

CYLINDER PRESSURE SENSOR INSTALLATIONS

- CONSIDERATIONS
- SENSOR PLACEMENT
- TOOLS
- MACHINING
- CRANK TRIGGERING
- SPECIAL APPLICATIONS

DC Inc Sensitive Data c 2023

Intro to Sensor Placement

- **No data is better than bad data, quality data starts with properly installed cylinder pressure sensors**
- To end right we must start right
- Being uninformed is better than being misinformed
- Quality data analysis starts with quality data

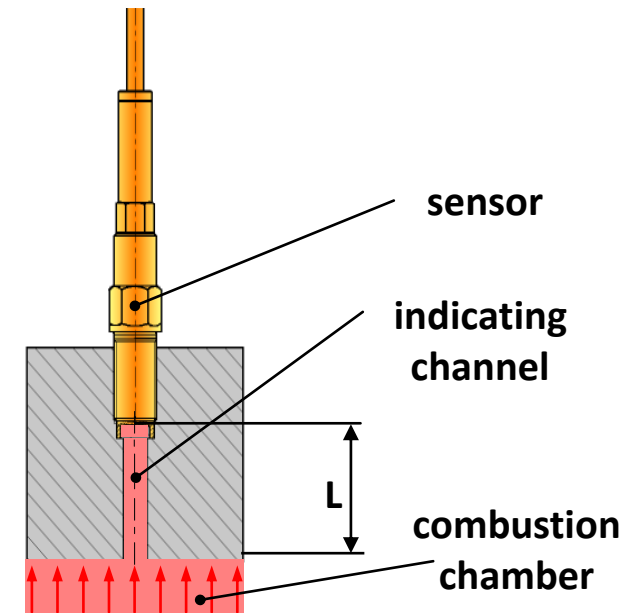
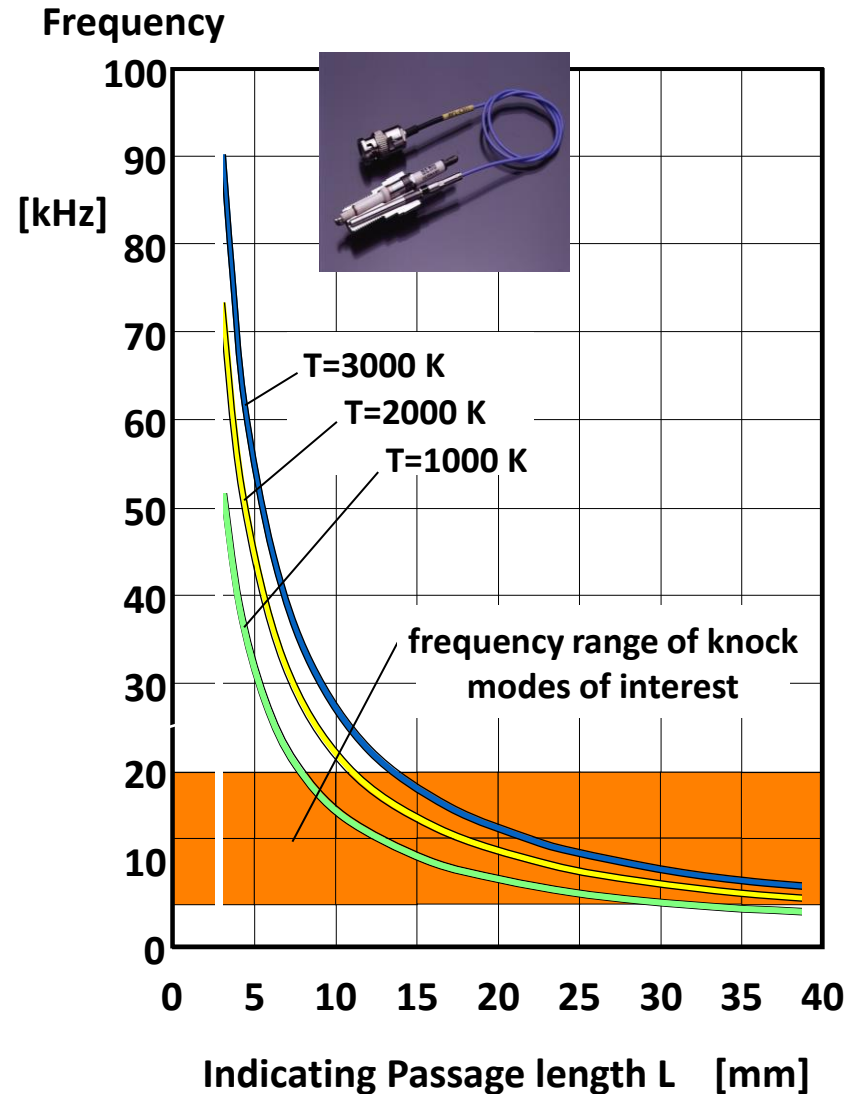
Considerations for Sensor Placement

