

IGNITION PEAK VOLTAGE MEASUREMENTS

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PURPOSE: The purpose of these specifications is to provide reference information for equipment and procedures to be used in the measurement of ignition voltages.

SCOPE: These specifications contain general information about the characteristics of ignition systems and measuring techniques; recommended types of voltage dividers and output indicators; calibration procedures.

1. GENERAL CONSIDERATIONS CONCERNING PEAK IGNITION VOLTAGE MEASUREMENTS

1.1 Ignition System Characteristics

Ignition systems are usually designed to produce sparking pulses of several thousand volts occurring at various repetition rates depending upon engine speed. The waveform and amplitude of these pulses vary widely with the design of the ignition system and with the characteristics of the spark plugs or other loading devices to which the ignition system is connected.

Measurements are usually made on ignition systems to determine:

- a. The maximum voltage which can be developed by the ignition system under controlled and specified conditions. (Ignition system test)
- b. The voltage required by the spark plug or other load under specified conditions of operation. (Load system test)

For the above two purposes the peak value of the ignition voltage is usually adequate information, however, in the study of the performance of ignition systems it may be desirable to analyze the waveform of the output pulse.

Accurate measurements can be made upon ignition systems only if careful attention is paid to both the conditions under which the test is conducted and the equipment used to make the measurement. The input variables to the ignition system must be carefully controlled in order that changes in the output voltage are not thought to be errors in the measuring equipment. In the case of magnetos the only input variable is the speed. Battery powered ignition systems have the additional input variable of input voltage. The power source for a battery ignition system must have good load regulation in order to assure that the input voltage which is effective at the time the ignition pulse is developed can be known and controlled accurately. Power supplies which contain appreciable ripple voltage or which exhibit poor transient regulation characteristics can cause a wide variation of ignition system output voltage.

The load conditions which are imposed upon the ignition system must also be accurately known. Since most ignition pulses contain a relatively fixed amount of energy, the voltage which is developed across the load will be largely a function of the load characteristics. Most ignition

systems are quite susceptible to the amount of capacity exhibited by the load. For this reason the total capacity of the load including any measuring equipment must be known and, where possible, adjusted to some desired reference value. Even small changes in the location of the wiring connected to the secondary of the ignition system can cause appreciable changes in the output voltage.

Resistance loading will also cause changes in the output voltage, however, this is usually maintained at a very high value. In most cases, if the total load resistance including the measuring equipment does not fall below 20 megohms, there will be little effect on the output of the ignition system. Errors are frequently caused by unexpected high voltage effects, such as corona and arcing. The normal procedures for eliminating these effects, such as adequate spacing, proper insulation, and the elimination of sharp points in the secondary wiring, are usually effective.

1.2 Ignition Voltage Characteristics

An analysis of secondary ignition voltage waveforms of aircraft and industrial magnetos, flywheel magnetos, and battery ignition systems has shown them to have the following characteristics during the initial voltage pulse:

Fundamental Frequency of Oscillation - 1.0 - 8.0 KC/Sec.

Typical Leading Edge Rise Time of Pulse - 15 to 100 uSec.

*Maximum Leading Edge Rise Time Converted to Band Width - 24.0 KC/Sec.

The above characteristics are based on waveforms obtained without a distributor in the ignition system. In systems which utilize a distributor, the voltage waveform is not a smooth continuous curve but may have steep rising portions or discontinuities due to the break-down of the jump gap distributor. In this case the required band width of the measuring instrumentation must be 50 KC or greater to respond to these faster rise times.

1.3 Instrumentation Considerations in Measuring Ignition Systems Voltage

It is recommended that the load imposed upon the ignition system by the measuring equipment be not less than 20 megohms resistance and not greater than 10 uuf capacity. The equipment should be high voltage stable, that is, capable of operating at 30,000 volts peak without corona or arc-over effects. In some specialized applications it may be necessary to design for higher voltages according to the expected output of the ignition system.

The accuracy of the measuring equipment should be within $\pm 5\%$. As explained in a later section on detail design of the equipment, the frequency response or band width of the measuring equipment will depend upon the type of measurement desired. Equipment which has

*Rise Time $TR = \frac{.36}{\text{freq. in MC}}$, "Graphical Aid for Amplifier Design",

R.E. Ricketts, ELECTRONIC DESIGN, July 1953.



a frequency response of 50 CPS to 50 KC will be satisfactory for measurements of peak voltages. If it is desired to make careful study of the waveform of the ignition pulses, it will be necessary to extend the frequency response either lower or higher or both according to the requirements of the measurements.

2. SPECIFIC INSTRUMENTATION REQUIREMENTS FOR ACCURATE PEAK VOLTAGE MEASUREMENTS

2.1 Indicating Device

An oscilloscope is recommended as an indicating device for ignition system measurement. The use of an oscilloscope permits observation of the waveform and may frequently show unexpected arc-over effects. In addition its output does not depend upon peak reading types of circuitry which might not respond to the true peak value under the various conditions of speed, duty cycle, humidity, atmospheric pressure, etc.

