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# STANDARD TEST PROCEDURE FOR GENERAL PURPOSE SPARK ARRESTERS



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|   |   |
|---|---|
| I. Scope .....  | 1 |
| II. Overview .....  | 1 |
| III. Hardware Setup                                       |   |
| A. Stack Selection and Installation .....                 | 2 |
| B. Initial Orifice Plate Selection and Installation ..... | 3 |
| C. Valve Control .....                                    | 3 |
| D. Blower Motor Start-Up .....                            | 3 |
| E. Signal Conditioning Panel Calibration .....            | 4 |
| F. Initial Back Pressure Adjustment .....                 | 4 |
| G. Mounting the Test Spark Arrester .....                 | 4 |
| H. Pretest System Adjustment .....                        | 4 |
| IV. Preliminary Test Run .....                            | 5 |
| V. Test Run .....   | 5 |
| VI. Cleanout Run .....                                    | 6 |
| VII. Subsequent Runs .....                                | 6 |
| VIII. Low Spark Arrester Efficiencies .....               | 6 |
| IX. Screen Type Spark Arrester Test Procedure             |   |
| A. Scope .....  | 7 |
| B. Screen and Periphery Probe .....                       | 7 |
| C. Effective Screen Open Area Calculations .....          | 7 |

Appendixes

|   |    |
|---|----|
| A. Abbreviated Test Procedure .....                       | 11 |
| B. System Symbols and Maximum (Do Not Exceed) Values .... | 13 |
| C. Diagrams and Parts List .....                          | 15 |
| D. Preparing Test Carbon .....                            | 21 |
| E. Orifice Factors .....                                  | 23 |
| F. Facility Certification .....                           | 25 |
| G. Console Calibration Check .....                        | 31 |

**TABLE  
OF  
CONTENTS**

# STANDARD TEST PROCEDURE FOR GENERAL PURPOSE SPARK ARRESTERS

## I. SCOPE

This test procedure establishes equipment and procedures for testing spark arresters used on medium size, single-position internal combustion engines used in proximity to grass, brush, timber and similar cellulose material in accordance with Forest Service Standard 5100-1c, Spark Arresters for Internal Combustion Engines. The document also includes special requirements for screen type devices. The procedure outlined in the text is based on equipment used in the spark arrester laboratory maintained by the USDA Forest Service, San Dimas Technology and Development Center.

Spark arresters qualified to the Forest Service standard are listed in the Spark Arrester Guide Volume 1, General Purpose and Locomotive. This guide is to be used by field personnel to inspect internal combustion engine exhaust systems in the field.

## II. OVERVIEW

Internal combustion engines typically build up deposits of solid materials (mostly carbon) on the surfaces inside the combustion chamber and exhaust system. These deposits can break away and be expelled at high temperatures along with the exhaust gasses, in the form of “sparks”. If the sparks are large enough, they can hold enough heat to ignite flammable materials and start a wildfire. Research has shown that particles larger than 0.023 inches (0.584 mm) have enough energy to start wildfires. A spark arrester is a device used to separate solid particles from the exhaust gasses of an internal combustion engine. Alternatively, the spark arrester

may break apart the particles to a size small enough to eliminate fire ignition potential. A spark arrester can either be an add-on device, or an integral part of the exhaust system. The challenge for the spark arrester manufacturer is to design an arrester that effectively traps or pulverizes the solid particles without restricting the flow of exhaust gasses such that the engine performance is adversely affected.

Spark arresters are tested for their effectiveness by introducing special carbon particles (simulated sparks) while air (simulated exhaust gas) is flowing through the device. The effectiveness is quantified simply by the ratio of particles trapped or pulverized by the arrester to those introduced during the test. This test is performed at several flow rates to simulate a normal range of engine speeds. To accomplish this, the test apparatus basically consists of a blower to supply the air flow, valves and instruments to control and measure the flow of air, a particle injection system, and a means to collect, separate, and weigh the particles that pass through the spark arrester.

The test chamber is primarily the joining of two 42-inch (1.07 m) diameter cylinders. The vertical cylinder is used for structural support and to house an inlet air plenum. The vertical cylinder also serves as one of two outlet air ducts. The horizontal cylinder is approximately 13 feet (4 m) long and has access doors on both ends. The horizontal cylinder serves as the main test chamber. The spark arrester is mounted in the test chamber in a position specified by the manufacturer. Stacks and adapters are used to insure proper mounting.



Figure 1—Spark Arrester chamber.

Air flow is provided to the test chamber via a positive displacement Roots blower commonly used for the aspiration of large diesel engines. Power to the blower is provided by a 3-speed, 150 horsepower (112 kW) electric motor. Air flow is regulated by four linear actuated, gate type, throttling valves (bypass valves). Two of these valves are

## STANDARD TEST PROCEDURE FOR GENERAL PURPOSE SPARK ARRESTERS

used to bypass excess air from the blower to the roof stacks where it is discharged to the outside atmosphere. The third valve dumps excess blower air via a closed coupled blower vent line located under the test chamber where it is discharged into the test chamber room. The fourth valve restricts air flow to the test spark arrester and is located immediately upstream of the test fixture inside the supply air plenum. By manipulating the air flow, pressure across the spark arrester and in the chamber could be varied. Pressure is measure by pressure transducers and readings are read in the control room. Test flow rates are determined by measuring the pressure drop across a calibrated orifice plate located on the roof. The proper orifice plate must be selected to prevent over pressuring the transducers and to maintain accuracy of the flow measurement.



*Figure 2—Orifice Plates.*

Test carbon to simulate engine exhaust particles are fed into the test spark arrester. The injection mechanism is made up of a canister to hold the carbon and a cylinder to feed the carbon. The carbon in the carbon injector canister is fluidized by air to ensure a constant feed rate. Fluidized carbon is injected into the inlet of the spark arrester as the cylinder in the carbon canister rises. The carbon passes through the arrester and carbon particles expelled from the arrester are gathered in the trap.

The instrumentation in the control room and the transducers in the test chamber room are delicate equipment. This equipment must be calibrated periodically. Current calibration certifications and associated certificates are maintained by SDTDC.

Data collection is performed using a computer spreadsheet. Data is manually entered into the spreadsheet. Calculations are automatically done once all data fields are complete. The data file is saved under a common directory.

**Appendix A** is an abbreviated test procedure for general purpose spark arresters. This procedure should only be used by technicians thoroughly familiar with the general procedure.

**Appendix B** provides a listing of system symbols used in the test procedure and maximum values.

**Appendix C** contains photographs, illustrations and a listing of parts to assist in identifying laboratory components.

**Appendix D** describes the method used to prepare the test carbon.

**Appendix E** is a table of orifice factors.

**Appendix F** is the test procedure for certifying a test facility.

**Appendix G** is the Calibration Data Sheet for the signal conditioning panel.

### **III. HARDWARE SETUP**

#### **A. Stack Selection and Installation**

A series of stacks with different diameters to match arrester inlets are available. Each is equipped with a back pressure connection fixture and a test carbon feed inlet. A stack should have an inside diameter equal to or larger than that of the spark arrester to insure proper gas flow. Adapters must be used when a properly sized stack is not available. Adapters shall be provided by the manufacturer. Figure 3 illustrates the proper stack selection and spark arrester installation.

1. Select a stack with the inside diameter equal to or larger

than the inside diameter of the spark arrester inlet pipe.

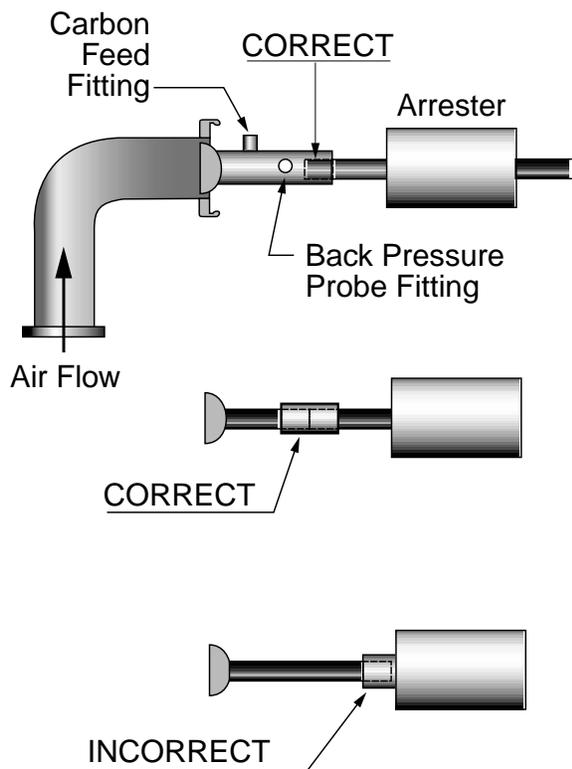


Figure 3—A series of stacks.

2. Determine the position of application of the spark arrester. The collection agreement should have this information. Any questions concerning the mounting position must be resolved prior to testing.

3. Select an inlet mounting tube and install in the proper inlet. There are two inlet mounting tubes available. In general, the first inlet is used with the horizontal inlet mounting tube (it has a 90 degree bend) for horizontal applications and the second inlet with the vertical inlet mounting tube for vertical applications. Refer to appendix C for proper identification. It is important to use only one inlet at a time. The other inlet must be sealed.

4. Attach stack to the mounting tubes using the toggle clamps. Verify that the carbon tube will align with the stack carbon tube. Improper alignment implies that the wrong inlet was used with the inlet mounting tube.

5. Attach any adapters.

6. Connect the carbon feed tube to the stack's carbon tube.

7. Attach back pressure probe to the stack.

8. Attach portable manometer to the back pressure probe.

## B. Initial Orifice Plate Selection and Installation

1. Select the orifice plate with a slightly larger opening than the inlet pipe of the arrester. For example, for an arrester inlet pipe size of 1.25 inches (31.75 mm), the 1.375-inch (34.93 mm) orifice plate should be used.

2. Install orifice plate in the tube by removing fasteners and tightening the spreader bolt. Remove existing orifice plate and insert the appropriate size. Loosen spreader bolt and tighten fasteners.