- Avoid water passages
- Avoid oil passages and areas where oil draining can contaminate the sensor and cable
- Cable routing to avoid hot surfaces such as exhaust or rotating devices such as belts, flywheels and drive systems
- Access to installation and removal of sensors
- Projected angle which accomplishes intersecting combustion chamber
- Length of sensor passage
- Sensor as perpendicular to deck surface as possible (generally not possible to be equal)

Passage Frequency

- Face sealing transducers a passage will exist between the measuring diaphragm and the chamber wall. This passage will have a distinct natural frequency that will be a function of its length, and the temperature of the gas in the passage.

- Minimizing the length of this passage is always good form, to move the natural frequency of the passage above twice the frequency range for knock (typically 5-20 kHz).



Frequency $f = C / 4L$ with:

$c = \sqrt{\gamma RT}$ velocity of sound [m/s]

R ... gas constant 287 J/kg•K

γ ... isentropic exponent 1.32

T ... average gas temperature in the indicating channel [K]

L ... length of indicating channel [mm]

Critical Dimensions



- Sensor depth .100 minimum to .125 (2.5-3mm) measured from chamber to sensor seating surface
- Sensors installed on angles need to maintain .100" on minimum depth on the short side of the sensor port
- Sensor torque is 1.5 NM (newton meter)
- Sensor plug torque is also 1.5 NM (sensor block off plugs purchased through Kistler)

Sensor Location in Combustion Space

- Sensor passage would ideally bisect squish zone and combustion chamber as shown in the photo →
- Targeting squish and combustion chamber intersection point allows for squish flows and port flows that would normally distort the pressure signal to be rejected from the measurement location (sensor passage)
- Sensor placement should be as far from the valves as possible due to ringing noise which influences data by creating abnormalities
- The sensor should be as far from the spark plug as possible to delay the arrival of the flame front, which is 4000°F hotter than the unburned mixture in the cylinder during combustion.
- Consideration to future cylinder head modification of chamber and squish surface (chamber shaping and milling) should be considered prior to sensor placement
- Sensor placement directly influences data quality, and the quality of any analysis is dependent on the quality of the data.



Flame Arrestor

- Reduces cyclic temperature drift up to 50%
- Increases sensor lifespan
- Minimizing sensor damage from high pressure knock events



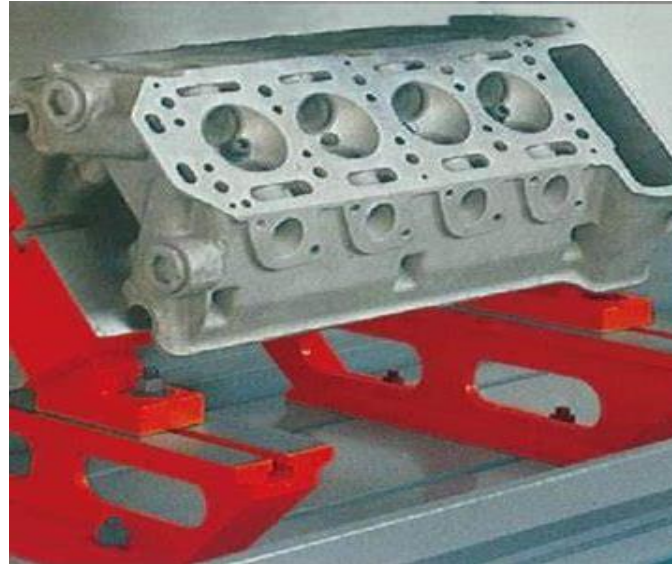
Tooling

- Form tool machines the following:
 - .120 passage (3mm)
 - Tap drill for M5×0.5 thread
 - Sealing surface for sensor
 - Socket clearance
 - Can also be accomplished with 3 separate machine tools if customer preferred.
-



