SAE The Engineering Society For Advancing Mobility Land Sea Air and Space® INTERNATIONAL
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SURFACE VEHICLE RECOMMENDED PRACTICE

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IGNITION SYSTEM MEASUREMENTS PROCEDURE

1. ***Scope***—This SAE Recommended Practice is intended to provide any technical person or group interested in ignition system design and/or evaluation with the specific equipment, conditions, and methods which will produce test results definitive and reproducible for his own work and yet sufficiently standardized to be acceptable to other groups working on battery ignition systems for automotive engines.

2. ***References***

2.1 Applicable Document—The following publication forms a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE AIR84—Ignition Peak Voltage Measurements
(R) SAE J139—Ignition System Nomenclature and Terminology

3. ***DC Source***—The source of DC voltage to be used in ignition system measurements shall be a variable DC power supply having a 10 to 90% transient recovery time of not more than 50 µs over the load range encountered in use. It must have no more than 10 mV variation in average voltage from no load to full ignition system load and no more than 50 mV peak-to-peak ripple over the same load range. This power supply shall be shunted by a suitably tapped automotive-type lead acid battery and be positioned immediately adjacent to the test area so that the source impedance of a vehicle is simulated as closely as possible.

4. ***Ignition System Definition***—The ignition system as defined for the tests tabulated in this report shall consist of:

a. A coil. This can be the conventional induction coil or an air or magnetic core transformer.

(R) b. A coil external primary (ballast) resistor or resistors if the coil being tested requires an external primary (ballast) resistor.

c. A distributor. This is defined as any device which incorporates a timing mechanism, a spark advance mechanism or mechanisms, and a spark distribution mechanism, all of which have a proper angular interrelationship to themselves and, through a mechanical drive, to the engine.

d. High voltage, metal conductor ignition cables: coil to distributor—455 mm (18 in) long, distributor to spark gap—610 mm (24 in) long. Metal conductor cables are specified to eliminate the varying effects of the different kinds of cable with high impedance conductors. Resistance per foot, as well as inductance of spark plug cables built to suppress radiation, can be quite different from manufacturer to manufacturer.

NOTE—Some ignition systems may not function properly with metallic secondary cables due to EMI and may require low resistance inductance cables.

e. Any auxiliary switching means implicit with the system being tested such as a transistorized control unit.

The preceding devices shall be interconnected as the manufacturer recommends or similar to the conventional system illustrated in Figure 1.

5. ***System Load***—The load connected to the ignition system shall be a multigap spark gap test stand, each gap being individually variable, the number of gaps used being the same as the number of towers on the distributor cap. Using an 8-cylinder distributor as an example, seven gaps will be set to fire at a nominal 12 kV, the remaining gap will be opened to the point where it never can fire. Attached to the nonfiring gap, by not less than 305 mm (1 ft) of secondary ignition cable, will be a high quality (dissipation factor of 3% or less), high voltage, 50 pico farad capacitor (this can be a section of shielded ignition cable) to simulate the capacitance of the cables and spark plugs as normally encountered on a vehicle, and at suitable times a low voltage coefficient (0.0005%/V max), noninductive approximately 10 W, 1.0 MΩ resistor. The resistor simulates lead or carbon fouled spark plugs.

For certain tests, as designated in Section 6, the capacitive and resistive loads will be directly connected to the coil high voltage tower with the coil not firing.

6. *Measurements to be Made*

6.1 Group A

6.1.1 AVAILABLE VOLTAGE AT SPARK PLUG—This measurement is fundamental to spark ignition. Comparing available voltage to voltage required to fire spark plugs (in a given engine) determines the adequacy of the ignition system. (See Figure 2A.)

6.1.2 PEAK COIL PRIMARY CURRENT—This measurement indicates energy into the coil ($E = 1/2\ Li^2$) and must be controlled to insure adequate distributor contact life. (See Figure 2B.)

NOTE—Contacts are only used in distributors with mechanical switching.

6.1.3 AVERAGE COIL PRIMARY CURRENT—This measurement determines the average current draw of the system with respect to the DC source (alternator, generator, battery, etc.).