## C. Valve Control

The readout on the console displays percent open. Always start with controls toggled to “slow” when manipulating valves. The switch could be toggled over to “fast” when large valve movements are required. When manipulating valves first open the arrester inlet valve to achieve more flow. Slowly close the bypass valves when higher flows are required.

The defeat limit (DEF Limit) switch must be depressed when moving from the limits of the bypass and arrester inlet valves. For example, when all the bypass valves are open and the arrester inlet valve is open. The DEF Limit switch must be depressed to close the valves.

**CAUTION: Never close the side bypass valves and the valve to the arrester at the same time. The air has nowhere to exhaust and will blow the safety diaphragm.**

## D. Blower Motor Start-up

1. Set all by-pass valves ( $V_1$ ,  $V_3$ , and  $V_4$ ) to 100 percent **open** and the spark arrester inlet valve ( $V_2$ ) to 100 percent **closed**. This prevents over pressuring the chamber. The readout on the console displays percent open when manipulating valves.

2. Start oil pump.
3. Start blower motor at desired speed. The higher the speed setting indicates a higher the flow rate. The blower motor can not be started until the blower is properly lubricated. Proper blower lubrication will be indicated by a green light labeled oil pump.

## **E. Signal Conditioning Panel**

### **Calibration.**

1. Verify that the doors are closed and sealed, the carbon feed and fluidization valves are closed.
2. Locate the calibration data sheet, Appendix G, and check each transducer for the prescribed readings.
3. Adjust transducers using a small screwdriver to turn the adjustment screw.
4. Record readings on the data sheet.

## **F. Initial Back Pressure Adjustment**

The back pressure probe must be adjusted to obtain a minimum pressure reading. The back pressure fitting, which has one venturi hole and three stagnation holes, should be adjusted for minimum positive correction values by rotating the probe stagnation holes into the airstream so that stagnation pressure just offsets venturi effects over the anticipated flow range of the arrester to be tested. All adapters must be mounted during this initial setup procedure. To adjust the back pressure probe, perform the following:

1. Attach the portable digital manometer to the pressure probe.
2. Turn blower motor on, following the procedure prescribed in Section III D.
3. With the blower running, rotate the back pressure probe until a minimum reading is achieved.
4. Disconnect the portable manometer from the back pressure probe.

## **G. Mounting the Test Spark Arrester**

1. Weigh the spark arrester and record reading.
2. Some spark arresters are equipped with aspiration tubes. These tubes must be blocked before the test.
3. Attach the spark arrester to the stack assembly. The center rail on top of the horizontal chamber can be used to secure the arrester. Use string to secure one end of the arrester to the rail. Pay close attention to the distance between the arrester outlet and the wall of the chamber. Positioning the arrester outlet close to a wall could result in pulverization of the carbon as it hits the wall. This would influence the accuracy of the test. A minimum of 5 inches (127 mm) is desired. The inlet may be shortened to mount the arrester. Consult the manufacturer before making any modifications to the arrester.
4. As a general rule, the clean out plug is at the bottom of the arrester. Consult data package for proper mounting position and location of the clean out plug in relation to the arrester body.
5. Connect the back pressure probe to the system.
6. Close chamber doors.

## **H. Pretest System Adjustment.**

1. Open all bypass valves ( $V_1$ ,  $V_3$ , and  $V_4$ ) and close the arrester inlet valve ( $V_2$ ). The chamber doors must be closed.
2. Turn blower on. Allow the system to achieve steady state, wait five minutes before making adjustments.
3. Slowly open the arrester inlet valve ( $V_2$ ) to start introducing air to the system. Open the valve until the spark arrester back pressure ( $DP_1$ ) indicates 1 psi (6.9 kPa) or the pressure differential across the orifice plate ( $DP_2$ ) indicates 4 inches of water (996 Pa).
4. The orifice plate must be changed to the next largest plate when  $DP_2$  indicates 4 inches of water (996 Pa) and  $DP_1$  is below 1 psi (6.9 kPa).

**Caution: Do not exceed 5 inches of water (1.2 kPa).**

## STANDARD TEST PROCEDURE FOR GENERAL PURPOSE SPARK ARRESTERS

5. The next smaller orifice plate must be used when  $DP_1$  reads 1 psi (6.9 kPa) and  $DP_2$  is less than 2 inches of water (498 Pa).
6. Record  $DP_2$  value.
7. Shutdown the blower and then lubrication pump.
8. Open all bypass valves and close arrester inlet valves.
9. Remove spark arrester.
10. Turn lubricating pump on and then blower motor.
11. Slowly adjust valves so that  $DP_2$  value reads the same as the earlier recorded value.
12.  $DP_1$  should indicate a “zero”. Follow Section III F to readjust the back pressure probe. Record the  $DP_1$  reading if a “zero” reading can not be achieved.
13. Remount the test spark arrester.

### IV. PRELIMINARY TEST RUN

The preliminary test run is performed to establish the test flow points and also the amount of carbon to use for each test run. In accordance with the standard, the arrester must be tested at five qualification points and one flow point at 2 psi (13.8 kPa) back pressure. The 2 psi (13.8 kPa) test run provides data to determine if an arrester may be used above its 1 psi (6.9 kPa) flow rate. Many two-stroke engine applications are designed to operate at greater than 1 psi (6.9 kPa) back pressure. For each test point, two runs must be performed. One run using large carbon and the other using small carbon. The test points are as follows: one flow test point at a flow rate at  $DP_1$  psi (6.9 kPa) and three points equally spaced between the two endpoints. Since the instrumentation reads directly in flow rates, the initial value of  $DP_2$  is used. When using the computer spreadsheet to collect and record data, the test points are calculated out.

1. Open all bypass valves and close the spark arrester inlet valve.
2. Verify that the spark arrester is properly

installed and test chamber doors are closed and sealed.

3. Follow blower motor start up procedures in Section III D.

4. Slowly adjust the valves until sufficient flow is directed through the arrester to register a 1 psi (6.9 kPa)  $DP_1$ . First adjust the spark arrester inlet valve before closing the bypass valves. At  $DP_1$  equals 1 psi (6.9 kPa), record all values in the boxes on the spark arrester preliminary run data sheet. This is not a carbon run. Record orifice plate diameter and stack size. Calculate flow at  $DP_1$  equals 1 psi (6.9 kPa).

5. Record orifice differential pressure ( $DP_2$ ) at the 1 psi (6.9 kPa) back pressure.  $DP_2$  must be greater than 1 inch of water (249 Pa). A smaller orifice plate must be used if the reading is below 1 inch of water (249 Pa).

6. Verify that a flow rate has been calculated. If not, verify that all preliminary fields have been entered.

### V. TEST RUN

1. Prepare carbon sample and load into carbon feed cylinder. The test carbon for each test run is to be 0.2 grams (3.1 gr) of carbon for each cubic foot of air flow per minute with a minimum of 25 grams (0.88 oz) and a maximum of 200 grams (7 oz). The flow rate is established during the preliminary run. There should be sufficient carbon in the drying oven for the test. The standard requires that the carbon samples be dried for 6 hours. Check that ample supply of carbon is available after performing a qualification test. Carbon samples for the next qualification test may be prepared by following the procedure in appendix D.

2. Open all bypass valves and close the spark arrester inlet valve.

3. Verify that the spark arrester is properly installed and test chamber doors are closed and sealed.

4. Follow blower motor start up procedures in Section III D.

## STANDARD TEST PROCEDURE FOR GENERAL PURPOSE SPARK ARRESTERS

5. Start carbon feed motor and timer 1.
6. Slowly adjust the valves until sufficient flow is directed through the arrester and desired DP<sub>2</sub> setting is established. The DP<sub>2</sub> settings are calculated by the preliminary test data spreadsheet.
7. Set carbon feed and fluid air pressure, DP<sub>3</sub> and DP<sub>4</sub> respectively. Always set the DP<sub>4</sub> fluid setting first. For large carbon: DP<sub>4</sub> equals 0.5 psi (3.45 kPa) and DP<sub>3</sub> equals 0.2 psi (1.38 kPa). For small carbon: DP<sub>4</sub> equals 0.35 psi (2.41 kPa) and DP<sub>3</sub> equals 0.15 psi (1.03 kPa). During the first run, examine the fluidization and the feed rate of carbon through the glass feed viewer. Verify that the carbon is fluidized.
8. Check DP<sub>2</sub> value and adjust if necessary. Verify that the chamber pressure does not exceed 7 psi (48.26 kPa). The safety diaphragm will rupture when the chamber pressure exceeds 7 psi (48.26 kPa).
9. Check carbon feed cylinder after 5 and 10 minutes. Adjust if necessary.
10. Record the following data after 12 minutes: down stream pressure (GP<sub>3</sub>); DP<sub>1</sub>; DP<sub>2</sub>; barometric pressure (AP<sub>1</sub>); and trap pressure (GP<sub>2</sub>).
11. Verify that the carbon feed cylinder is empty after 15 minutes.
12. Stop carbon feed/fluid air, blower motor, and lubricating pump.
13. Run the blow-down fan for 30 seconds in each direction.
14. Open the chamber door slowly. A pan may be used to catch carbon particles resting up against the door. Collect and weigh the carbon from the trap. A brush and compressed air may be used to gather the particles. The carbon collected is designated as "T".
15. Place the collected carbon on the sieve. Weigh and record measurement of the carbon retained in the sieve. This weight is designated as "F".
16. Move the piston on the carbon feed cylinder down to the start position.

### VI. CLEANOUT RUN

1. Refer to manufacturers cleanout instructions. Follow specific instructions given by the manufacturer. Most spark arresters are equipped with cleanout plugs. The procedure following will address this situation.
2. Remove the cleanout plug(s) and tap arrester with a small rawhide mallet. Block the arrester outlet if necessary.
3. Close manual valve.
4. Run the blower at 50 percent of the flow achieved during the preliminary test run. This is approximately 25 percent of the DP<sub>2</sub> value. Stop after 2 minutes and then run the blow-down fan in each direction.
5. Collect the carbon from the trap and record its weight. Designate measurement as "Cr".
6. Replace cleanout plugs.
7. Weigh the carbon after the 12th run.