Setup for Machining and Replication

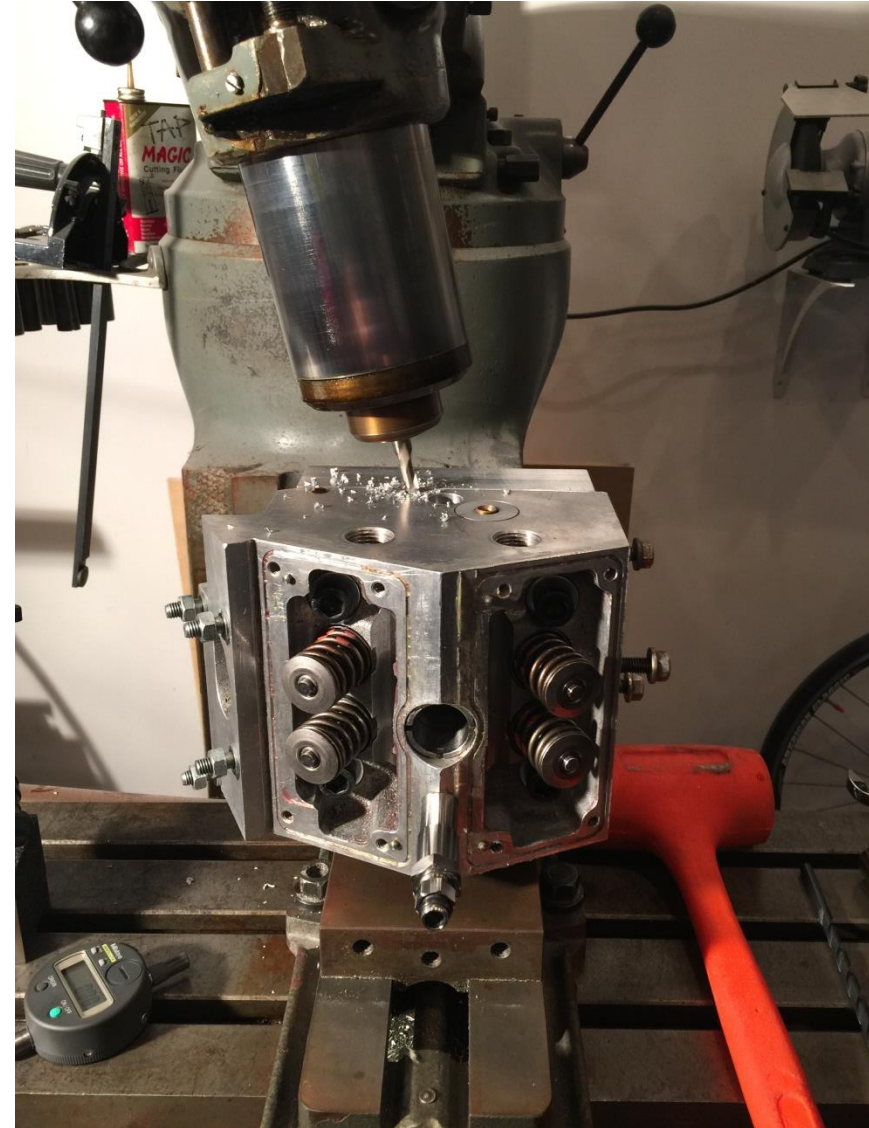
- Milling machine or CNC ability to angle head depending on fixture ability to position vs project needs
- Robust roll over fixture/ fixture plate
- Ability to create machine moves off dowel location in fixture plate supports repeatable results and removal during time of proofing machining
- Ability to move on bore center cylinder to cylinder
- Ability to see the combustion chamber is a plus for proofing first hole to depth
- Setting a positive stop for Z depth on mills quill (manual)



Pre-Drill Operation

BEFORE DRILLING WITH THE STEP DRILL, IT IS IMPORTANT TO SPOT FACE AND CENTER DRILL TO ENSURE THE DRILL PENETRATES THE CYLINDER HEAD IN A STRAIGHT LINE.

