



Intake Manifold Rapid Pressurization Test

1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. The purpose of this test is to determine the robustness of an intake manifold, or similar system component, to withstand a combustion event of an air and fuel vapor mixture internal to the air intake system. This standard defines all requirements for component burst resistance validation to a rapid pressurization event.

1.2 Applicability. This procedure applies to intake manifolds and similar components for all gasoline and gaseous fueled spark ignition engines. It is intended primarily for intake manifolds made from composite materials or other materials and construction methods which may not easily withstand pressures over 750 kPa internal pressure. It may also be adapted to evaluate induction systems or other vessels that may contain air and fuel mixture vapor.

1.3 Remarks. Intake manifold rapid pressurization refers to a nearly instantaneous combustion event internal to the intake manifold, which results in a peak internal pressure much greater than ambient.

Intake manifold over pressurization refers to a combustion event internal to the intake manifold which results in a manifold failure. The failure may be catastrophic, such as a structural failure of the manifold cavity which causes an excessive air leak, or a minor failure, such as a hose or component that becomes dislodged and causes a small air leak. Either condition is considered component failure.

Rapid pressurization implies a high-pressure event duration of approximately (~) 10 ms to 100 ms. Intake manifolds manufactured of composite materials may be most prone to failure due to an erroneous engine backfire. To investigate this, a laboratory component bench test is needed to simulate the potential in-field phenomena: The Intake Manifold Rapid Pressurization Test. This test was developed to closely simulate the conditions that may potentially occur during vehicle operation.

Backfire refers to an event during engine operation or engine starting, when a combustible mixture of fuel and air in any cylinder is ignited and a flame front propagates into the intake manifold. The intake manifold may or may not contain an ignitable mixture of fuel and air. If the manifold does contain an ignitable mixture of fuel and air, the mixture will burn, causing a rapid pressure rise. Typically, the flame front within the cylinder may be considered laminar in formation, while in contrast the flame front within the intake manifold plenum may be substantially more turbulent and therefore more damaging to the components that may contain it.

Propane is the test fuel utilized in place of gasoline, considering that propane mixes easily with air and remains a vapor at typical ambient or room temperatures and is safer to handle than gasoline. The volume specific energy content of gasoline is 3.51 kJ/L, compared to propane at 3.38 kJ/L, therefore propane is considered adequate and safer for testing purposes. For other gaseous fuel systems in place of or in addition to gasoline engine systems, the test fuel may require further consideration relative to containing similar energy content.

The theoretical maximum internal pressure from an internal combustion event is 930 kPa. This may result from the combustion of a stoichiometric mixture of air and gasoline vapor at ambient conditions. This pressure level assumes complete combustion of all air and vapor with no leakage. For this condition to occur, all leak paths, including all intake and exhaust valves, must be closed which is always unlikely, and often impossible, depending on the engine configuration.

Combustion tests have demonstrated significant differences in peak pressure between manifold designs. This is due to differences in burn characteristics that result from differences primarily in manifold geometry. For this reason, the acceptance criterion is a safety factor and not a generalized single standard target pressure.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

None

2.3 Additional References.

Statement of Requirements (SOR)

3 Resources

3.1 Facilities. A room is required which can provide protection to the operators foremost, and the surroundings, from possible flying component debris. Protection from noise, i.e., hearing protection, emanating from the detonation of combustible mixtures inside of intake manifolds should also be provided. In addition, adequate ventilation is required to remove any combustible mixtures of fuel and air from the ambient surroundings.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.2 Equipment.

3.2.1 Basic Test Apparatus. Figure A1 in Appendix A illustrates the basic arrangement and elements of the test apparatus required to perform the procedure. The illustration represents a typical test setup for a four-cylinder engine intake manifold.

3.2.1.1 Fuel and Air Mixing, and Regulating Device. A device is required which can receive an input of fuel (propane) and air, regulating the pressure of each gas, and mixing the combination in various Air/Fuel (A/F) ratios to create the charge mixture. Typically, a stoichiometric mixture is used. Slightly rich or lean of stoichiometric are used occasionally. This device must contain a shutoff valve for the mixture tube and separate shutoff valves for the propane and compressed air source. The test device shall also have capability of regulating the entire mixture pressure to a minimum 100 kPa above atmospheric conditions, even though test conditions are typically limited to 35 kPa.

3.2.1.2 Propane Tank. A tank containing propane must be provided having enough capacity to deliver fuel which is to be mixed into the desired charge A/F ratio.

