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IGNITION EXCITER OUTPUT VOLTAGE PULSE MEASUREMENT USING A PRESSURIZED BALL GAP

PURPOSE

The purpose of this report is to provide reference information for equipment and procedure to be used in measurement of high tension ignition exciter output voltage pulses using a pressurized ball gap.

SCOPE

This report includes a procedure for typical pulse voltage measurement using the pressurized ball gap, calibration procedure, and a description of the pressurized ball gap.

1. INTRODUCTION

- 1.1 The high tension capacitor discharge ignition system produces an initial ionizing voltage of a magnitude as large as necessary (within design limits) to ionize the gap of the high tension igniter. The rise time of the ionizing pulse (zero to peak voltage) approximates one microsecond in most high tension ignition systems. The magnitude of the ionizing pulse is determined by the high tension igniter demand under the conditions of pressure, temperature, and atmosphere within which it is required to ionize.
- 1.2 Determination of the output pulse magnitude is important since sufficient voltage must be supplied from the exciter to ionize the spark igniter. It also may be desirable to determine the maximum output voltage pulse magnitude so that leads and terminations are not damaged should the spark igniter be quenched.
- 1.3 These requirements to determine minimum and maximum output pulse voltage amplitude of high tension exciters require measurement equipment that is responsive to the output pulse rise time and magnitude and is reasonably repeatable.
- 1.4 Since inspection test criteria usually establish go-no go levels, the pressurized ball gap lends itself to this type of requirement. Specific determination of output voltage pulse magnitude may also be made.
- 1.5 The pressurized ball gap described herein is adequately sensitive, consistent and stable to produce the desired results. It minimizes the shortcomings which have existed in the past that affect accuracy and subsequent use such as:
 - a. Effects of barometric pressure and relative humidity
 - b. Stray capacity effects caused by nearby grounds
 - c. Oxidation of electrodes
 - d. Poor ionization characteristics
 - e. Poor resolution and readability
 - f. Method of calibration

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2. SPECIFICATIONS FOR PRESSURIZED BALL GAP

The general specifications for the pressurized ball gap described by this report are as follows:

<u>Range:</u>	5 to 30 KV Peak Voltage
<u>Risetime:</u>	Designed to measure pulses with zero to peak voltage rise times of 800 nanoseconds to 50 microseconds
<u>Accuracy:</u>	+ 1% of full scale from ref. std.
<u>Operating Pressure:</u>	800 torr (mm Hg)
<u>Pressurizing Gas:</u>	Dry Nitrogen
<u>Construction:</u>	Sealed system with controlled purge rate
<u>Weight:</u>	50 lb
<u>Internal Capacitance:</u>	25 pf

Fig. 1 shows the pressurized ball gap described.

3. PROCEDURE FOR TYPICAL PULSE VOLTAGE MEASUREMENT USING PRESSURIZED BALL GAP

3.1 Test Method Configuration

- a. Fig. 2 shows an exciter unit with associated ball gap used for pulse voltage measurement.
- b. Fig. 3 is a block diagram showing the equipment arrangement used in the measurement.

3.2 Detailed Procedure for Go-No Go Requirement

- a. Connect a dry nitrogen tank to ball gap and adjust pancake regulator at top of ball gap to produce 800 torr absolute pressure on indicator. A size 1A gas bottle is recommended and will furnish approximately 48 hr of gas supply.
- b. If ball gap has not been in continuous use, allow to purge one-half hour minimum to guarantee a homogeneous gas flow.
- c. Insure that proper capacitance loading applicable to test piece is applied across exciter output. The total load must include the internal capacitance of the ball gap.
- d. Connect exciter output to appropriate "HV" and "GND" terminals of the ball gap.
- e. Obtain desired specification lower voltage limit and convert to dial divisions on the ball gap turn counting dial through use of calibration curve of ball gap. See Fig. 4 for a typical curve.
- f. Energize unit. Ball gap should fire consistently for prescribed period of time dictated on specification for exciter unit.
- g. Obtain desired specification upper voltage limit and convert to dial divisions on the ball gap turn counting dial through use of the calibration curve.
- h. Energize unit. Ball gap should not fire for the prescribed period of time dictated on the specification for the exciter unit.

3.3 Specific Determination of Maximum Output Voltage Pulse

- a. To obtain a specific coming-in or firing point, proceed as above except initially adjust ball gap turn, counting dial to insure non-firing by adjustment to a voltage level much higher than expected.
- b. Energize unit and, if firing does not occur, decrease ball gap spacing at about five division increments until consistent firing occurs.
- c. Convert ball gap turn counting dial divisions to output KV via calibration curve of gap.

Initial gap setting must be to the non-firing side to eliminate the "drawing-out" effect when approaching from the opposite direction.