### VII. SUBSEQUENT RUNS

1. Repeat steps outlined in Section V and Section VI for each flow point. A total of 12 runs must be conducted.
2. Weigh the arrester after the 12th run.

### VIII. LOW SPARK ARRESTER EFFICIENCIES

1. Test runs indicating efficiencies below 80 percent must be repeated.
2. Three consecutive runs below 80 percent constitute a failure. Terminate testing.

### IX. SCREEN TYPE SPARK ARRESTER TEST PROCEDURE

#### **A. Scope.**

This section covers the test procedure for screen type spark arresters. A screen type spark arrester uses a screen to trap large particles while still

## STANDARD TEST PROCEDURE FOR GENERAL PURPOSE SPARK ARRESTERS

allowing other gases and smaller particles to flow through. In order for a screen type spark arrester to be effective, the following design parameters must be met:

1. 100 percent of exhaust gases must pass through the screen.
2. Screen and housing openings must not exceed 0.023 inches (0.584 mm) in diameter.
3. Effective open area must be 200 percent greater than the smallest restriction on the exhaust port.
4. Screen material must be heat and corrosion resistant.

### **B. Screen and Periphery Probe.**

1. Remove the screen type spark arrester from the exhaust system.
2. Inspect the screen and the housing for large openings. Pay special attention to areas where the screen is welded on to the housing.
3. Take a 0.023 inch/0.024 inch (0.584 mm/0.610 mm) GO/NO GO gauge and probe the screen. Start with the "NO GO" end (red handle). Check the periphery. Check a minimum of twenty areas.

**Caution: DO NOT use excessive force. Rotate probe while applying a gentle force. Do not allow the probe to expand the opening.**

4. The "NO GO" side must not pass through the screen. The spark arrester is not qualified if the "NO GO" plug gauge passes through the screen.

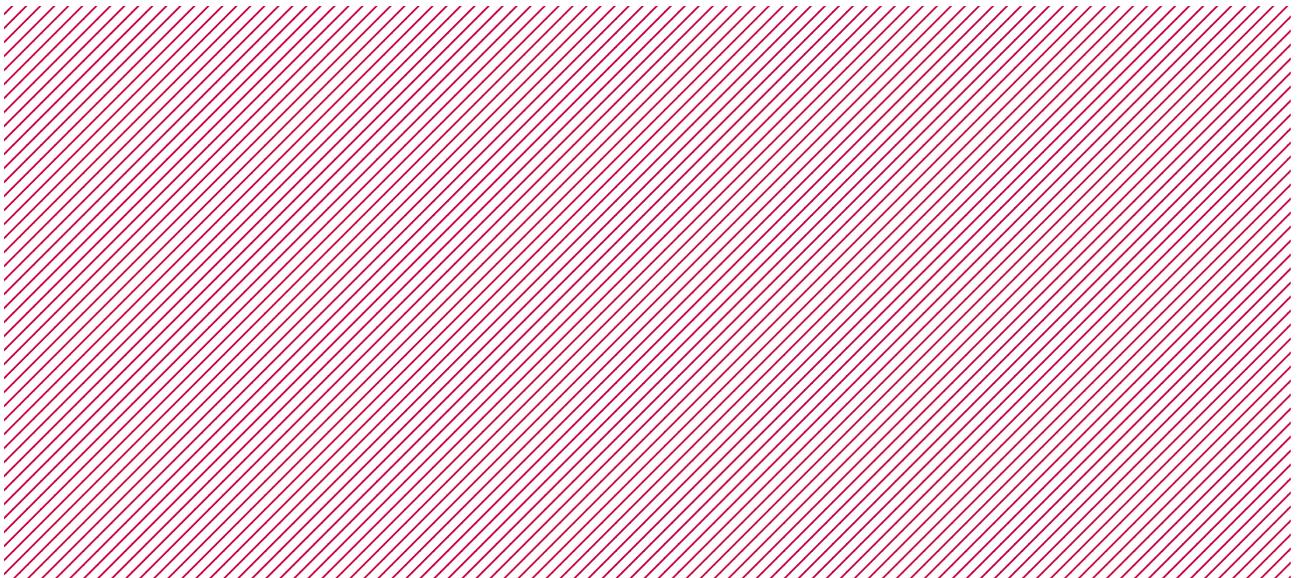
5. Repeat step B3 with the "GO" end (green handle).

6. The "GO" end may or may not pass through.

7. If the "GO" end does not pass through replace the plug gauge with the next smaller plug and repeat step B3 until five passes are achieved.

### **C. Effective Screen Open Area Calculations**

1. Measure the total surface area of the screen.
2. Measure the surface area of any screen overlaps or obstructions on the screen. An obstruction is any feature that blocks the passage of exhaust gasses through the screen.
3. Subtract the surface area of the overlaps and obstructions from the total area of the screen.
4. Using Table 1, locate the percentage open area by first matching the wire diameter size.
5. Multiply the effective surface area by the number obtained from the table. This is the effective open area.



STANDARD TEST PROCEDURE FOR GENERAL PURPOSE SPARK ARRESTERS

| MESH      | WIRE SIZE        |                 | OPENING     |                 |             | APPROXIMATE WEIGHTS<br>Per 100 Sq. Ft. |             |                         |             |             |       |
|-----------|------------------|-----------------|-------------|-----------------|-------------|--|-------------|-------------------------|-------------|-------------|-------|
|           | Center to Center | Diam. in Inches | Diam. in mm | Width in Inches | Width in mm | % Open Area                            | Plain Steel | 302-304 Stainless Steel | Pure Copper | 80/20 Brass | Monel |
| <b>30</b> | .015             | .381            | .018        | .46             | 30.1        | 47.4                                   | 47.9        | 53.7                    | 52.4        | 53.2        |       |
|           | .014             | .356            | .019        | .49             | 33.5        | 40.8                                   | 41.2        | 46.2                    | 45.1        | 45.8        |       |
|           | .013             | .330            | .020        | .52             | 37.1        | 34.8                                   | 35.1        | 39.0                    | 38.5        | 39.0        |       |
|           | .012             | .305            | .021        | .54             | 40.8        | 29.4                                   | 29.7        | 33.3                    | 32.5        | 33.0        |       |
|           | .011             | .279            | .022        | .57             | 44.8        | 24.5                                   | 24.7        | 27.8                    | 27.1        | 27.5        |       |
|           | .010             | .254            | .023        | .59             | 48.9        | 20.0                                   | 20.2        | 22.7                    | 22.1        | 22.4        |       |
|           | .0095            | .241            | .024        | .61             | 51.0        | 18.0                                   | 18.2        | 20.4                    | 19.9        | 20.2        |       |
|           | .009             | .229            | .024        | .62             | 53.1        | 16.1                                   | 16.3        | 18.3                    | 17.8        | 18.1        |       |
|           | .0085            | .216            | .025        | .63             | 55.4        | 14.3                                   | 14.4        | 16.2                    | 15.8        | 16.0        |       |
|           | .008             | .203            | .025        | .64             | 57.6        | 12.6                                   | 12.7        | 14.3                    | 13.9        | 14.1        |       |
|           | .0075            | .191            | .026        | .66             | 59.9        | 11.1                                   | 11.2        | 12.6                    | 12.3        | 12.5        |       |
|           | <b>32</b>        | .014            | .356        | .017            | .44         | 30.6                                   | 44.0        | 44.4                    | 49.9        | 48.6        | 49.4  |
|           |                  | .013            | .330        | .018            | .46         | 34.3                                   | 37.5        | 37.9                    | 42.5        | 41.4        | 42.1  |
|           |                  | .012            | .305        | .019            | .49         | 31.0                                   | 31.6        | 31.9                    | 35.8        | 34.9        | 35.5  |
| .011      |                  | .279            | .020        | .52             | 42.2        | 26.3                                   | 26.6        | 29.8                    | 29.1        | 29.5        |       |
| .010      |                  | .245            | .021        | .54             | 46.5        | 21.5                                   | 21.7        | 24.4                    | 23.8        | 24.1        |       |
| .0095     |                  | .241            | .022        | .55             | 48.7        | 19.3                                   | 19.5        | 21.9                    | 21.3        | 21.7        |       |
| .009      |                  | .229            | .022        | .57             | 50.9        | 17.3                                   | 17.5        | 19.6                    | 19.1        | 19.4        |       |
| .0085     |                  | .216            | .023        | .58             | 53.2        | 15.3                                   | 15.4        | 17.3                    | 16.9        | 17.2        |       |
| .008      |                  | .203            | .023        | .59             | 55.6        | 13.5                                   | 13.6        | 15.3                    | 14.9        | 15.1        |       |
| .0075     |                  | .191            | .024        | .61             | 58.0        | 11.8                                   | 11.9        | 13.4                    | 13.0        | 13.2        |       |
| .007      |                  | .178            | .024        | .62             | 60.5        | 10.3                                   | 10.4        | 11.7                    | 11.4        | 11.6        |       |
| <b>35</b> |                  | .012            | .305        | .017            | .42         | 33.8                                   | 35.0        | 35.4                    | 39.7        | 38.7        | 39.3  |
|           |                  | .011            | .279        | .018            | .45         | 37.9                                   | 29.0        | 29.3                    | 32.9        | 32.0        | 32.5  |
|           |                  | .010            | .254        | .019            | .47         | 42.4                                   | 23.7        | 23.9                    | 26.9        | 26.2        | 26.6  |
|           | .0095            | .241            | .019        | .49             | 44.7        | 21.3                                   | 21.5        | 24.1                    | 23.5        | 23.9        |       |
|           | .009             | .229            | .020        | .50             | 47.1        | 19.0                                   | 19.2        | 21.5                    | 21.0        | 21.3        |       |
|           | .0085            | .216            | .020        | .51             | 49.5        | 16.9                                   | 17.1        | 19.2                    | 18.7        | 19.0        |       |
|           | .008             | .203            | .021        | .52             | 52.0        | 14.9                                   | 15.0        | 16.9                    | 16.5        | 16.7        |       |
|           | .0075            | .191            | .021        | .54             | 54.5        | 13.0                                   | 13.1        | 14.7                    | 14.4        | 14.6        |       |
|           | .007             | .178            | .022        | .55             | 57.2        | 11.3                                   | 11.4        | 12.8                    | 12.5        | 12.7        |       |
|           | <b>38</b>        | .011            | .279        | .015            | .39         | 33.8                                   | 31.9        | 32.2                    | 36.2        | 35.3        | 35.8  |
|           |                  | .010            | .254        | .016            | .41         | 38.4                                   | 26.0        | 26.3                    | 29.5        | 28.7        | 29.2  |
|           |                  | .0095           | .241        | .017            | .43         | 40.8                                   | 23.3        | 23.5                    | 26.4        | 25.7        | 26.1  |
|           |                  | .009            | .229        | .017            | .44         | 43.2                                   | 20.8        | 21.0                    | 23.6        | 23.0        | 23.3  |
|           |                  | .0085           | .216        | .018            | .45         | 45.8                                   | 18.5        | 18.7                    | 21.0        | 20.4        | 20.8  |
| .008      |                  | .203            | .018        | .47             | 48.4        | 16.3                                   | 16.5        | 18.5                    | 18.0        | 18.3        |       |
| .0075     |                  | .191            | .019        | .48             | 51.0        | 14.2                                   | 14.3        | 16.1                    | 15.7        | 15.9        |       |
| .007      |                  | .178            | .019        | .49             | 53.8        | 12.3                                   | 12.4        | 13.9                    | 13.6        | 13.8        |       |
| <b>40</b> |                  | .011            | .279        | .014            | .36         | 31.4                                   | 33.8        | 34.1                    | 38.3        | 37.4        | 37.9  |
|           |                  | .010            | .254        | .015            | .38         | 36.0                                   | 27.6        | 27.9                    | 31.3        | 30.5        | 31.0  |