6.1.4 SPARK DURATION—Within limits, this measurement is indicative of the igniting capability of a spark under marginal fuel conditions. It also is an indication of the amount of erosion which will occur on spark plug electrodes due to electrical means. Because of the complexity of both of these areas, however, experience is required to use this information effectively. (See Figure 2C.)

6.1.5 SPARK VOLTAGE—This is the instantaneous voltage observed across the spark gap halfway through the discharge. (See Figure 2E.)

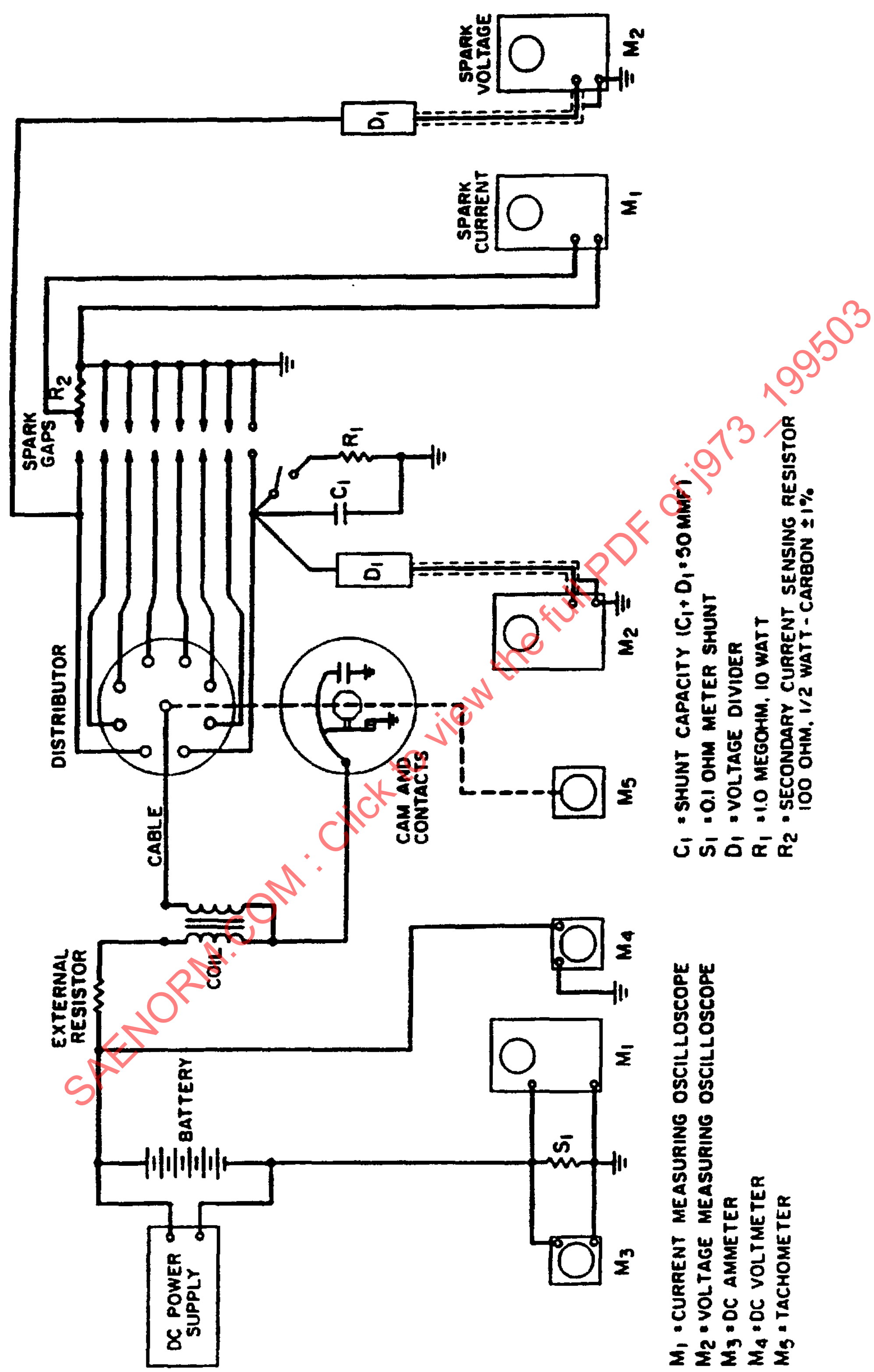


FIGURE 1—TEST CIRCUIT ARRANGEMENT FOR GROUP A TESTS

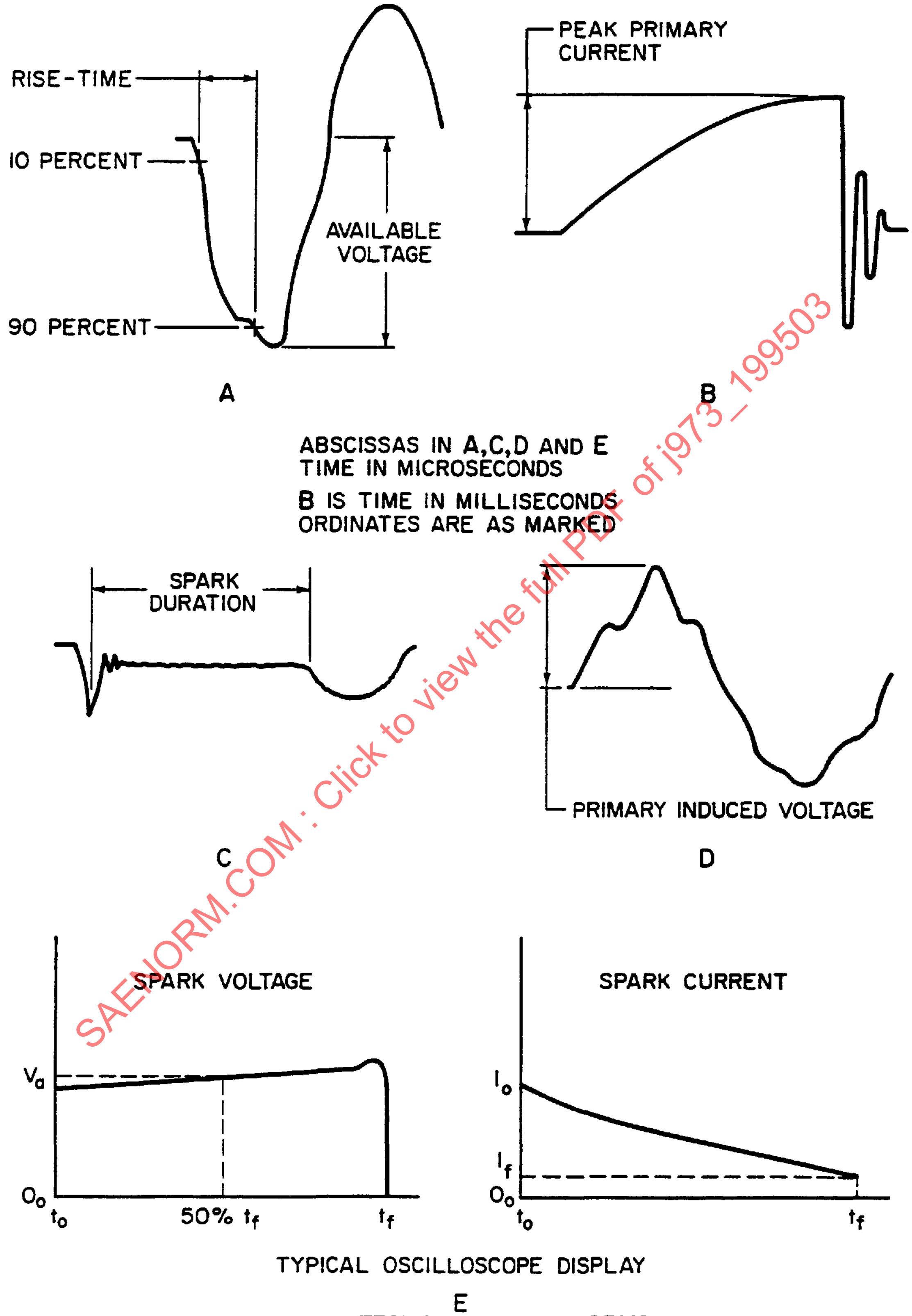


FIGURE 2—TEST CIRCUIT WAVEFORMS

6.1.6 Spark Current—This is the instantaneous current from the secondary winding of the ignition coil flowing through the spark gap after breakdown. (See Figure 2E.)