- Form tool maximum diameter is $\varnothing 7.5\text{mm}$ so an $\varnothing 8\text{mm}$ center cutting end mill was used to spot face the outside of the cylinder head. The end mill is plunged into the side of the cylinder until it had cleaned up a fully circular pad at the angle.
- The spot face is followed by a center-drill that provided a precisely centered feature for the step drill to start.



Machining for Sensor Installation

USE CUTTING FLUID DESIGNED FOR THE MATERIAL BEING MACHINED WITH HIGH SPEED STEEL (HSS) CUTTER

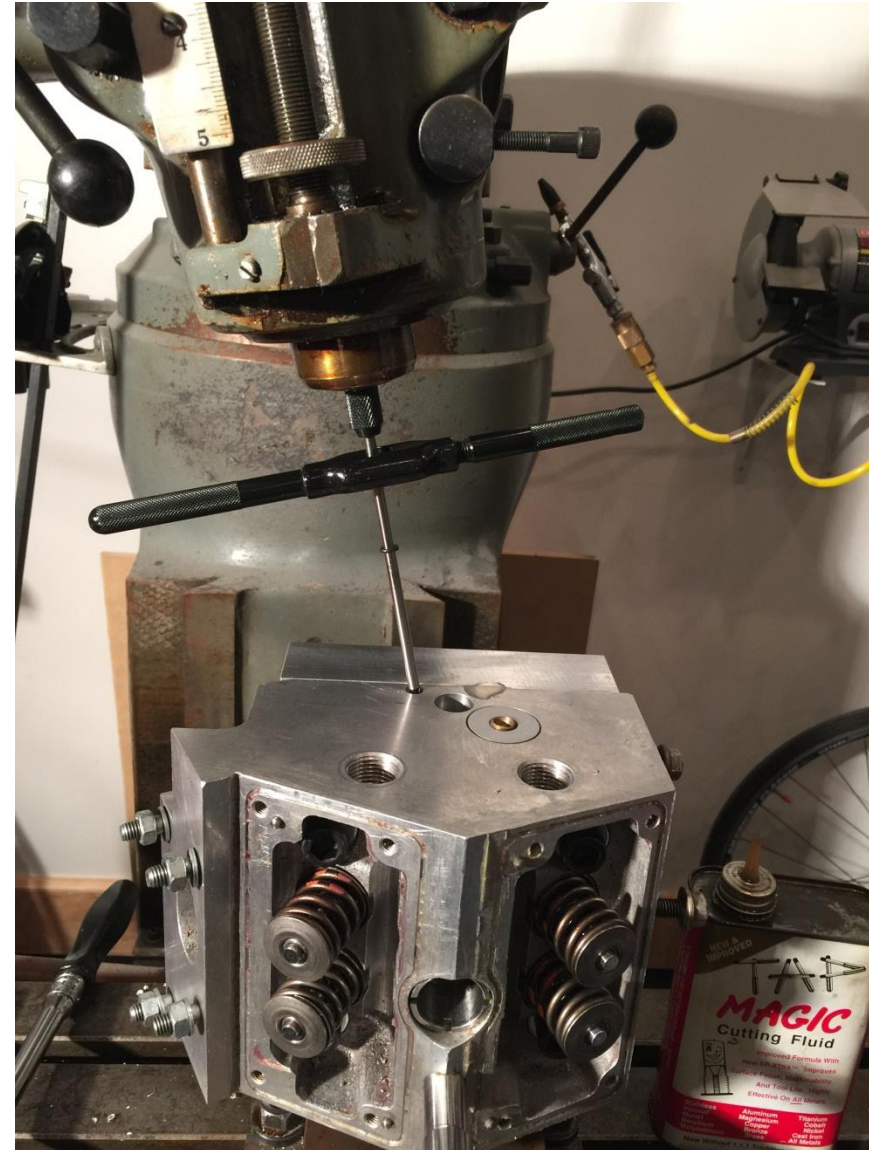
- Drill thru with step drill into the centering and spot faced area.
- Set depth based on CAD data or measure tip protrusion of form drill into chamber. Subtract the protruding tip from the overall length of the .120 diameter section which indicates the depth of the seating shoulder above.
- For deeper holes, clear chips regularly and use an appropriate cutting fluid.



