COMBUSTION, EFFICIENCY, AND FUEL EFFECTS IN A SPARK-ASSISTED HCCI GASOLINE ENGINE

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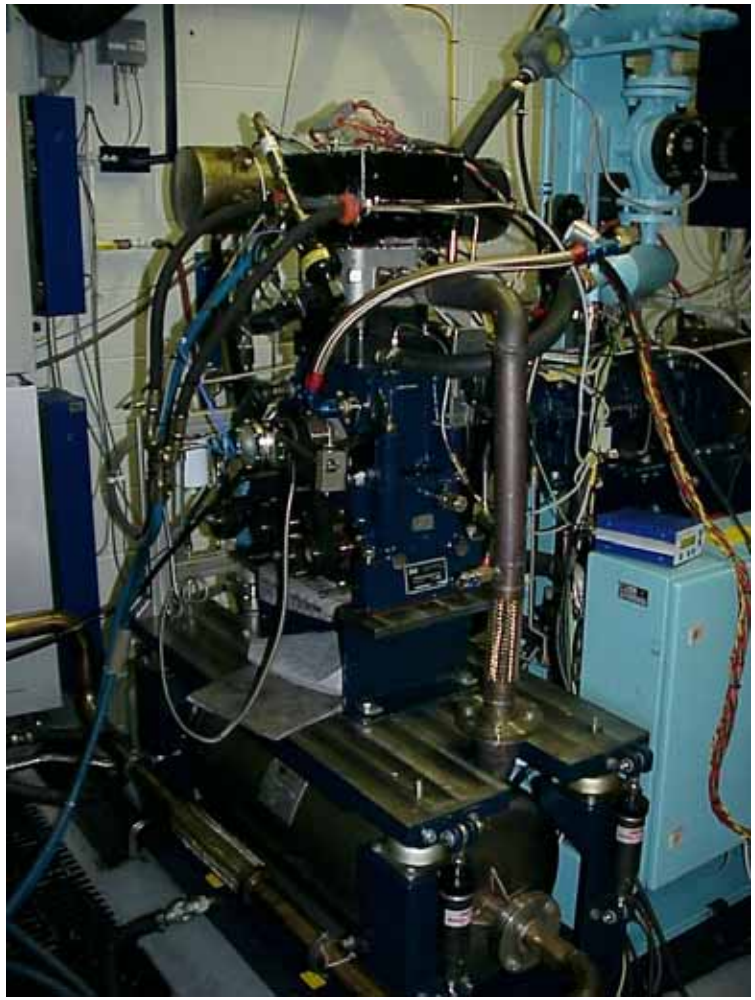
Overview

- **HCCI stability and control continue to be major barriers to the implementation of HCCI**
- **Although the operating envelop of HCCI is expanding, it is likely that conventional combustion will still be used for some operating conditions**
- **Spark ignition has been used by others for engine starting and to assist transition to HCCI, but results relative to HCCI combustion control have been mixed**
- **HCCI engine platform is also being used to evaluate fuel effects**

Single cylinder research engine used for studies



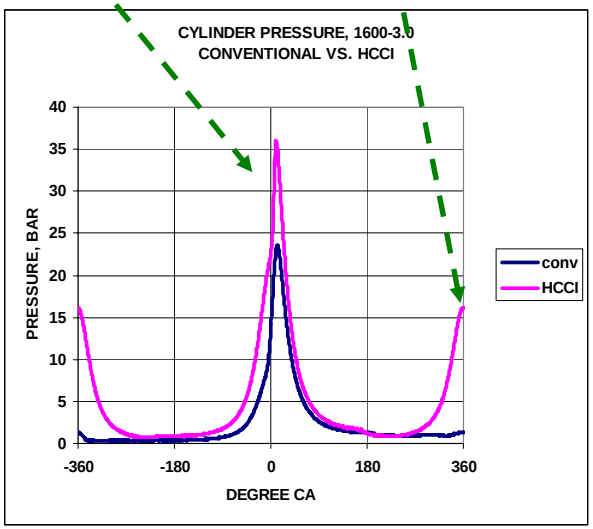
- Capable of HCCI, mixed mode, and conventional operation
- 500 cc, 11.34 C/R
- 2 valves, naturally aspirated
- Gasoline port fuel injection
- Spark ignition
- Fully variable valve actuation
- HCCI currently initiated by early exhaust valve closing
  - "negative overlap"
  - Retains heat in cylinder
  - Retains internal EGR
  - Typically operates at > 50% EGR