6.1.7 Spark Energy—This is the inductive portion of energy dissipated in the spark after breakdown. It is calculated as shown:

$$E_{spark} = \frac{V_a(t_f - t_o)(i_f + i_o)}{2} \quad \text{(Eq.1)}$$

where:

t_o and i_o = initial values of time and current of the spark after breakdown
t_f and i_f = final values of time and current of the spark after breakdown
V_a = spark voltage at $(t_f - t_o)/2$

6.2 Group B

6.2.1 Coil Secondary Voltage Risetime—This measurement is an indication of the ability of an ignition system to fire shunted (fouled) spark plugs. The shorter the risetime, the less system energy is lost across the fouled shunt and the more voltage is available to fire the plug. (See Figure 2A.)

6.2.2 Coil Primary Induced Voltage—This measurement is useful with respect to distributor contact life on conventional ignition systems and is a measure of the stress on a semiconductor power switch in inductive energy storage ignition systems. (See Figure 2D.) This measurement is not applicable to capacitor discharge ignition systems.

7. Test Equipment

7.1 A voltage divider and oscilloscope for measuring high voltage as defined in SAE AIR84 should be used to measure available voltage, risetime, and spark duration.

7.2 An oscilloscope with a maximum risetime of 0.035 µs and with a minimum band pass of 10MC (ref. Tektronix 535A with a type L plug-in unit) with its input connected across a noninductive meter shunt which is in series with the coil primary for peak coil primary current measurements. The sensing resistor shall not have a resistance greater than 0.1 Ω. The oscilloscope must have a minimum deflection sensitivity of 50 mV/cm.

7.3 A good quality DC ammeter of the permanent magnet-moving coil type should be used for average coil primary current measurements. The meter range selected should easily allow reading resolutions of at least 0.1 A.

7.4 The same oscilloscope required in 7.2 should be used to measure primary induced voltage.

(R) **7.5** A good quality DC voltmeter with an input resistance of at least 1000 Ω/V (ohms-per-volt) and with sufficient resolution to easily indicate differences of 0.1 V. To achieve this resolution the full scale deflection should be appropriate to the voltage rating of the ignition system being tested.

7.6 A distributor drive stand and attached tachometer which will have:

a. An eccentricity between the mounting fixture and drive of 0.076 mm (0.003 in) maximum.
b. A continuously variable speed adjustment with a total speed variation between 15 and 3500 rpm possible.
c. Speed stability within 5% at any given speed.
d. A tachometer accurate within 3% of indicated speed and independent of the electrical portion of the ignition system.

8. Procedures

8.1 Group A Tests—The conventional circuit arrangement as shown in Figure 1 with instrumentation in place, or modified with an auxiliary switching unit connected as the manufacturer intended, can be used to measure available voltage, peak primary coil current, average primary coil current, spark duration, spark voltage, and spark current at the distributor speeds and input voltages listed in Table 1.

The calculation described in 6.1.7 plus the procedure described here determines the inductive portion of the spark energy dissipated in a 12 kV spark gap under the conditions shown in Table 1. Spark currents and voltages can be measured and spark energy calculated equally well under other conditions and with different spark gaps. This procedure can be used in relating the effective amount of spark energy required to ignite a given fuel mixture.

If 6 V ignition systems are to be tested, divide the primary voltages listed in Table 1 by two; for 24 V systems, multiply by two.