Table 1—Screen Open Area.

**STANDARD TEST PROCEDURE FOR GENERAL PURPOSE SPARK ARRESTERS**

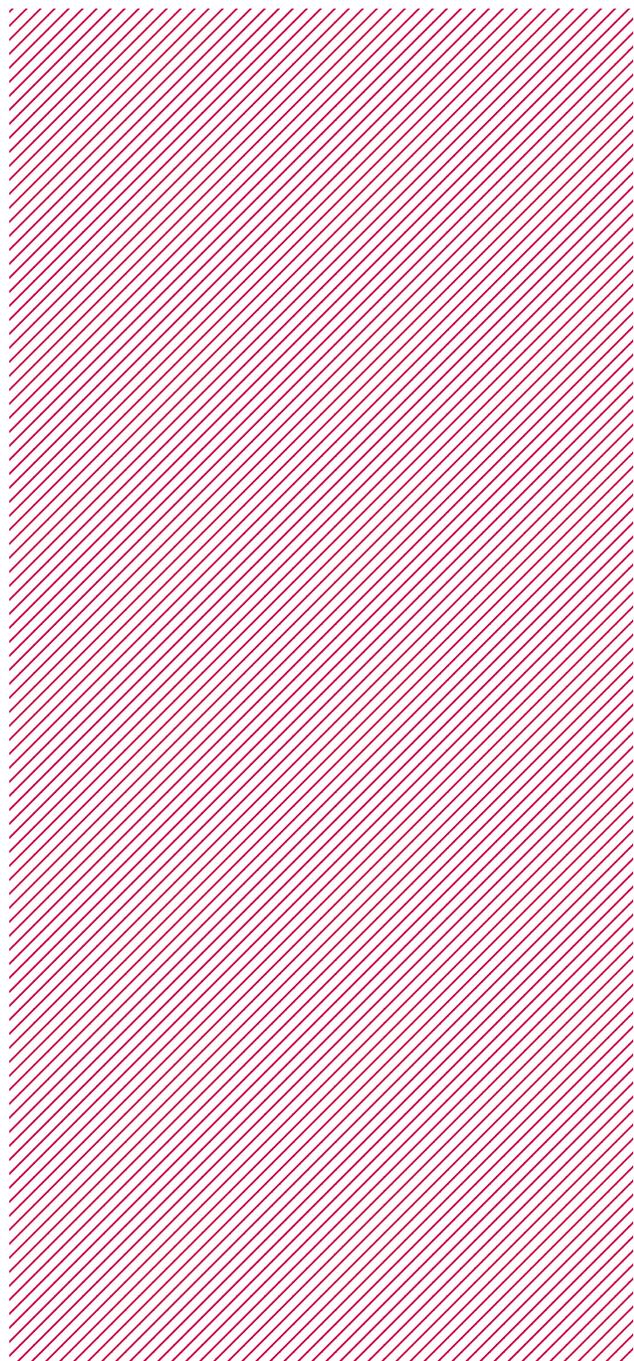
| MESH       | WIRE SIZE              |                       | OPENING           |                       |                   | APPROXIMATE WEIGHTS<br>Per 100 Sq. Ft. |                |                               |                |                |       |
|------------|------------------------|-----------------------|-------------------|-----------------------|-------------------|--|----------------|-------------------------------|----------------|----------------|-------|
|            | Center<br>to<br>Center | Diam.<br>in<br>Inches | Diam.<br>in<br>mm | Width<br>in<br>Inches | Width<br>in<br>mm | %<br>Open<br>Area                      | Plain<br>Steel | 302-304<br>Stainless<br>Steel | Pure<br>Copper | 80/20<br>Brass | Monel |
| <b>42</b>  |                        | .0095                 | .241              | .016                  | .39               | 38.4                                   | 24.7           | 24.9                          | 28.0           | 27.3           | 27.7  |
|            |                        | .009                  | .229              | .016                  | .41               | 41.0                                   | 22.0           | 22.2                          | 24.9           | 24.3           | 24.7  |
|            |                        | .0085                 | .216              | .017                  | .42               | 43.6                                   | 19.5           | 19.7                          | 22.1           | 21.5           | 21.9  |
|            |                        | .008                  | .203              | .017                  | .43               | 46.2                                   | 17.2           | 17.4                          | 19.5           | 19.0           | 19.3  |
|            |                        | .0075                 | .191              | .018                  | .45               | 49.0                                   | 15.0           | 15.2                          | 17.0           | 16.6           | 16.8  |
|            |                        | .007                  | .178              | .018                  | .46               | 51.8                                   | 13.0           | 13.1                          | 14.7           | 14.4           | 14.6  |
|            |                        | .010                  | .254              | .014                  | .35               | 33.6                                   | 29.2           | 29.5                          | 33.1           | 32.3           | 32.8  |
|            |                        | .0095                 | .241              | .014                  | .36               | 36.1                                   | 26.1           | 26.4                          | 29.6           | 28.8           | 29.3  |
|            |                        | .009                  | .229              | .015                  | .38               | 38.6                                   | 23.3           | 23.5                          | 26.4           | 25.7           | 26.1  |
|            | <b>45</b>              |                       | .010              | .254                  | .012              | .31                                    | 30.1           | 31.6                          | 31.9           | 35.8           | 34.9  |
|            |                        | .0095                 | .241              | .013                  | .32               | 32.7                                   | 28.3           | 28.6                          | 32.1           | 31.3           | 31.8  |
|            |                        | .009                  | .229              | .013                  | .34               | 35.3                                   | 25.2           | 25.4                          | 28.6           | 27.8           | 28.3  |
|            |                        | .0085                 | .216              | .014                  | .35               | 38.0                                   | 22.3           | 22.5                          | 25.3           | 24.6           | 25.0  |
|            |                        | .008                  | .203              | .014                  | .36               | 40.8                                   | 19.6           | 19.8                          | 22.2           | 21.7           | 22.0  |
| <b>50</b>  |                        | .0075                 | .191              | .015                  | .37               | 43.8                                   | 17.1           | 17.3                          | 19.4           | 18.9           | 19.2  |
|            |                        | .009                  | .229              | .011                  | .28               | 30.3                                   | 28.4           | 28.7                          | 32.2           | 31.4           | 31.9  |
|            |                        | .0085                 | .216              | .012                  | .29               | 33.1                                   | 25.1           | 25.4                          | 28.5           | 27.7           | 28.2  |
|            |                        | .008                  | .203              | .012                  | .31               | 36.0                                   | 22.1           | 22.3                          | 25.1           | 24.4           | 24.8  |
|            |                        | .0075                 | .191              | .013                  | .32               | 39.1                                   | 19.2           | 19.4                          | 21.8           | 21.2           | 21.5  |
| <b>55</b>  |                        | .008                  | .203              | .010                  | .26               | 31.5                                   | 24.6           | 24.8                          | 27.9           | 27.2           | 27.6  |
|            |                        | .0075                 | .191              | .011                  | .27               | 34.6                                   | 21.4           | 21.6                          | 24.3           | 23.6           | 24.0  |
|            |                        | .007                  | .178              | .011                  | .28               | 37.9                                   | 18.5           | 18.7                          | 21.0           | 20.4           | 20.8  |
| <b>60</b>  |                        | .0075                 | .191              | .009                  | .23               | 30.5                                   | 23.7           | 23.9                          | 26.9           | 26.2           | 26.6  |
|            |                        | .007                  | .178              | .010                  | .25               | 33.9                                   | 20.4           | 20.6                          | 23.1           | 22.5           | 22.9  |
|            |                        | .0065                 | .165              | .010                  | .26               | 37.5                                   | 17.4           | 17.6                          | 19.7           | 19.2           | 19.5  |
| <b>65</b>  |                        | .006                  | .152              | .011                  | .27               | 41.2                                   | 14.7           | 14.8                          | 16.7           | 16.2           | 16.5  |
|            |                        | .007                  | .178              | .008                  | .21               | 29.8                                   | 22.4           | 22.6                          | 25.4           | 24.8           | 25.1  |
|            |                        | .0065                 | .165              | .009                  | .23               | 33.5                                   | 19.1           | 19.3                          | 21.6           | 21.1           | 21.4  |
| <b>70</b>  |                        | .0065                 | .165              | .008                  | .20               | 29.8                                   | 20.8           | 21.0                          | 23.6           | 23.0           | 23.3  |
|            |                        | .006                  | .152              | .008                  | .21               | 33.8                                   | 17.5           | 17.7                          | 19.8           | 19.3           | 19.6  |
| <b>80</b>  |                        | .0055                 | .140              | .007                  | .19               | 31.4                                   | 16.9           | 17.1                          | 19.2           | 18.7           | 19.0  |
|            |                        | .005                  | .127              | .008                  | .19               | 36.0                                   | 13.8           | 13.9                          | 15.6           | 15.3           | 15.5  |
| <b>90</b>  |                        | .005                  | .127              | .006                  | .16               | 30.1                                   | 15.8           | 16.0                          | 17.9           | 17.5           | 17.7  |
| <b>100</b> |                        | .0045                 | .114              | .006                  | .14               | 30.3                                   | 14.2           | 14.3                          | 16.1           | 15.7           | 15.9  |
|            |                        | .004                  | .102              | .006                  | .15               | 36.0                                   | 11.0           | 11.1                          | 12.5           | 12.2           | 12.3  |
|            |                        | .0035                 | .089              | .007                  | .17               | 42.3                                   | 8.3            | 8.4                           | 9.4            | 9.2            | 9.3   |
|            |                        | .003                  | .076              | .007                  | .18               | 49.0                                   | 6.0            | 6.1                           | 6.8            | 6.6            | 6.7   |

## Applicable Documents

USDA Forest Service Specification 5100-1c, Spark Arresters for Internal Combustion Engines.