Comparison of conventional combustion to HCCI combustion

Comparison of conventional to ‘negative overlap’ HCCI combustion

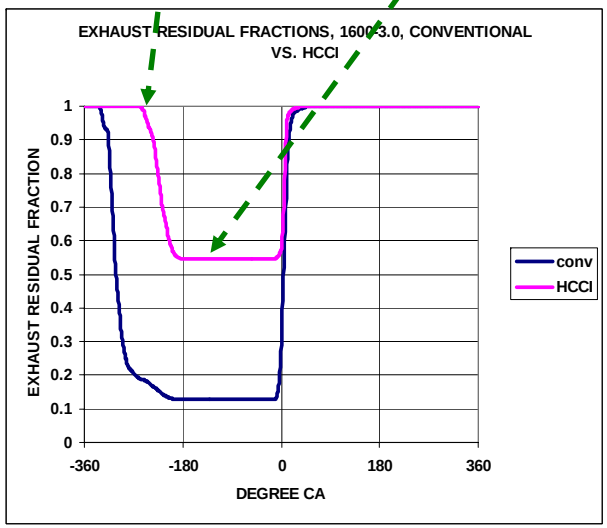
HCCI has higher peak cylinder pressure and more rapid heat release

HCCI shows recompression of retained exhaust due to early exhaust valve closing



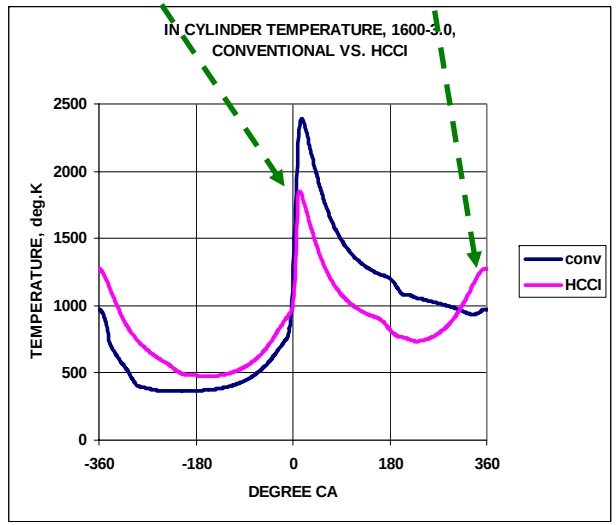
HCCI has later intake valve opening

HCCI has higher level of retained exhaust



HCCI has lower peak combustion temperature

HCCI shows recompression of retained exhaust due to early exhaust valve closing