TABLE 1—TEST CONDITIONS FOR GROUP A TESTS

Distributor rpm	Primary Volts	Environment Temperature °C	Environment Temperature °F	Operating Condition
20	5.0	-29 ± 1	-20 ± 2	Cold Starting
30	5.0	-29 ± 1	-20 ± 2	Cold Starting
40	5.0	-29 ± 1	-20 ± 2	Cold Starting
50	11.0	27 ± 3	80 ± 5	Hot Starting
60	11.0	27 ± 3	80 ± 5	Hot Starting
70	11.0	27 ± 3	80 ± 5	Hot Starting
250	14.0	27 ± 3	80 ± 5	Running
500	14.0	27 ± 3	80 ± 5	Running
750	14.0	27 ± 3	80 ± 5	Running
1000	14.0	27 ± 3	80 ± 5	Running
1250	14.0	27 ± 3	80 ± 5	Running
1500	14.0	27 ± 3	80 ± 5	Running
1750	14.0	27 ± 3	80 ± 5	Running
2000	14.0	27 ± 3	80 ± 5	Running
2250	14.0	27 ± 3	80 ± 5	Running
2500	14.0	27 ± 3	80 ± 5	Running
2750	14.0	27 ± 3	80 ± 5	Running
3000	14.0	27 ± 3	80 ± 5	Running

Allow the ignition system to soak at least 1 h at the temperatures listed in Table 1 before beginning tests. Before any readings are recorded at any of the test points, the system should be allowed to come to a thermally stable operating condition (typically, this takes about 2 min).

Output voltage amplitudes vary due to contact arcing and other small but accumulative factors. It is recommended that the minimum peak amplitude be recorded. This represents the level which can be guaranteed by the system under test.

The voltage divider lead would have to be connected to a firing spark gap for spark duration measurements and this gap set carefully to fire at 12 kV ± 1/2 kV. To secure firing voltages stability of this magnitude, special gaps and/or arrangements are usually required. Firing across a surface may help stability. Firing a gap under pressure using a dry inert gas and spherical electrodes also helps.

When environmental equipment is used to control ambient test temperatures, care must be taken that wire and/or cable lengths and, consequently, impedances do not affect test results.

During simulated starting tests, the system shall be operated under conditions simulating vehicle application: that is, if primary resistor in series with coil is normally bypassed during vehicle cranking, resistor should be bypassed for this portion of bench tests.

8.2 Group B Tests—The circuit arrangement shown in Figure 3 is appropriate to measure the coil's primary induced voltage and secondary voltage. When the 1.0 MΩ resistor is connected, it is also appropriate to measure the risetime of the secondary voltage. The distributor and spark gaps are dispensed within these tests, as the waveform irregularities they introduce add nothing to the results and make stabilized patterns on the oscilloscope difficult to achieve. Oscillograph M_1 is used to measure primary induced voltage in this case. These measurements should be made at an ambient temperature of 27 °C ± 3 °C (80 °F ± 5 °F), a distributor speed of 1000 rpm, and a primary voltage of 14 V. Primary induced voltage test results are usually more meaningful if compared to secondary voltage values measured simultaneously. A satisfactory ratio of secondary voltage to primary induced voltage should be established by each group making these tests if they wish to insure that neither contacts nor semiconductors are overstressed.

Because risetime is measured between 10 and 90% of the peak voltage amplitude, it is usually easier to photograph the oscillograph waveform than to attempt to read this figure directly. Most manufacturers of oscilloscopes furnish compatible cameras for this purpose.

8.3 Ignition Coil Energy Measurement (Zener Technique)

8.3.1 The measurement procedure measures the energy dissipated in a Zener string connected on the secondary side. The measured energy is an indication of:

a. Energy stored in the ignition coil at the time of interruption of the primary current and
b. The efficiency of the ignition coil in transferring that energy to the Zener string. The energy delivered to the spark plug gap in an engine will be different.

The Zener Technique is used to provide a more reproducible measurement, eliminating the variability and RF noise of the spark gap.