Sensor Threading and Tapping

USING A CENTERING GUIDE (LIGHTLY SPRING LOADED), PERFORM TAPPING OPERATION.

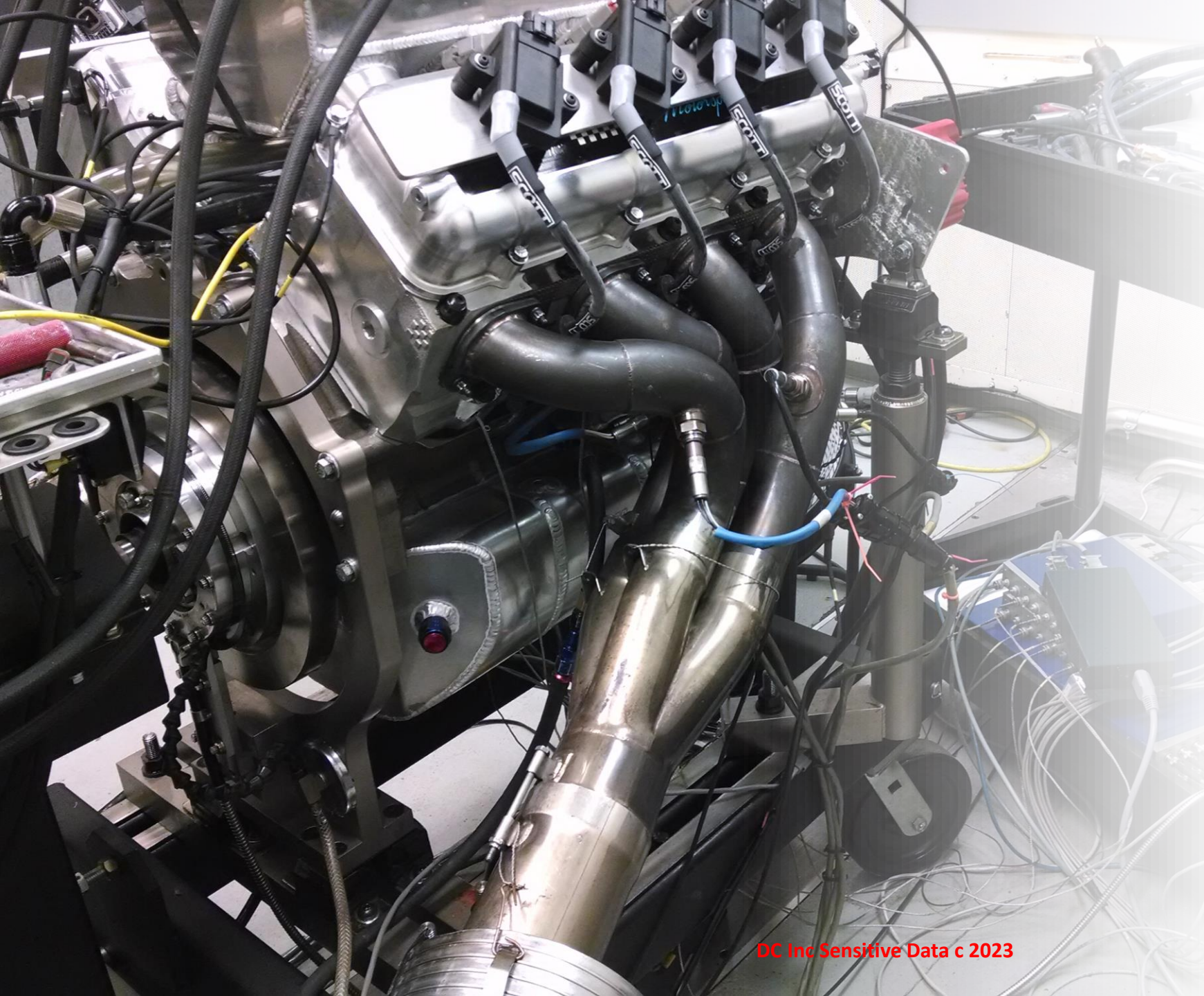
- The spring-loaded centering point holds the tap precisely on the center line of the machined bore. Such centering points are available with convex and concave tips, for use with taps that have centers or points.
- Use the appropriate cutting fluid such as Tap Magic for aluminum.
- Tap guide in piloted hole when having to hand tap to ensure proper threading without machine guidance
- **16 Turns is fully threaded**
- After tapping operation is complete, the new machined features should be deburred and thoroughly cleaned