Society of Automotive Engineers (SAE) Surface Vehicle Standard J997- Spark Arrester Test Carbon.

Society of Automotive Engineers Recommended Practice J350 - Spark Arrester Test Procedure for Medium Size Engines.



## APPENDIX A ABBREVIATED TEST PROCEDURE

This abbreviated test procedure should only be used by an experienced test technician. It may be used as a checklist while completing the full procedure.

### Initial Setup

1. Create spreadsheet file. Save file using the collection agreement number as the file name. Save file in `K:/test_folder/filename.as`.

2. Fill out the top section of the preliminary data sheet.

3. Weigh spark arrester.

4. Adjust the back pressure probe to minimum pressure reading using the portable manometer.

5. Obtain back pressure correction value:

a. Install arrester and adjust flow to achieve 1.00 psi (6.89 kPa) indicated back pressure ( $DP_1$ ).

b. Record orifice pressure ( $DP_2$ )

c. Remove spark arrester.

d. Adjust flow to achieve the above recorded  $DP_2$  value, and record back pressure ( $DP_1$ ) reading.

6. Preliminary Test Run:

a. Install arrester and adjust flow to achieve 1.00 psi (6.89 kPa) back pressure plus the correction value (in any).

b. Verify that  $DP_2$  indicates a reading greater than 1 inch of water (249 Pa). A smaller orifice plate must be used if the reading is below. A larger orifice plate must be used if the reading is greater than 4 inches of water (996 Pa).

**Caution: Do not exceed 5 inches of water (1.2 kPa)!**

c. After 12 minutes record the pressure and temperature to fill out the bottom section of the preliminary data sheet.

### Carbon Test Runs

1. Weigh and load carbon sample. Adjust carbon feed piston if necessary. The minimum sample

size is 25 grams (0.88 oz) and the maximum of 200 grams (7 oz).

2. Start with all bypass valves 100 percent open and the arrester inlet valve closed.

3. Start oil pump and blower motor.

4. Set desired  $DP_2$  value.

5. Start carbon feed motor and start timer 1.

6. Set carbon feed and fluid air pressure ( $DP_3$  and  $DP_4$ ) according to labels on the control panel.

7. Check  $DP_2$  and adjust if necessary.

8. Check carbon feed after 5 and 10 minutes, adjust if necessary.

9. Record data after 12 minutes.

10. Stop the blower, pump, feed motor and turn off feed/fluid air after 15 minutes.

11. Run the blow-down fan for 30 seconds in each direction.

12. Collect the carbon from the trap and record its weight (T). Sift it, then record the weight of the carbon retained on the sieve (F).

### Cleanout Run

1. Refer to manufacturers cleanout instructions and follow any special cleanout instructions.

2. If equipped with a cleanout plug(s), remove the cleanout plug(s) and tap with the small rawhide mallet. Block the arrester outlet if necessary.

3. Close the manual valve.

4. Run the blower for 2 minutes at 50 percent of the flow achieved during the preliminary test run. ( $0.25 \times DP_2$ )

5. Run blow-down fan for 30 seconds in each direction.

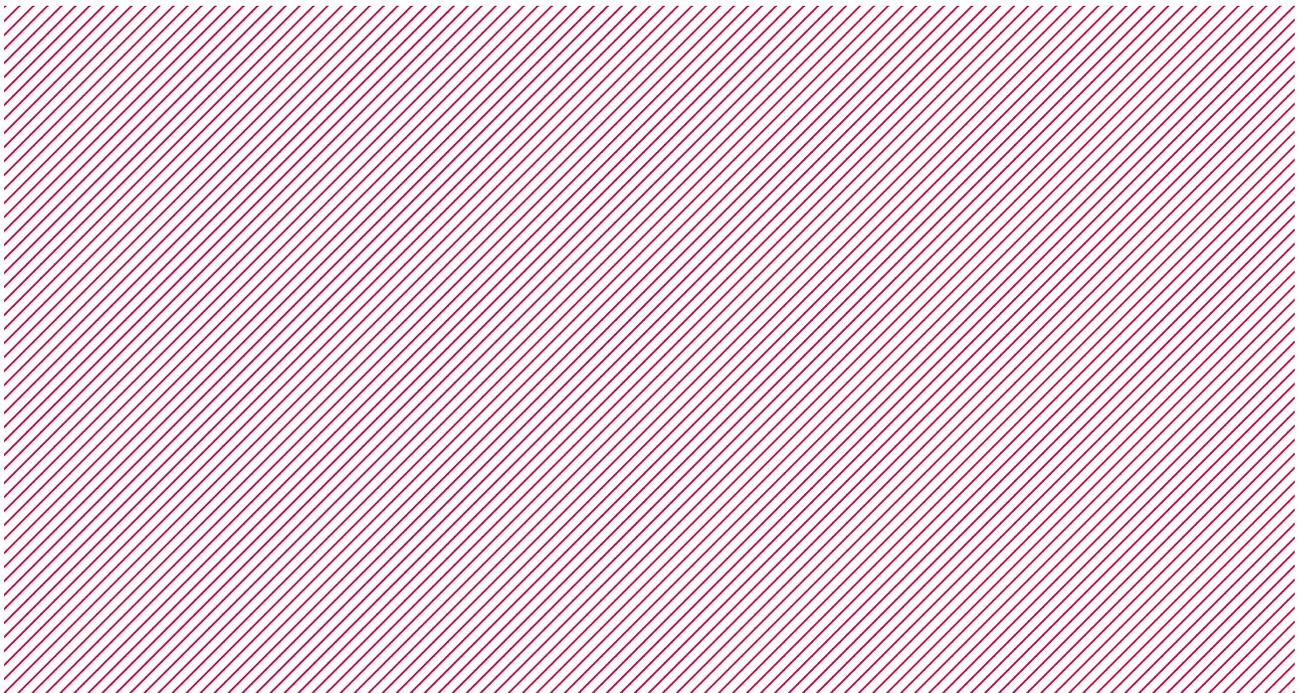
6. Collect the carbon from the trap and record its weight (Cr).

7. Replace the cleanout plugs.

8. Weigh the arrester after the 12th run.

**APPENDIX B**  
**SYSTEM SYMBOLS AND MAXIMUM (DO NOT EXCEED) VALUES**

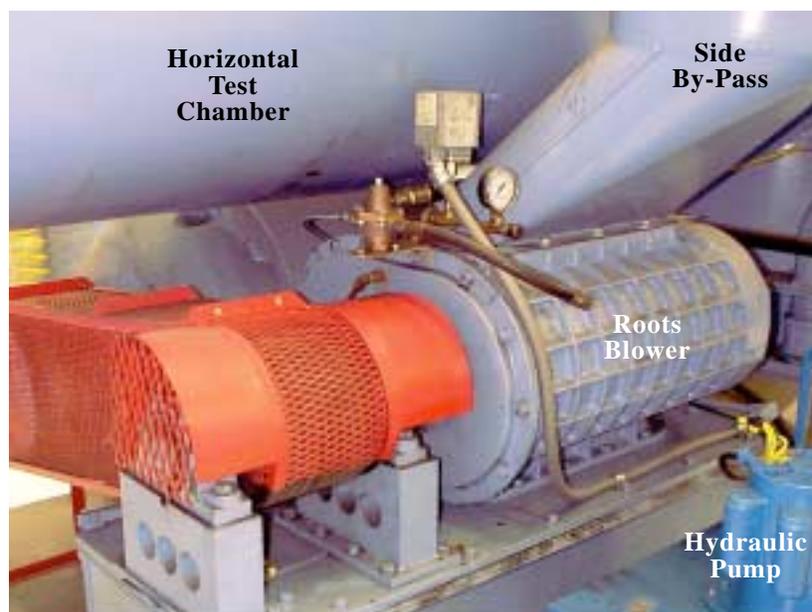
| <b>Symbol</b>   | <b>Meaning</b>                                       | <b>Maximum Value</b> |
|-----------------|--|----------------------|
| AP <sub>1</sub> | Barometric pressure                                  | 16 - 32 in. Hg       |
| DP <sub>1</sub> | Back pressure differential across the spark arrester | 10 psi               |
| DP <sub>2</sub> | Pressure differential across the orifice plate       | 5.0 in. water        |
| DP <sub>3</sub> | Air feed differential pressure                       | 5.0 psi              |
| DP <sub>4</sub> | Air fluid differential pressure                      | 5.0 psi              |
| GP <sub>1</sub> | Tank pressure  | 10.0 psi             |
| GP <sub>2</sub> | Trap pressure  | 20.0 in. water gauge |
| GP <sub>3</sub> | Orifice down stream pressure                         | 4.0 in. water gauge  |
| T <sub>1</sub>  | Arrester inlet temperature                           | 0 - 100 °C           |
| T <sub>2</sub>  | Orifice outlet temperature                           | 0 - 100 °C           |
| V <sub>1</sub>  | Blower dump valve                                    | 0 - 100 % open       |
| V <sub>2</sub>  | Arrester inlet valve                                 | 0 - 100 % open       |
| V <sub>3</sub>  | Tank west side bypass valve                          | 0 - 100 % open       |
| V <sub>4</sub>  | Tank east side bypass valve                          | 0 - 100 % open       |