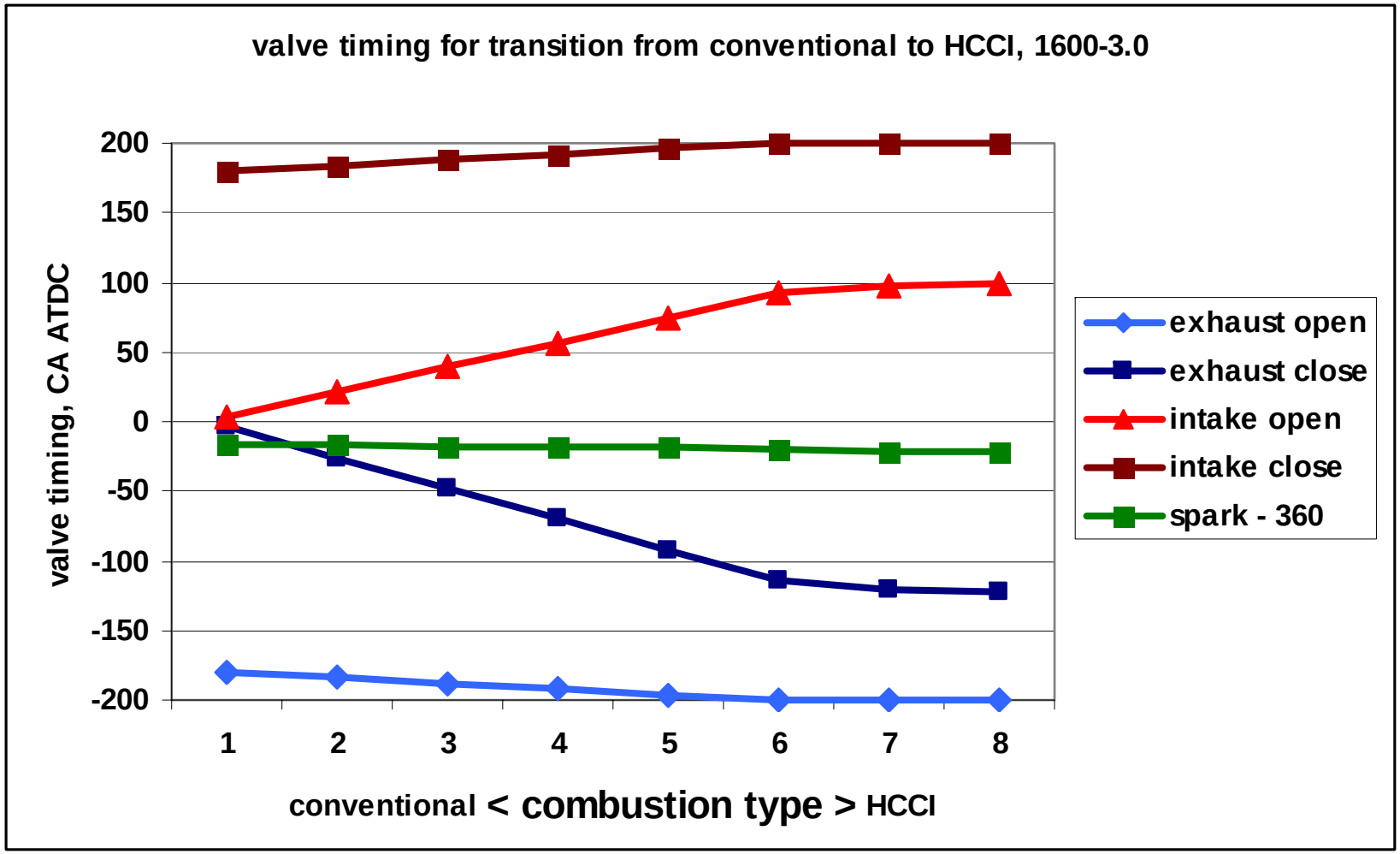
Average results
1200 to 2400 rpm, 1.5 to 4.5 bar IMEP

- **HCCI operation improved fuel economy by 12% vs. conventional**
- **HCCI operation reduced NOX emissions by 95% vs. conventional**
- **Spark assist slightly improved stability of HCCI combustion**
- **Some speed / load combinations would not run except spark assisted**

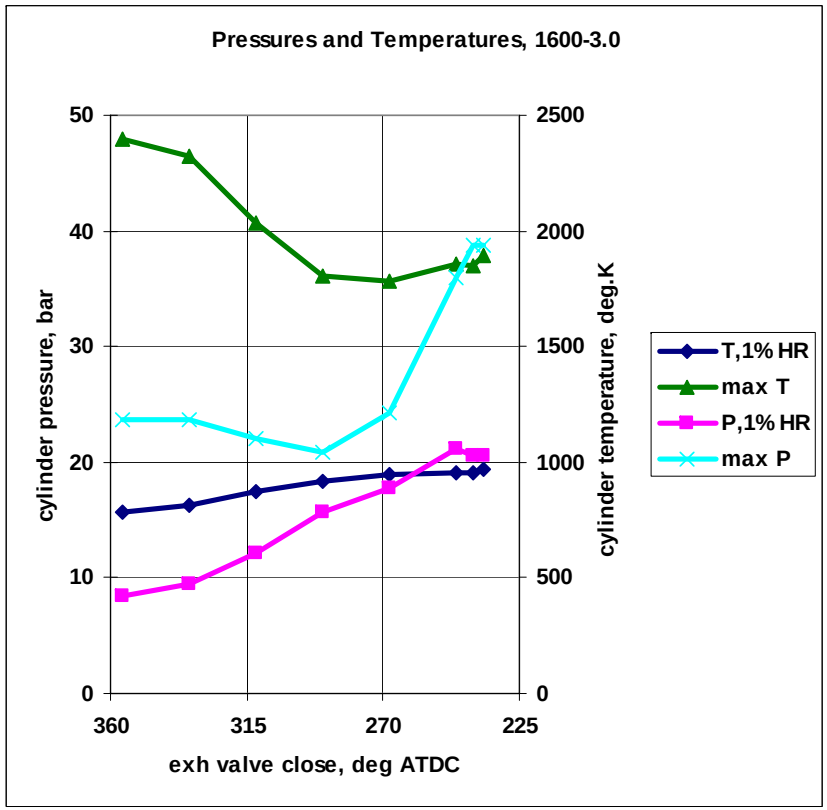
- **Only data from 1600 rpm, 3.0 bar IMEP will be presented in subsequent detailed analysis, similar results found at all speeds and loads evaluated**