Optimal Mounting



- Avoids Water and Oil Passages when possible
- Easy Access to Installation and Removal
- Cable Routing Avoids Hot or Moving Parts
- Sensor is Placed Correctly in Chamber for High Quality Data
- Accomplished Equally on all Cylinders
- Mounted in Parent Material



• Crank Triggering

Utilizing rear of crankshaft increases accuracy by minimizing torsional deflection that would be present at the crank snout.

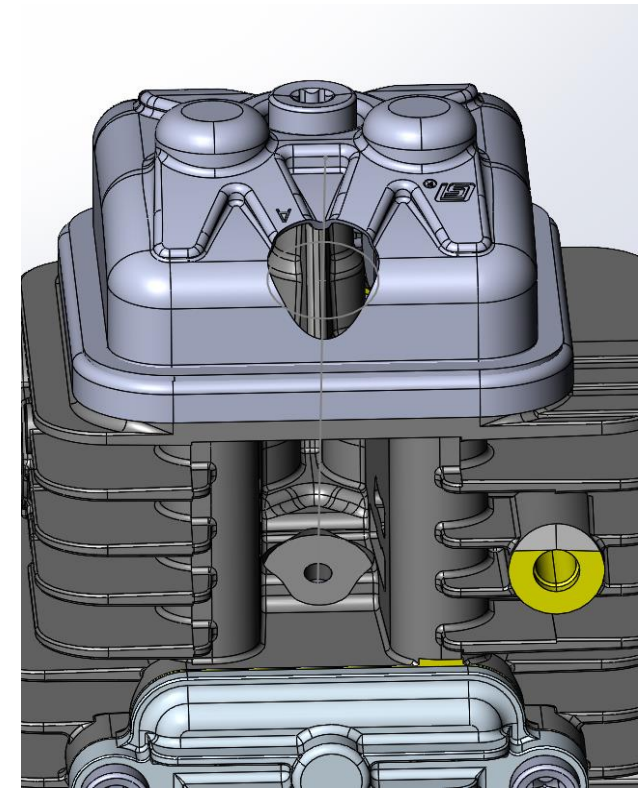
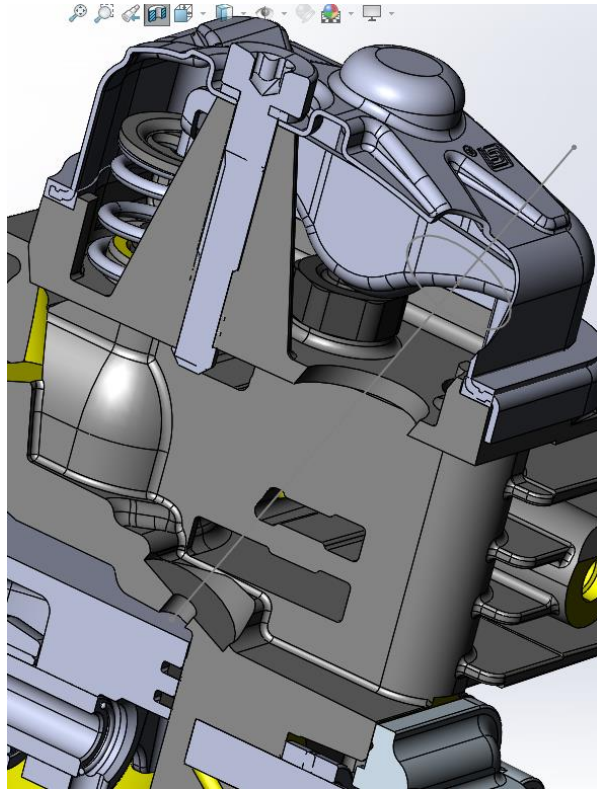
Modern engines such as LS and Gen3 Hemis, powersports and imports can utilize the factory reluctor by splicing the signal from the factory crank pickup to the Plex system.

