

APPLICATION NOTE

INJECTION OF INTAKE GASES INTO THE EXHAUST MANIFOLD

OFT sensor temperature waveforms provide engine signatures that can be related to the events occurring within the cylinder. One of the most distinctive appears to be due to the ingestion of intake gases into the exhaust manifold during valve overlap. Examples of the pattern are shown in Figures 1 and 2. The measurements were conducted in a 3.78 liter, V6, 8:1 C/R carbureted General Motors engine was operated in a chassis dynamometer at 1800 RPM and road tested at 1600 RPM. The engine conditions are listed below:

	Dynamometer Test	Road Tests
Torque	15 Ft. Lbs.	
RPM	1800 RPM	1600 RPM
Speed	40 MPH	Automobile with automatic transmission engine run in gear with brake engaged. Load was unknown.
Vacuum	-12 In. Hg	
Dwell	27 Degrees	

An OFT sensor was located approximately 0.5 in. from the cylinder wall near the spark plug during the dynamometer tests. A 12-bit digitizer recorded the data in 0.02 ms time increments; the digital resolution was approximately 0.035 F (Figure 1). Earlier road test data were measured with a sensor located 0.375 in. from the cylinder wall near the exhaust valve. An 8-bit digitizer recorded the data in 0.4 and 0.02 ms time increments; the digital resolution was approximately 0.56°F (Figure 2). In both cases, the analog resolution of the OFT system was on the order of 0.005°F. The difference in the quality of the waveforms in Figures 1 and 2 is apparent and points out the importance of using at least a 12 bit digitizer to utilize the unusual signal-to-noise ratio of the OFT technology.

The area circled in Figure 1a is expanded in Figure 1b and correlated with the engine crank angle, the opening of intake valve (IVO) and the closing of the exhaust valve (EVO). When the intake valve is opened, sensors located on the opposite side of the cylinder are cooled even before top dead center. It appears that the intake gases swirl around the cylinder and enter the exhaust manifold during the

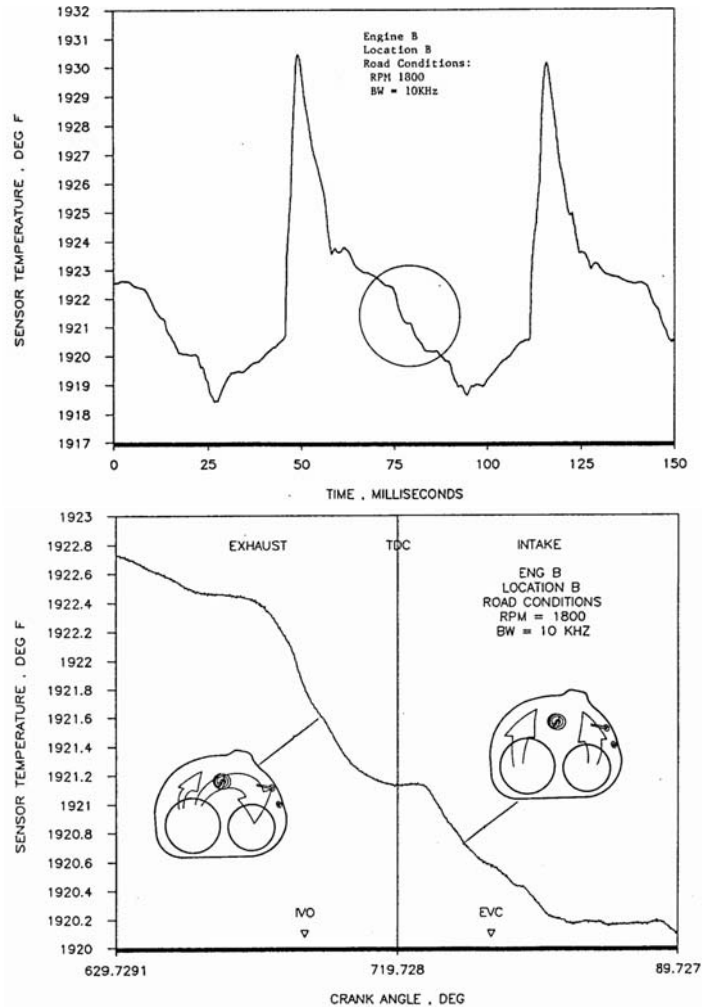


Figure 1: Sensor temperature waveforms indicating ingestion of intake gases into the exhaust manifold. Road conditions: 15 lbs. ft. lbs. torque, 1800 RPM, 40 MPH, -12 In. Hg vacuum, -12 Deg. BTDC timing, sensor located as shown in (b); (a) multiple cycle waveform, (b) expanded waveform near TDC.