In the choice of an oscilloscope for ignition measurements, the following points should be given consideration:

- 2.1.1 Band Width - The vertical amplifier band width used for this field of ignition peak voltage measurements should have flat response to 50 KC or greater.
- 2.1.2 Power Supply - The oscilloscope must be of a design which will give a constant deflection sensitivity regardless of power line voltages and other environmental variations. If this is not inherent in the design of the oscilloscope, it will be necessary to provide external regulation or to make frequent calibration checks of the deflection sensitivity.
- 2.1.3 Input Attenuators - Precision input attenuators are desirable on an oscilloscope, however, the accuracy of these attenuators are within 3% and in some cases $\pm 5\%$. This is insufficient accuracy, therefore it is recommended that the oscilloscope attenuator setting, used for measurement and/or calibrating purposes, be accurately calibrated. A simple calibrator can be constructed using a DC battery and a potentiometer to produce a DC voltage divider. The output voltage used for calibrating can be monitored with a precision DC voltmeter ($1/4$ to $1/2$ of 1%). If the oscilloscope does not have DC response the calibrating voltage will have to be chopped.
- 2.1.4 Sensitivity - The oscilloscope should have sufficient sensitivity so the ignition peak voltage divided by the voltage divider ratio will produce sufficient deflection for accurate readings.
- 2.1.5 Focus and Intensity Controls - If these controls have an effect on deflection sensitivity, they should not be adjusted after calibration.

An analysis of the above factors indicates that practically all commercially available oscilloscopes will perform as satisfactory indicating instruments.

2.2 High Voltage Dividers

Two high voltage dividers which will accurately measure peak ignition voltages, as defined in this specification, are (a) the capacitance divider, (b) the resistance-capacitance compensated divider.

These dividers have different band width characteristics which are dependent on construction, divider constants and method of integration with the oscilloscope. In Figure I are general curves showing the response of these voltage dividers as a function of input voltage frequency.

Attenuation (or Divider) Ratio x 1000

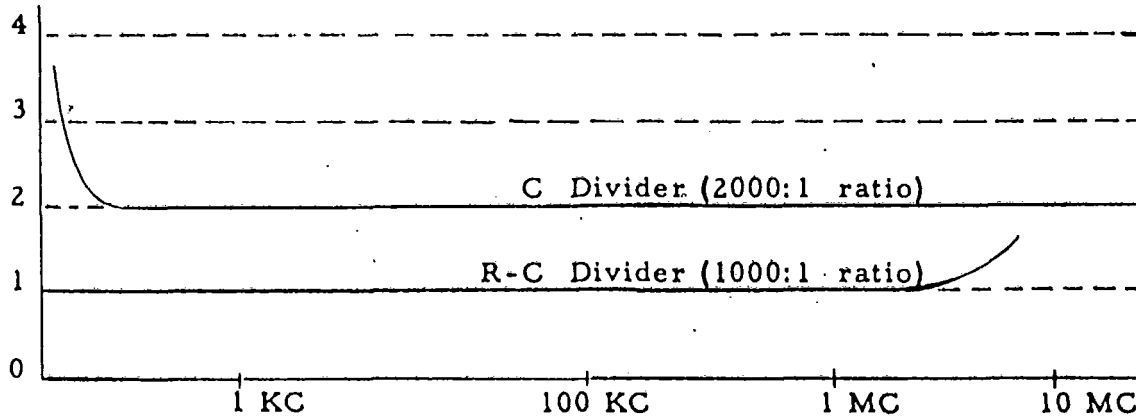


Figure I. Frequency Response Characteristics of Capacitance and Resistance-Capacitance Voltage Dividers

It is apparent from Figure I that both dividers can be constructed to have a constant attenuation ratio for the range of frequency components encountered in general ignition peak voltage measurements as defined.

The type of divider selected for these measurements will depend on available instrumentation, calibrating instrumentation, and the response characteristics of the divider desirable for other types of voltage measurements.

2.2.1 Capacitance Dividers

The design of a capacitance voltage divider is governed by the following equation:

$$\text{Attenuation Ratio}^* = \sqrt{\frac{1}{(\omega RC_1)^2} + \left(\frac{C_1 + C_2}{C_1}\right)^2} \quad (1)$$

$\omega = 2 \pi f$, $f = \text{Frequency of Applied Voltage}$

$R = \text{Shunt Resistance Across Low Voltage Capacitor}$

$C_1 = \text{High Voltage Capacitor Value}$

$C_2 = \text{Low Voltage Capacitor Value}$

An analysis of equation (1) shows that at a particular low frequency response the ratio of the divider begins to increase (see Figure I). The frequency at which this occurs will be governed by the capacitive constants of the divider and the value of shunt resistance across the low voltage capacitor section.

*See Appendix I