Trigger wheels can be toothed, or encoder, in general the higher the tooth count the better the resolution. A 60-2 trigger wheel is a cost effective commercially available option that provides accurate results due to the sophisticated interpolation algorithms in the Plex system.

One-degree crank encoding for high-speed data is sufficient for IMEP based calculations. Moving to 0.5° sampling when assessing knock events along with filtering adjustments in the Plex system.



Special Applications



Examples of Adapter Sensor Port

- CAD helps determine location, machining depth, thicknesses, pierce point and obstructions faced before machining
- When parent material thickness is not available for tapping
- Access limits the ability to weld on a boss or extra material
- Need to get above oil or water
- This adapter is machined to fit bonded with epoxy into location welding was not an option for access and distortional constraints
- Very small cylinder (36 cc engine) with blind machining was a challenging configuration

Example of Passing Through Fluids

- Seating surface 37-degree matching taper mating surfaces to avoid leaks
- Epoxy to ensure sealing internally and externally
- Pressure checks should be performed prior to head assembly and installation



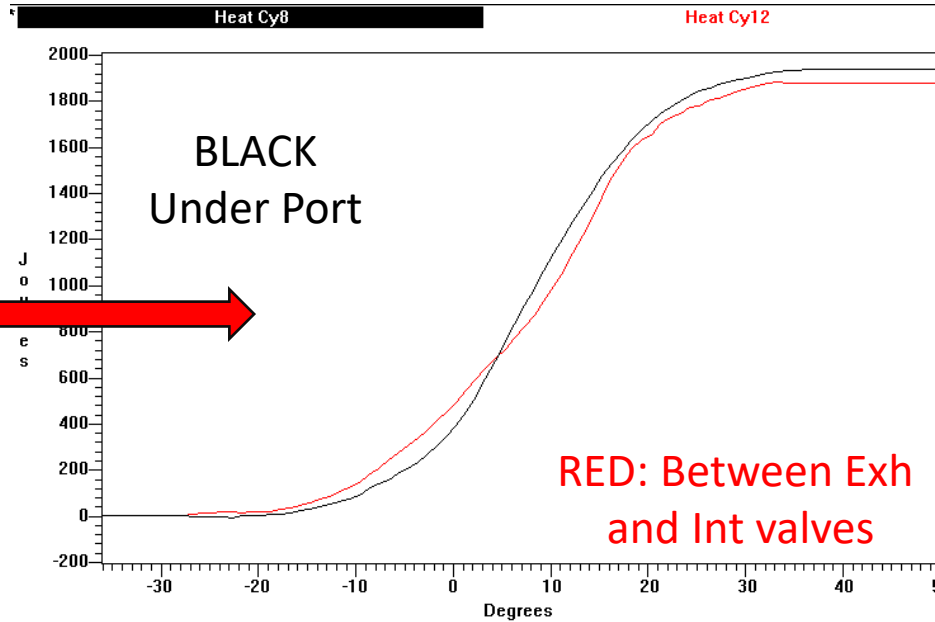
Mounting Position Comparison

- Position under port is the intersection of combustion space and squish zone
- Position centered in port has all influence of port flows without squish-based flow patterns
- In-between largest thermal contrast
- Sensor position has a direct effect on accuracy of collected data as presented in next slide