4. CALIBRATION OF THE PRESSURIZED BALL GAP

4.1 Calibration Method Configuration

Calibration of the subject ball gap can be done with a certified one-half percent of full scale electrostatic voltmeter in conjunction with a high voltage pulse calibrator (Ref. AIR 1091). Fig. 5 shows the associated equipment and connections required for calibration.

4.2 Detailed Calibration Procedure

- a. Connect a dry nitrogen tank to the ball gap and adjust the pancake regulator to indicate 800 torr absolute pressure on the gauge.
- b. Allow ball gap to purge a minimum of one-half hour to guarantee a homogeneous gas flow.
- c. Adjust turn counting dial at front of HV pulse calibrator at a point sufficient to guarantee non-firing of the internal switch.
- d. Using the "HV Coarse" and "HV Fine" control knobs on the front panel of the HV pulse calibrator, set desired test voltage on the electrostatic voltmeter.
- e. Set turn counting dial on ball gap to the non-firing side of the test point (usually test point plus 10 dial divisions). Refer to typical ball gap curve, Fig. 4.
- f. Decrease the internal switch spacing in the HV pulse calibrator with turn counting dial on front panel to initiate ball gap firing.
- g. If ball gap does not fire, repeat steps c and d with test ball gap vernier set one division lower each time until firing occurs. Repeat procedure at this setting as often as is felt necessary to guarantee that a consistent firing point has been established. Record this dial setting.
- h. Proceed to check ball gap over the range of 5 to 30 KV at one KV increments.
- i. Following initial calibration or after any remedial action has been taken, a curve of dial divisions vs kilovolts should be plotted and attached to ball gap.
- j. Subsequent calibrations of the ball gap must maintain ± 9 dial divisions of the attached curve to be a valid calibration.

5. DESCRIPTION OF THE PRESSURIZED BALL GAP

- 5.1 The ball gap assembly is essentially a sealed system employing a controlled purge rate of dry nitrogen gas. Purging is performed to eliminate oxide formation on the interior of the gap and is accomplished with a pipe plug exhaust vent placed in the side of the exterior Boltaron case. Lost gas is replaced utilizing a pancake regulator so that internal gas pressure remains at 800 torr. Internal pressure is monitored with an absolute pressure indicator spanning 400 to 800 torr.

- 5.2 An absolute pressure of 800 torr was selected because it is higher than ambient environmental pressure in areas where the gap is to be used. It is imperative that the working pressure be higher than ambient, since breathing will result if opposite is true and this would result in oxygen, water vapor, and other contaminants being forced into the gap. This pressure also affords easy control, measurement, and envelope fabrication.
- 5.3 Dry nitrogen gas was selected as a pressurizing medium because it is non-oxidizing under the conditions of use, it ionizes easily, is relatively inexpensive, and is available in pure form with controlled moisture content. Most important, however, is that it yields full travel of the balls over the desired voltage range with good resolution.
- 5.4 Nitrogen entering the ball gap cavity is directed by means of a nylon tube under the teaser. This reduces inconsistencies due to varying gas conditions in the area of the ionization teaser after firing.
- 5.5 Resolution and readability of the instrument is accomplished with a gear mechanism driven by a turn counting dial. (Ref. Fig. 6 and 7.)
- 5.6 The dial covers 10 turns with calibration allowing readings to the nearest 0.01 turn. The complete range of the turn counting dial, with gearing used, covers approximately 0.4 in. of ball separation or 400 micro-inches per dial division (about 30 volts).
- 5.7 The actual gap employs chrome steel balls 1.5 in. in diameter with tungsten inserts at all points where wear from sparking is likely to occur. This includes the main spark discharge area and the section of the ball which is directly under the ionization teaser. These inserts are silver brazed into the ball and then the ball is reground to its original spherical shape before installation in the gap mechanism.
- 5.8 Ionization of the ball gap is accomplished with a tungsten teaser. Also, attached to the teaser is a brass disc which produces better capacitance coupling between the teaser and the high voltage ball (see Fig. 6). The tangential spacing between the teaser tip and high voltage ball is fixed at 0.002 in. The vertical distance between the top of the ball and teaser tip is controlled to $0.05D$ where D is the ball diameter (see Fig. 8).
- 5.9 The external Boltaron housing is lined in the gap compartment with a thin brass sheet to fix a ground plane reference for the purpose of defining stray capacitance effects.

6. REFERENCES

"Development of a Device for Measuring Pulse Voltages" by D. Michel, Electrical Components Division, The Bendix Corporation.

AIR 1091, "High Voltage Pulse Generator"

AIR 1092, "High Tension Exciter Output Voltage Measurement Using The Cathode-Ray Oscilloscope" (Alternate Measurement Method)

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