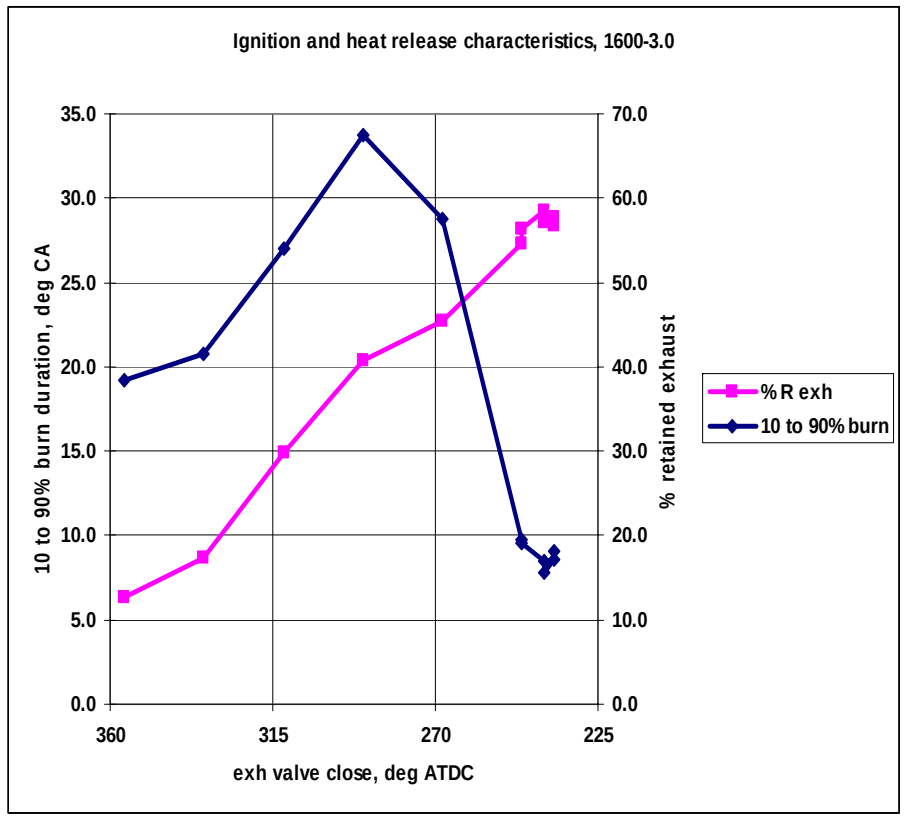
Transition from conventional to HCCI combustion

Valve timing control for transition to HCCI ("negative overlap")