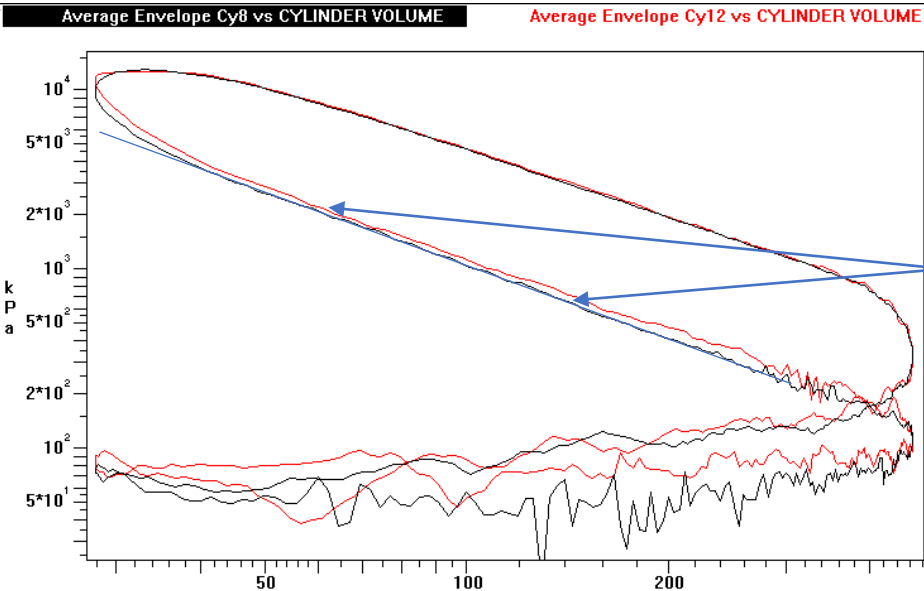


Data Quality vs Sensor Placement

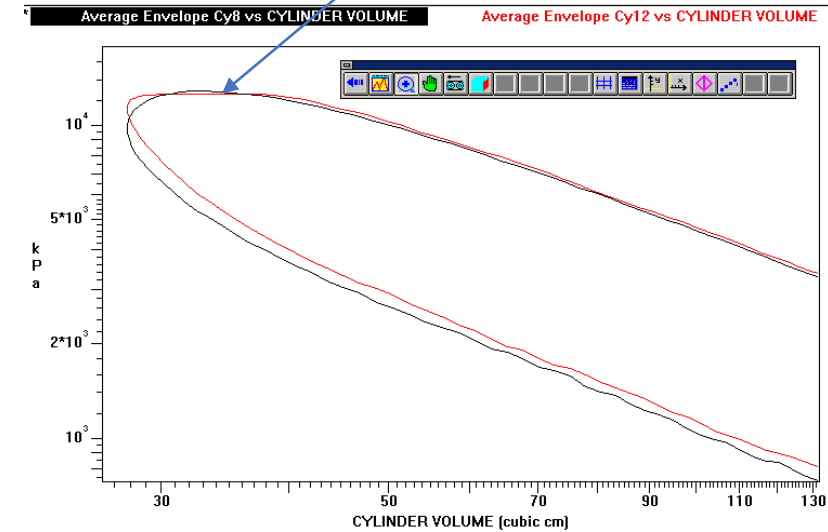
Heat release: **red** curve shows accelerating and decelerating and accelerating burn rates. Heat release is the foundation of all IMEP and burn rate calculations (ca10,ca50 etc.) must be correct.



Combustion pressure his is not normal



PV data **red** curve is unreasonable because of undulations during compression stroke.



General Overview

Taking the time to understand proper sensor installation is an investment with compounding returns

- DATA QUALITY IS DIRECTLY RELATED TO SENSOR PLACEMENT
- SENSORS AND CABLES ARE EXPENSIVE, GREAT CARE SHOULD BE TAKEN TO PROTECT SENSORS FROM CONTAMINATION, HEAT AND DAMAGE
- AVOID ADAPTERS AND INTERSECTING FLUIDS WHENEVER POSSIBLE, HOWEVER PROPERLY DESIGNED AND INSTALLED ADAPTERS CAN BE SUCCESSFUL IF REQUIRED
- USING CAD MODELS WHEN AVAILABLE TO SUPPORT PROPER SENSOR PLACEMENT CAN BE HIGHLY VALUABLE
- MAKING EDUCATED DECISIONS ON THE TRADEOFFS OF CASTING LIMITS VS SENSOR LOCATION PLACEMENT IS PART OF SUCCESSFUL SENSOR INSTALLATION
- PATIENCE AND EXPERIENCE WILL PREVAIL DURING SENSORS MOUNTING BORE ADAPTATION