3.2.1.3 Compressed Air Source. A source of pressurized air must be provided with enough capacity to be mixed into the desired charge A/F ratio.

3.2.1.4 Vent Valves. Valves which can vent the intake manifold when manually opened are necessary. One (1) for each runner and the pre-chamber is required to facilitate complete manifold filling and scavenging.

3.2.1.5 Pressure Relief Valves. These adjustable pressure relief valves, may be two (2) for each cylinder, i.e., two relative to inertia or flow rate, simulate the opening of the intake valves due to internal pressure. The pressure relief valves shall be set to 275 kPa.

3.2.1.6 Pre-Chamber. A pre-chamber is to be installed at the end of the manifold runner where ignition is intended to occur. Use of the pre-chamber has been shown to produce faster pressure rise and higher peak pressure. The volume of the pre-chamber is to be approximately 80% to 120% of one (1) cylinder's swept volume. The attaching pipe is to have an equivalent diameter of approximately 12.7 mm.

3.2.1.7 Spark Plug and Ignition Coil. A source of spark is required to ignite the charge in the pre-chamber, this may typically be most easily provided by an ignition coil and spark plug.

3.2.1.8 Main Flange Adapter Block-Off Plate. A plate is required to block off each manifold runner at the main flange. For each cylinder, two tapped holes are required to install the vent valves or pre-chamber connection. A single plate is used for each manifold runner flange, i.e., "V" engines will require two (2) plates, "line" engines require one (1) plate.

3.2.1.9 Throttle Body Flange Adapter Block-Off Plate. A single plate is required for each throttle body flange. This plate would contain the inlet for the vent air and charge mixture. Also, typically, the pressure transducer(s) would be mounted to this flange. In some testing scenarios, it may be desired to have the throttle body component in place during testing, in which case a membrane material may be utilized between the throttle body and intake flange or may be outboard the throttle body, in effort to contain the A/F charge.

3.2.1.10 Test Stand. Typically, a stand is necessary to mount the entire manifold and block-off plate assembly. The test stand must be suitably robust to many detonation events. Note: The test stand should be utilized within an operator safety protection test cell.

3.2.1.11 Debris Containment. Blankets or fabricated guards should be used to contain manifold parts, components, transducers and block-off plates.

3.2.2 Instrumentation.

3.2.2.1 Pressure Transducer(s). At minimum two (2) pressure transducers (one low speed for system control, and one high speed to measure the rapid pressure rise) are required to measure the pressure during the event. It must be fast enough in response to capture the precise peak of the event. It is also important to capture the pressure magnitude during initial pressurization of the charge into the manifold and throughout the detonation event. The pressure transducer is to be in the manifold plenum. The pressure transducer must provide continuous output, in which the pressure range may be later graphed over time domain.

3.2.2.2 Signal Conditioner and Data Processing Equipment. The appropriate conditioning instrumentation is also required to prepare the signal for data processing. Data processing equipment is needed to prepare the results for reporting. **Note:** The processing equipment is not represented in the appendix illustration.

3.2.2.3 Video Recording Equipment. High speed video recording equipment can be used to report the event, and as a valuable tool to help diagnose any failure events.

3.3 Test Vehicle/Test Piece.

3.3.1 Test Specimen and Material Required. The intake manifold assembly may include, but not limited to the following:

- Intake manifold finished machined casting or molding
- Throttle body seal
- Main flange seal
- Throttle body bolts/studs or nuts, representative of production intent
- Main flange bolts/studs and nuts, representative of production intent
- Charge Air Cooler (CAC) if applicable
- Production intent pressure relief valve (if applicable)
- Ancillary hole block-offs, plugs, or tubes (if applicable)
- Exhaust Gas Recirculation (EGR) pipe
- Positive Crankcase Ventilation (PCV) tube
- Heating, Ventilation, Air Conditioning (HVAC) hose
- Purge valve or tube
- Brake hose
- Related structural brackets

3.4 Test Time. Test time varies based on sample preparation (if required), i.e., heat aging per the Statement of Requirements (SOR), see 4.2.3, and moisture conditioning, see 4.2.4, and the number of samples run, see 4.3.

3.5 Test Required Information. Not applicable.

3.6 Personnel/Skills. The technician shall be trained and capable of safely operating the test equipment, able to record the test data, and record any applicable failure images as required

4 Procedure

4.1 Preparation. The technician shall determine that the intake manifold is suitable for testing by inspection of the overall initial condition and leak integrity of the intake manifold assembly. **Note:** The Tier 1 supplier may