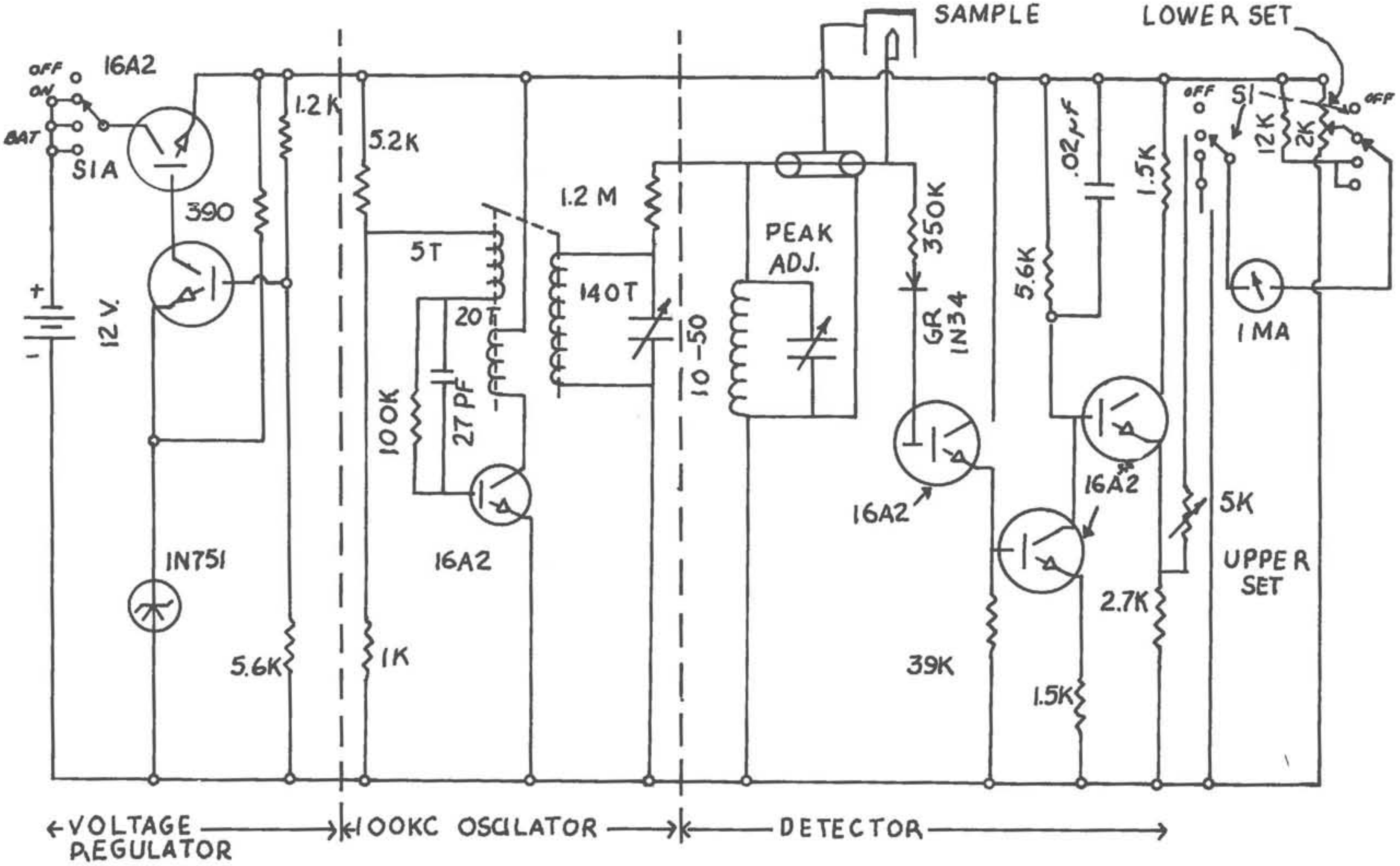


FIGURE 6



DIELECTRIC LOSS AND CAPACITANCE DETECTOR

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AUG. 1, 1967 BY L.L. Blackwell