exhaust portion of the engine cycle. The sensor is cooled since the temperature of the intake gas is much lower than the to 1900°F sensor temperature. At Top Dead Center (TDC), the velocity approaches zero during flow reversal and then the sensors are cooled again by gas from the intake or exhaust manifolds. Multiple sensor "time of flight" measurements indicate the velocity vector rotates after TDC. Before TDC, the signal from a sensor located away from the



exhaust valve leads the signal from the sensor near the exhaust valve; after TDC, the converse is true. This observation and the fact that the cooling rate of the sensors is reduced when the exhaust valve is closed suggests that the cool air measured in this area of the cylinder near TDC is coming from the exhaust manifold.

Similar results are shown in Figure 2. This distinctive sensor temperature pattern has been observed near the exhaust valve in several engines over a wide range of engine operating conditions but is not always observed. Figure 2a shows cycle-to-cycle variations in the sensor temperature which indicate that the combustion and flow are not reproduced exactly in each engine cycle.

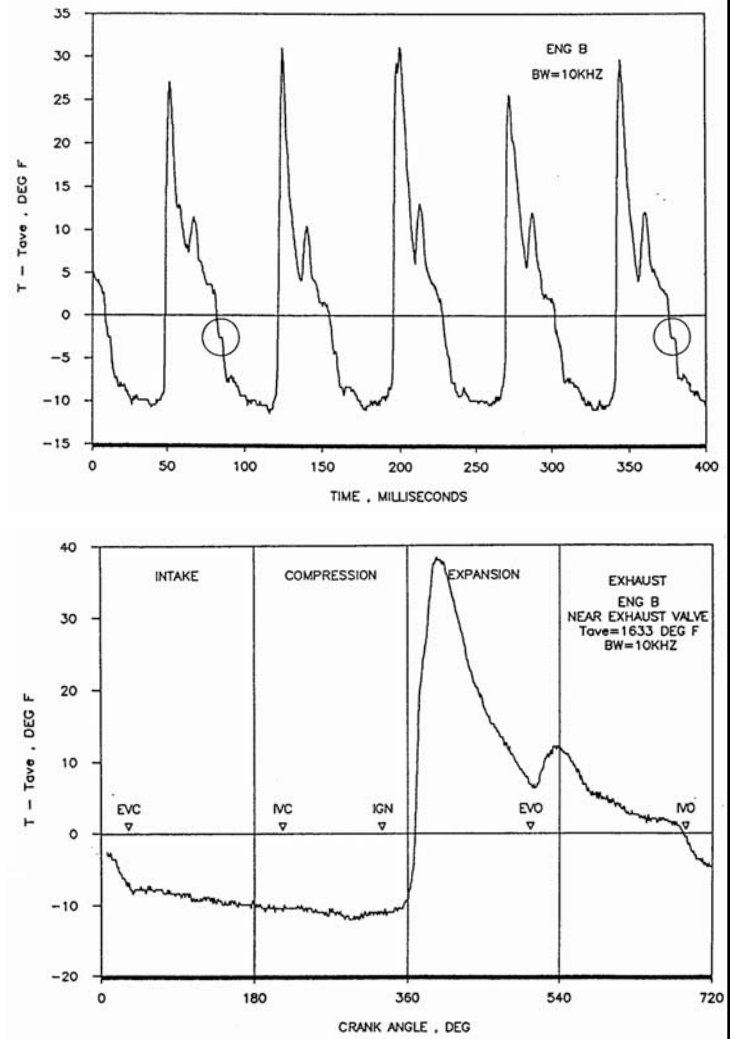


Figure 2: Sensor temperature waveforms measured near exhaust valve. Sensor located 0.375 in. from engine cylinder wall. 1600 RPM, automatic transmission; engine run in gear with brake engaged; torque converted load unknown. (a) multiple cycle waveforms, (b) single cycle waveform.