**APPENDIX C  
DIAGRAMS AND PARTS  
LIST**



*1. Spark arrester chamber view*

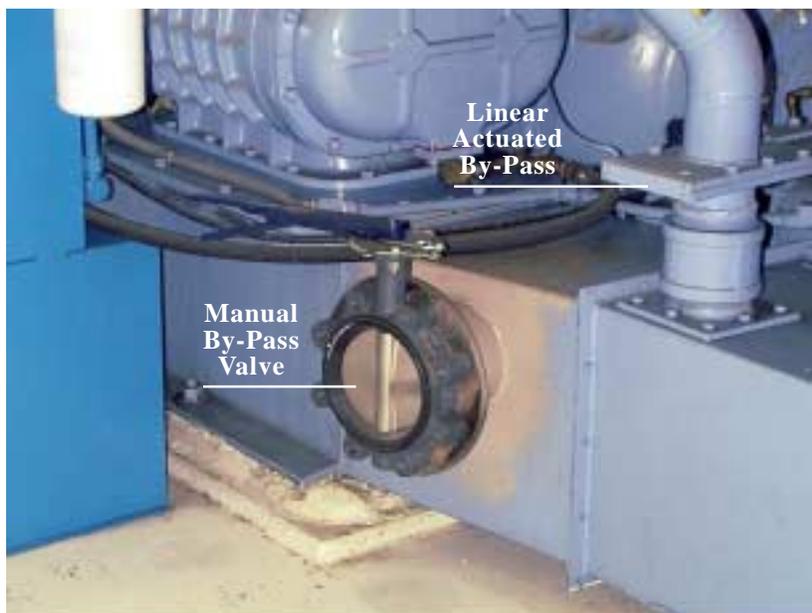


*2. Roots blower*

STANDARD TEST PROCEDURE FOR GENERAL PURPOSE SPARK ARRESTERS

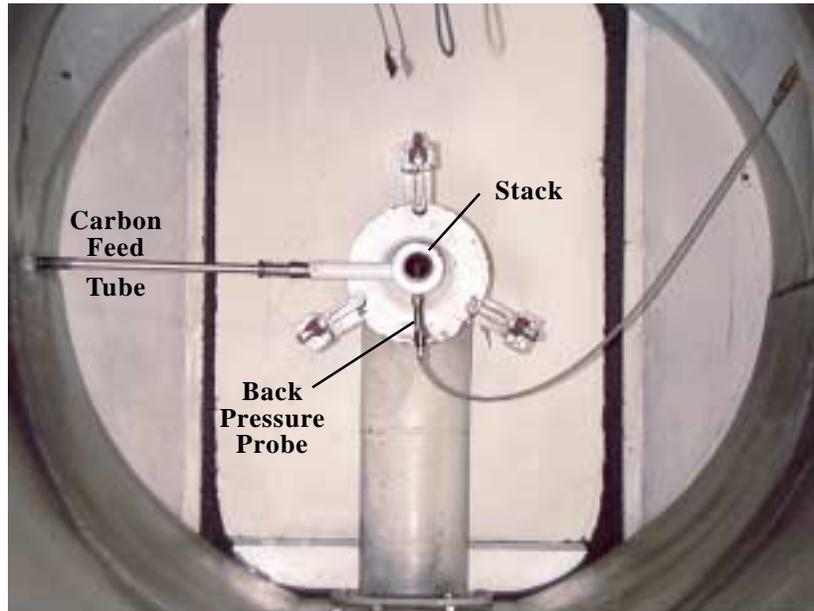


*3. 150 horsepower (112 kW) electric motor*

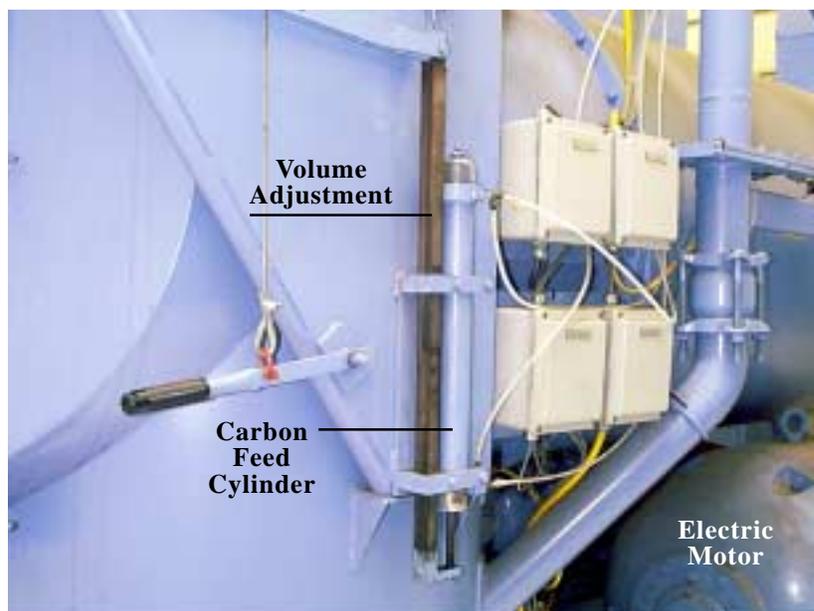


*4. Manual by-pass valve*

STANDARD TEST PROCEDURE FOR GENERAL PURPOSE SPARK ARRESTERS

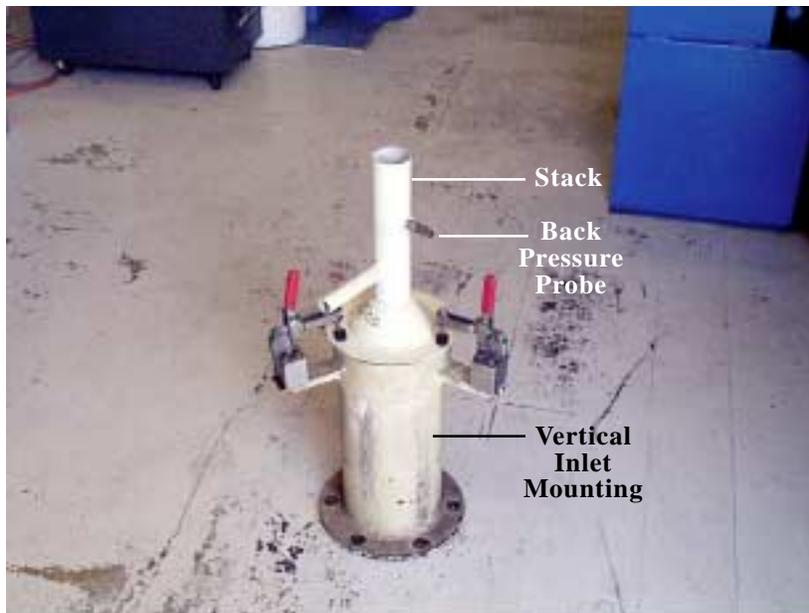


5. Carbon feed tube



6. Carbon feed cylinder

STANDARD TEST PROCEDURE FOR GENERAL PURPOSE SPARK ARRESTERS



7. Vertical inlet mounting tube with stack

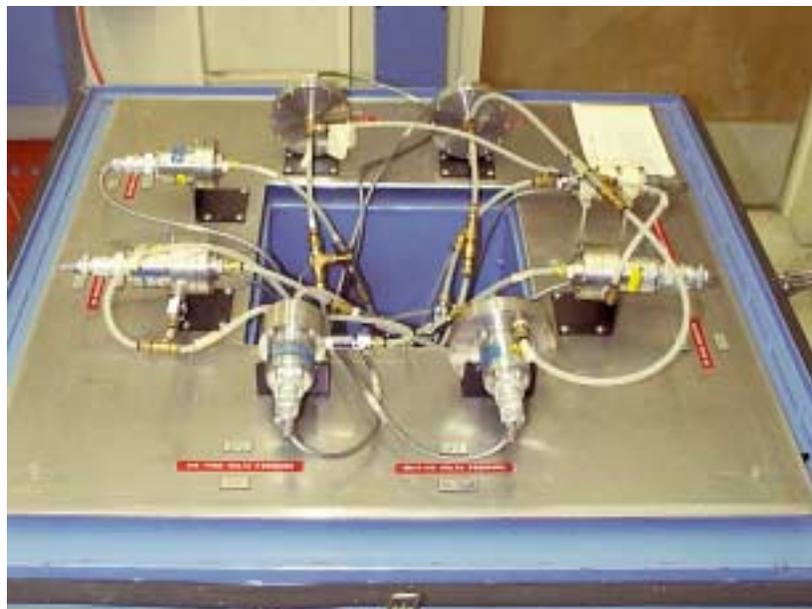


8. Orifice meter and flow discharge fixture

STANDARD TEST PROCEDURE FOR GENERAL PURPOSE SPARK ARRESTERS



*9. Orifice plates*



*10. Transducer bench  
(normally under cover)*

## APPENDIX D PREPARING TEST CARBON

1. All test carbon used for qualification purposes must be prepared according to SAE Standard J997.
2. Carbon is supplied in two rough screened size ranges. Commercial designation C-66-141-B 8/14X is coarse carbon, and commercial designation C-66-141-A 12/28X is fine carbon. The only difference is the size range. This is done for convenience in final screening of coarse and fine test carbon.
3. Using a series of US sieves, start with either coarse or fine carbon and combine with carbon retained on the sieves as labeled below and in the proportions indicated:

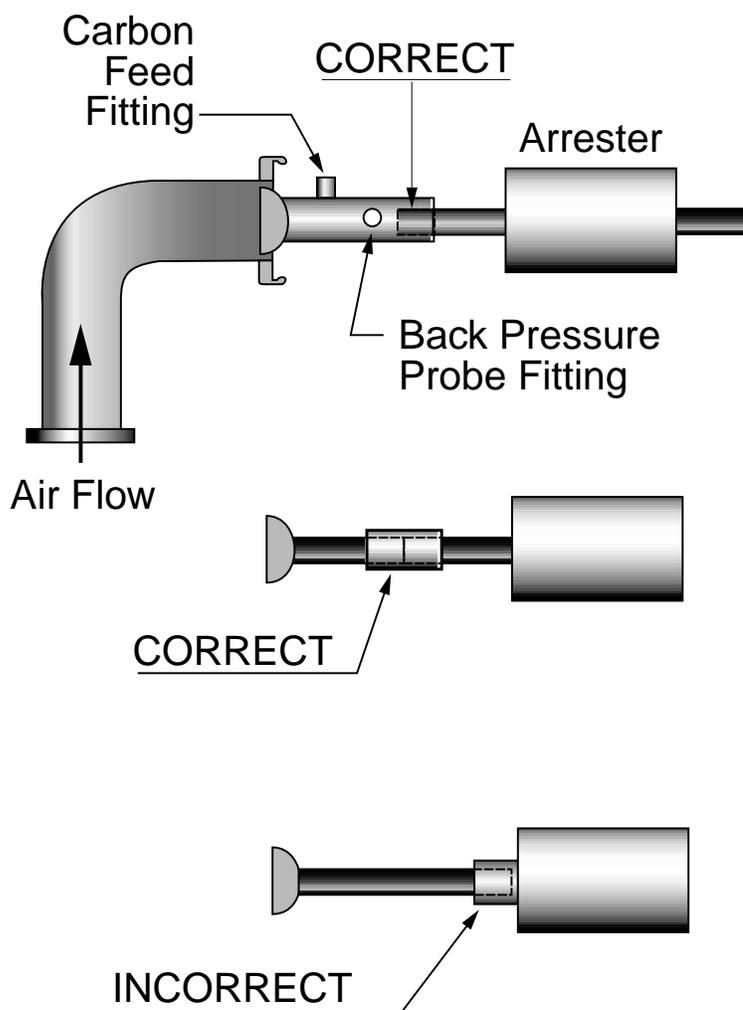
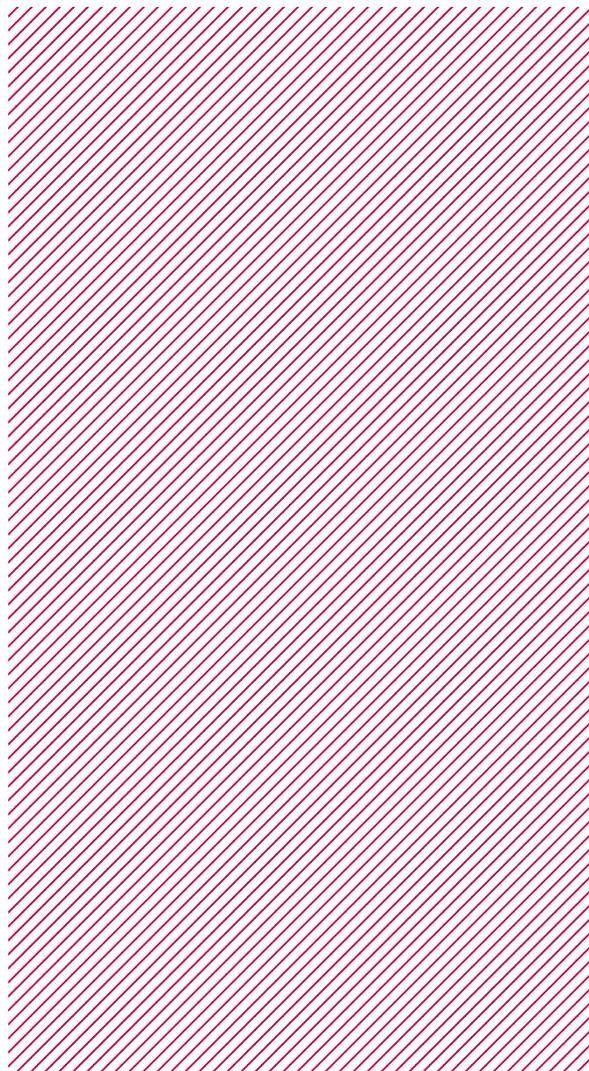


Figure D1. Arrangement of sieves for screening carbon.

4. In addition to sieving the carbon, all test carbon used for qualification must be baked at no less than 160 °F (71 °C) for at least 6 hours immediately before use.

**APPENDIX E  
ORIFICE FACTORS**

| <b>Orifice Diameter</b><br>Inches (mm) | <b>C</b> |
|--|----------|
| 1.37 (34.93)                           | 6.381    |
| 2.25 (57.15)                           | 16.93    |
| 3.50 (88.90)                           | 41.2     |
| 4.63 (117.60)                          | 72.1     |
| 6.25 (158.75)                          | 133.9    |
| 10.75 (273.05)                         | 449      |



## APPENDIX F FACILITY CERTIFICATION

### 1. General

(a) Familiarize yourself with the instruction manual for the Yokogawa Digital Manometer. This manometer is the standard for the laboratory and requires recertification at an outside metrology laboratory a minimum of once a year (more often if it is found to be necessary). During this review of the manual, make a special note of the maximum allowable pressures given in Table F1. Over pressure of the instrument could cause damage to it.

(b) The facility blower must be off during instrument calibration.

(c) The primary guideline for instrument full-scale readings is the system schematic. A copy is posted near the transducer stand in Room 16 and on the wall across from the control console in Room 16A. Refer to the schematic for all system problems and during calibration/certification.

(d) Attach the umbilical tube with air pump attached to the fitting on the front of the digital manometer. Make sure all the fittings on the umbilical tube are secure and free of leaks. Secure the tube tightly to the fitting on the manometer.

(e) For the initial calibration check, double check the tube fittings on the transducers and associated quick disconnects and valves to assure they are tight and leak free. This should also be done this prior to system start-up also.

(f) Place the manometer on the equipment cart; this will facilitate use and movement of the instrument around the transducer stand during calibration. The manometer does not need to be plugged in to an AC outlet during the calibration operation unless it is discovered that the battery is low.

### 2. Preparation

(a) Remove the cover on the transducer stand.

(b) Note the labeling on each transducer.

(c) Check the tube fittings as mentioned earlier.

(d) Use the system schematic for reference during calibration.

(e) Attach the umbilical appropriate quick disconnect to each transducer during calibration as required.

(f) During the calibration it is required that the readout on the manometer and the control console are in the same engineering units. Be sure to double check the units setting on the manometer prior to each transducer calibration.

### 3. Barometric Pressure AP<sub>1</sub>

(a) Make sure the valve on the umbilical tube is off.

(b) Attach the umbilical to the disconnect on the AP<sub>1</sub> unit. Make sure the proper units have been selected on the manometer.

(c) The reading on the manometer should agree with the reading in the test control room for barometric pressure.

(d) If the readings do not match notify the Spark Arrester Project Leader. There are no adjustments available on the signal conditioner for barometric pressure.

(e) Open valve on transducer input after calibration is completed.

### 4. Spark Arrester Back Pressure DP<sub>1</sub>

(a) Make sure the valve on the umbilical is off.

(b) Attach the umbilical to the line which is between DP<sub>1</sub> and DP<sub>3</sub> (Do not connect to line between GP<sub>2</sub> and DP<sub>1</sub>. If this error occurs a negative reading will result on the control room readout and possible damage to the transducer may occur). Disconnect the line between GP<sub>2</sub> and DP<sub>1</sub>.

(c) Again, Make sure the corresponding readout for DP<sub>1</sub> in the Control Room has been checked for zero.

(d) Select the proper units on the manometer (PSID = PSI). Use the pump on the umbilical to raise the reading on the manometer to 8 psi (55 kPa) (i.e. = absolute pressure of the 0-reading of about 14.2 (97.9 kPa) to 14.7 psi (101.4 kPa) + 8 psi (55 kPa) or about 22 psi (151.7 kPa). Need to add 8 psi (55 kPa) to manometer 0 reading!).

(e) Reading on the control panel should equal the manometer reading less the initial manometer reading of 14.2 to 14.7 psi (97.9 to 101.4 kPa) air pressure or about 8 psi (55 kPa). If not adjust the gain on the transducer signal conditioner until they agree and repeat calibration check.

(f) Open valve on transducer input after calibration is completed.

## 5. Orifice Differential Pressure, $DP_2$

(a) Attach umbilical to line between  $GP_3$  and  $DP_2$ .

(b) Set manometer to inches of water scale.

(c) Manometer reading prior to calibration should be about 390 to 393 inches of water (97 - 97.8 kPa). This value plus 4 inches of water (995 kPa) yields the proper value for calibration.

(d) Pump up manometer to proper reading. Check readout on control console panel and adjust, as before, accordingly.

(e) Open valve on transducer input after calibration is completed.

## 6. Air Feed Delta Pressure, $DP_3$

(a) Attach umbilical to center (end) input of the transducer.

(b) Repeat appropriate steps from the previous calibration for  $DP_1$  and  $DP_2$ .

(c) Add manometer reading in PSI (prior to cal) to 4 psi (27.6 kPa) to obtain the desired reading value for calibration.

(d) Pump to desired value and adjust reading on control console as before.

(e) Open valve on transducer input after calibration is completed.

## 7. Air Fluidization Delta Pressure, $DP_4$

(a) Attach umbilical to center (end) input of transducer.

(b) Repeat the appropriate steps from the previous DP calibrations.

(c) Check manometer scale; be sure it is set at PSI.

(d) Repeat steps given for  $DP_3$ .

(e) Open valve on transducer input after calibration is completed.

## 8. Tank Pressure, $GP_1$

(a) Attach umbilical to transducer input tube.

(b) Check manometer scale; be sure it is set at PSI.

(c) As before, add manometer reading to 8 psi (55 kPa) to obtain value for calibration.

(d) Calibrate as before.

(e) Open valve on transducer input after calibration is completed.