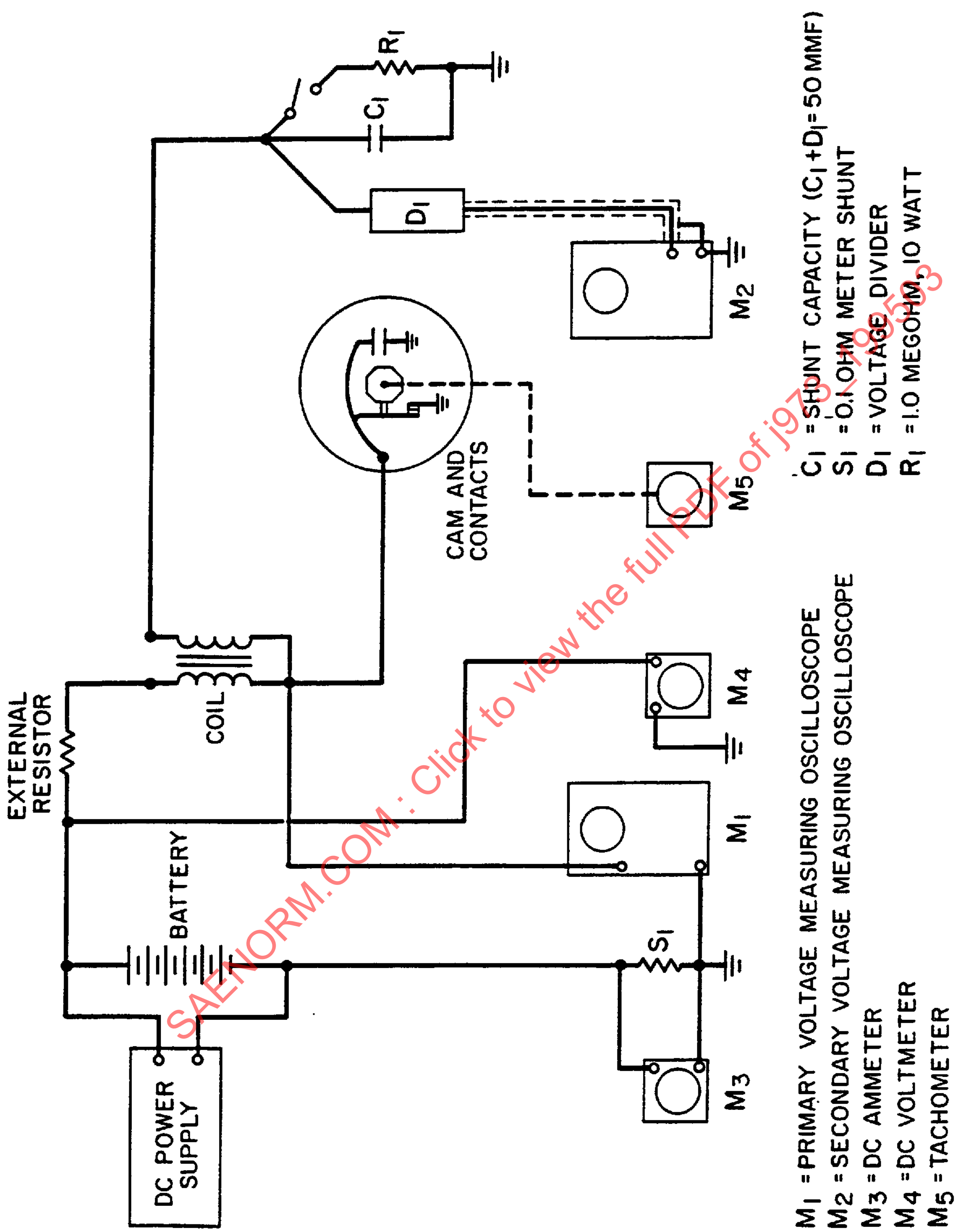
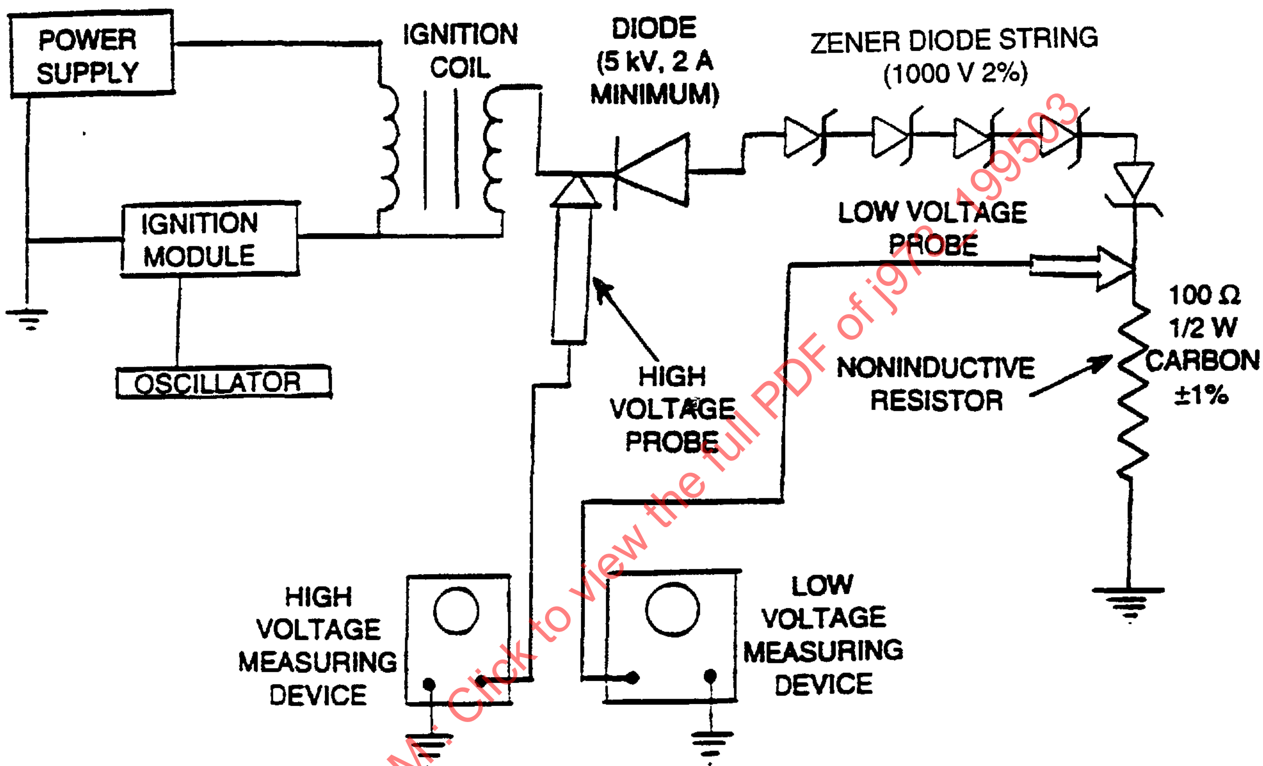


FIGURE 3—TEST CIRCUIT ARRANGEMENT FOR GROUP B TESTS

8.3.2 TEST PROCEDURE

8.3.2.1 Place the ignition coil to be tested in the circuit shown in Figure 4.

(R) NOTE—A Zener string value of 1000 V is recommended for this document; however, a different value may be more representative of certain ignition systems. When this occurs with agreement of the groups involved, the revised value should be noted in the data report.



(R) FIGURE 4—IGNITION COIL ENERGY MEASUREMENT (ZENER TECHNIQUE)

8.3.2.2 Stabilize the coil at 25 °C ± 5 °C or at another temperature consistent with usage or manufacturer's recommendations.

8.3.2.3 Adjust the input (power supply, ignition module, oscillator) so that the primary break current is at the manufacturer's recommended coil interruption current.

8.3.2.4 Energy delivered to the Zener string by the ignition coil can most accurately be obtained by using a sampling (or digital) oscilloscope and the following procedure:

a. Multiply Zener voltage and Zener current waveforms to get power waveform.
b. Energy is the area under the power waveform over the duration of energy delivery.

When a sampling scope is not available, the approximate formula is described in 8.3.2.5.