FIGURE 7

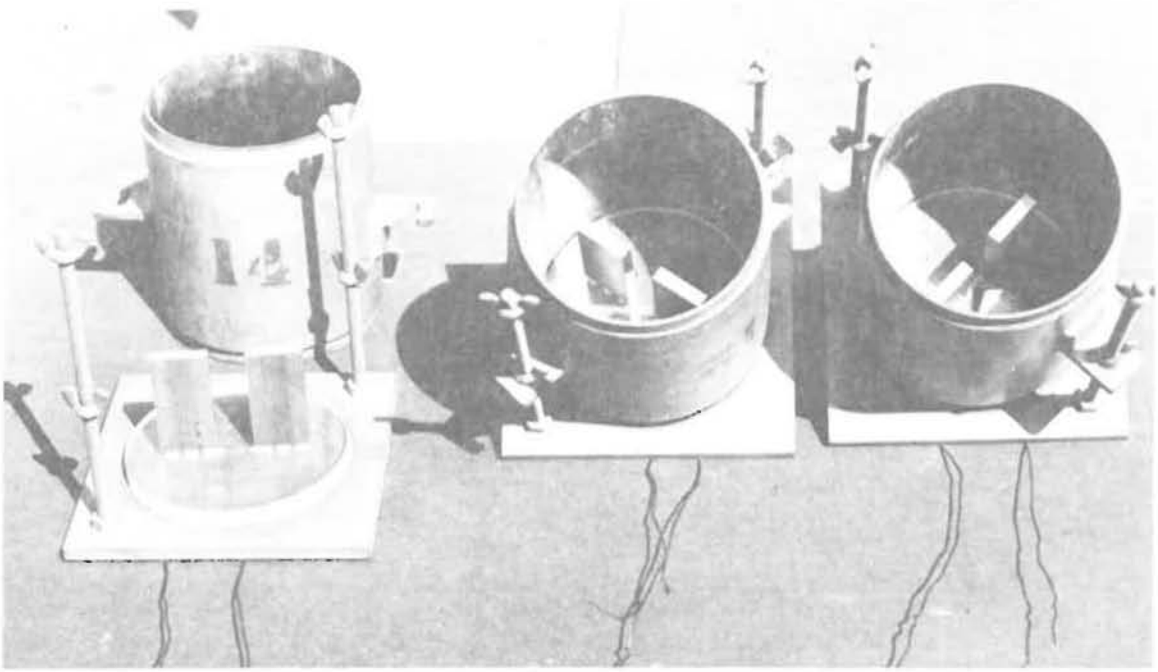

FIGURE 8

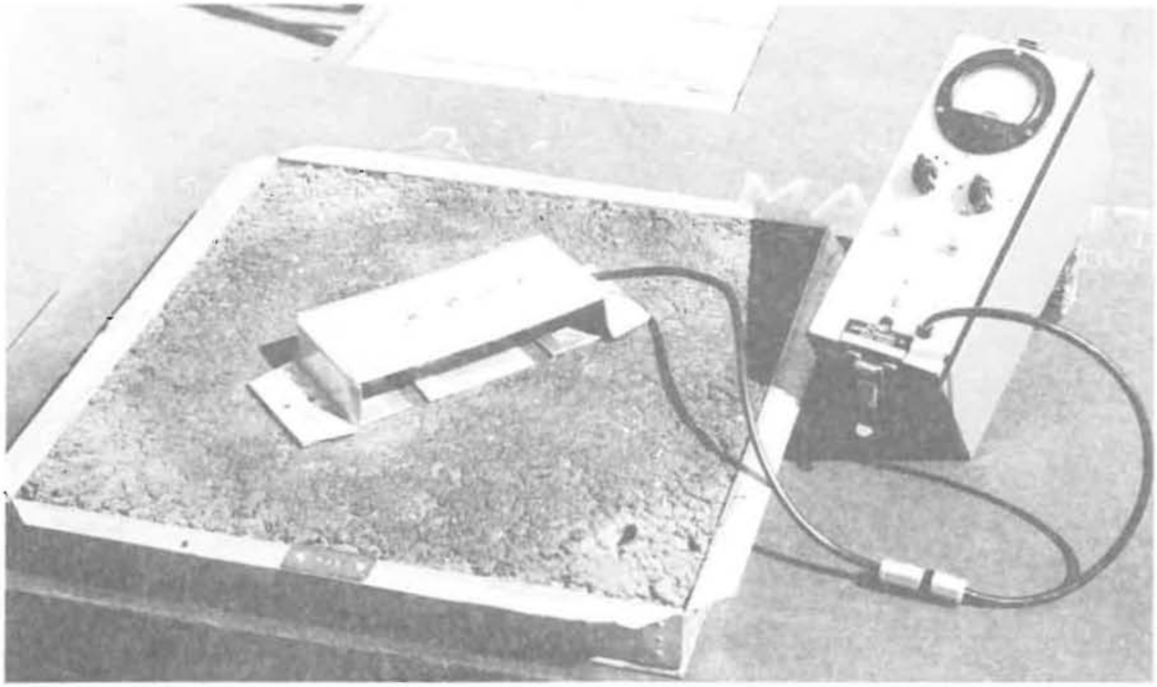

FIGURE 9

TABLE 1

TEST RESULTS FOR ASPHALT CONTENT

Response of the meter to four asphalt content samples compacted to a uniform density of 125 pcf. Measurements taken at resonance peak using dielectric equipment.

METER READING	ASPHALT CONTENT
5.75	4.0%
5.80	5.0%
6.00	6.0%
7.00	7.0%

TABLE 2

TEST RESULTS FOR ASPHALT DENSITY

Resonance peak readings for various asphalt densities. These measurements were made using the dielectric surface parallel plate detector spaced 1/16" and 1/4" from the surface.

SAMPLE	DENSITY PCF	METER READINGS * 1/16"	1/4"
Asphalt slab #2	116	8.0	8.0
Asphalt slab #4	140	6.8	7.6
Granite standard	163	4.8	6.2

* Meter readings are arbitrary and indicate the sensitivity of the dielectric meter rather than asphalt content.