## 9. Trap Pressure $GP_2$

(a) Close valve on transducer input line.

(b) Attach umbilical to  $GP_2$  side of tube between  $DP_1$  and  $GP_2$ .

(c) Set manometer scale to inches of water. Note reading as before and add 16 inches of water (3.9 kPa) to value to obtain the calibration setting.

(d) Perform calibration as before.

(e) Open valve on transducer input after calibration is completed.

## 10. Orifice Downstream Pressure, $GP_3$

(a) Close valve on transducer input line.

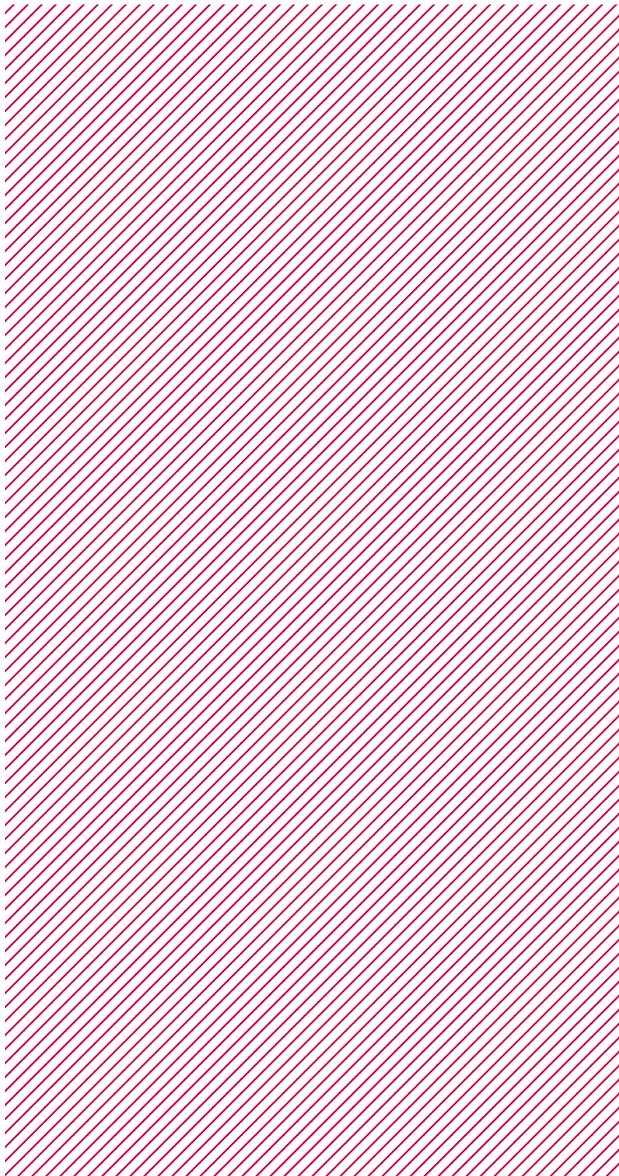
(b) Attach umbilical to  $GP_3$  side of tube between  $GP_3$  and  $DP_2$ .

(c) Set manometer scale to inches of water. Note initial reading and add 4 inches of water

## STANDARD TEST PROCEDURE FOR GENERAL PURPOSE SPARK ARRESTERS

- (995 kPa) to it to obtain the calibration setting.
- (d) Perform calibration as before.
- (e) Open valve on transducer input after calibration is completed.

This completes the initial system calibration. This process should be repeated at the beginning and end of each certification series of test runs (high and low flow tests) to validate the stability of the transducers and readout equipment. Once the system has been determined to be stable, this process should be repeated at least twice a year (more if necessary, the frequency will be determined after experience has been gained using the equipment).



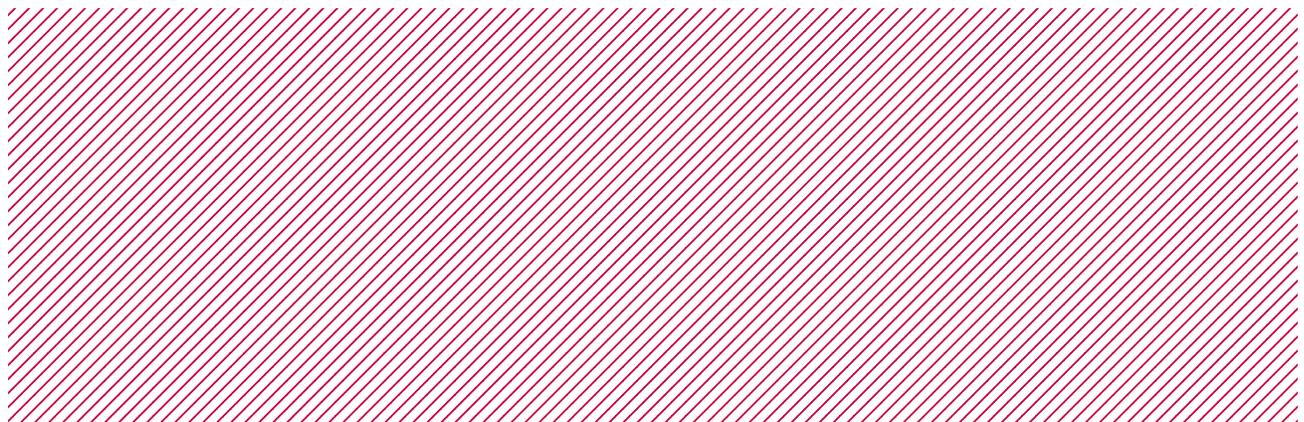
STANDARD TEST PROCEDURE FOR GENERAL PURPOSE SPARK ARRESTERS

*Table F1. Spark Arrester Lab Calibration Data Sheet*  
**SPARK ARRESTER LAB CALIBRATION DATA SHEET**

| Transducer                            | Applied Pressure | Indicated Pressure | Adjusted Reading | Constant |
|---------------------------------------|------------------|--------------------|------------------|----------|
| DP <sub>1</sub> (psi)                 | 0.50             |                    |                  |          |
|                                       | 1.00             |                    |                  |          |
|                                       | 1.50             |                    |                  |          |
|                                       | 2.00             |                    |                  |          |
|                                       | 4.00             |                    |                  |          |
|                                       | 3.00             |                    |                  |          |
| DP <sub>2</sub> (in H <sub>2</sub> O) | 1.00             |                    |                  |          |
|                                       | 2.00             |                    |                  |          |
|                                       | 3.00             |                    |                  |          |
|                                       | 4.00             |                    |                  |          |
|                                       | 2.00             |                    |                  |          |
|                                       | 1.00             |                    |                  |          |
| DP <sub>3</sub> (psi)                 | 0.00             |                    |                  |          |
|                                       | 1.00             |                    |                  |          |
|                                       | 2.00             |                    |                  |          |
|                                       | 3.00             |                    |                  |          |
|                                       | 4.00             |                    |                  |          |
|                                       | 2.00             |                    |                  |          |
| DP <sub>4</sub> (psi)                 | 1.00             |                    |                  |          |
|                                       | 2.00             |                    |                  |          |
|                                       | 3.00             |                    |                  |          |
|                                       | 4.00             |                    |                  |          |
|                                       | 2.00             |                    |                  |          |
|                                       | 1.00             |                    |                  |          |
| GP <sub>1</sub> (psi)                 | 0.00             |                    |                  |          |
|                                       | 1.00             |                    |                  |          |
|                                       | 2.00             |                    |                  |          |
|                                       | 3.00             |                    |                  |          |
| GP <sub>1</sub> (psi)                 | 4.00             |                    |                  |          |
|                                       | 6.00             |                    |                  |          |
|                                       | 8.00             |                    |                  |          |
|                                       |                  |                    |                  |          |

STANDARD TEST PROCEDURE FOR GENERAL PURPOSE SPARK ARRESTERS

| Transducer                            | Applied Pressure | Indicated Pressure | Adjusted Reading | Constant |
|---------------------------------------|------------------|--------------------|------------------|----------|
| GP <sub>2</sub> (in H <sub>2</sub> O) | 0.00             |                    |                  |          |
|                                       | 4.00             |                    |                  |          |
|                                       | 8.00             |                    |                  |          |
|                                       | 12.00            |                    |                  |          |
|                                       | 16.00            |                    |                  |          |
|                                       | 4.00             |                    |                  |          |
|                                       | 2.00             |                    |                  |          |
|                                       | 4.00             |                    |                  |          |
| GP <sub>3</sub> (in H <sub>2</sub> O) | 0.00             |                    |                  |          |
|                                       | 1.00             |                    |                  |          |
|                                       | 2.00             |                    |                  |          |
|                                       | 3.00             |                    |                  |          |
|                                       | 4.00             |                    |                  |          |
|                                       | 2.00             |                    |                  |          |
|                                       | 1.00             |                    |                  |          |
|                                       | 2.00             |                    |                  |          |
|                                       | 3.00             |                    |                  |          |
|                                       | 4.00             |                    |                  |          |
| AP <sub>1</sub> (in Hg)               | 28.786           |                    |                  |          |



APPENDIX G - CONSOLE CALIBRATION CHECK

| Transducer | Constant | Tested by |
|------------|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
|            |          | Date      |
| DP1        | 8.09     |           |           |           |           |           |           |           |
| DP2        | 4.05     |           |           |           |           |           |           |           |
| DP3        | 4.02     |           |           |           |           |           |           |           |
| DP4        | 4.02     |           |           |           |           |           |           |           |
| T1         | Agree    |           |           |           |           |           |           |           |
| GP1        | 8.00     |           |           |           |           |           |           |           |
| GP2        | 15.89    |           |           |           |           |           |           |           |
| GP3        | 3.93     |           |           |           |           |           |           |           |
| AP1        | 1.59     |           |           |           |           |           |           |           |
| T2         | Agree    |           |           |           |           |           |           |           |
| V1         | 6.67     |           |           |           |           |           |           |           |
| V2         | 6.36     |           |           |           |           |           |           |           |
| V3         | 5.27     |           |           |           |           |           |           |           |
| V4         | 6.15     |           |           |           |           |           |           |           |
| ALARM      |          |           |           |           |           |           |           |           |