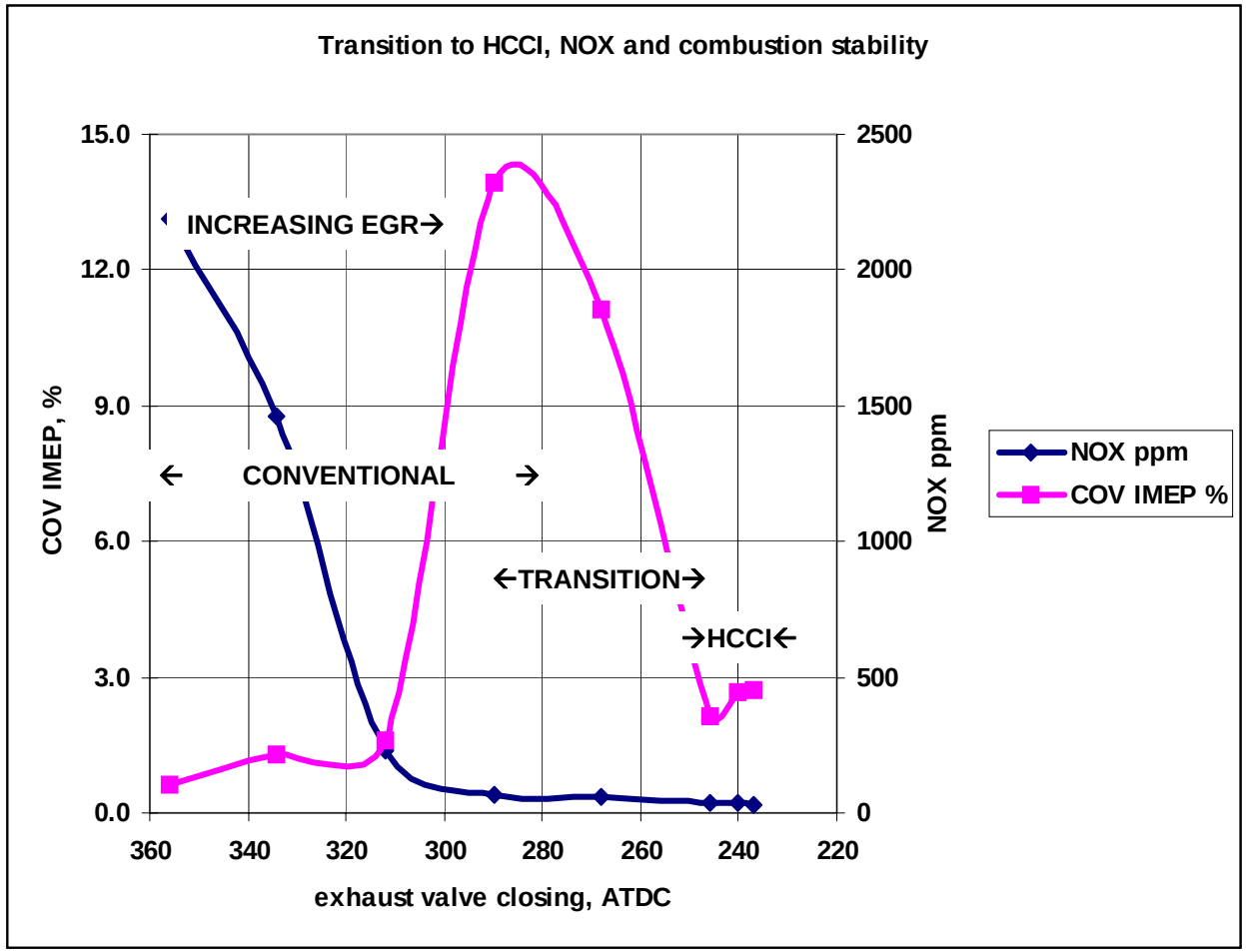


Transition from conventional to HCCI





Transition to HCCI, NOX and combustion stability



HCCI performance

- **Dilution with internally retained exhaust provides low NOX**
- **Fuel efficiency gains associated with faster heat release and un-throttled operation**
- **HCCI allows stable operation at very high EGR rates**
- **Spark provides transition to HCCI mode**
- **Once in HCCI, spark can be left on or turned off, but it still has some effect**

Fuels comparisons

Fuels test strategy

- Initial fuels matrix (complete)
  - Indolene baseline
  - Vary MON, fixed RON
- Second fuels matrix (in process)
  - Indolene baseline
  - Constant RON and MON
  - Vary fuel chemistry
  - One ethanol fuel
- Further work based on above results

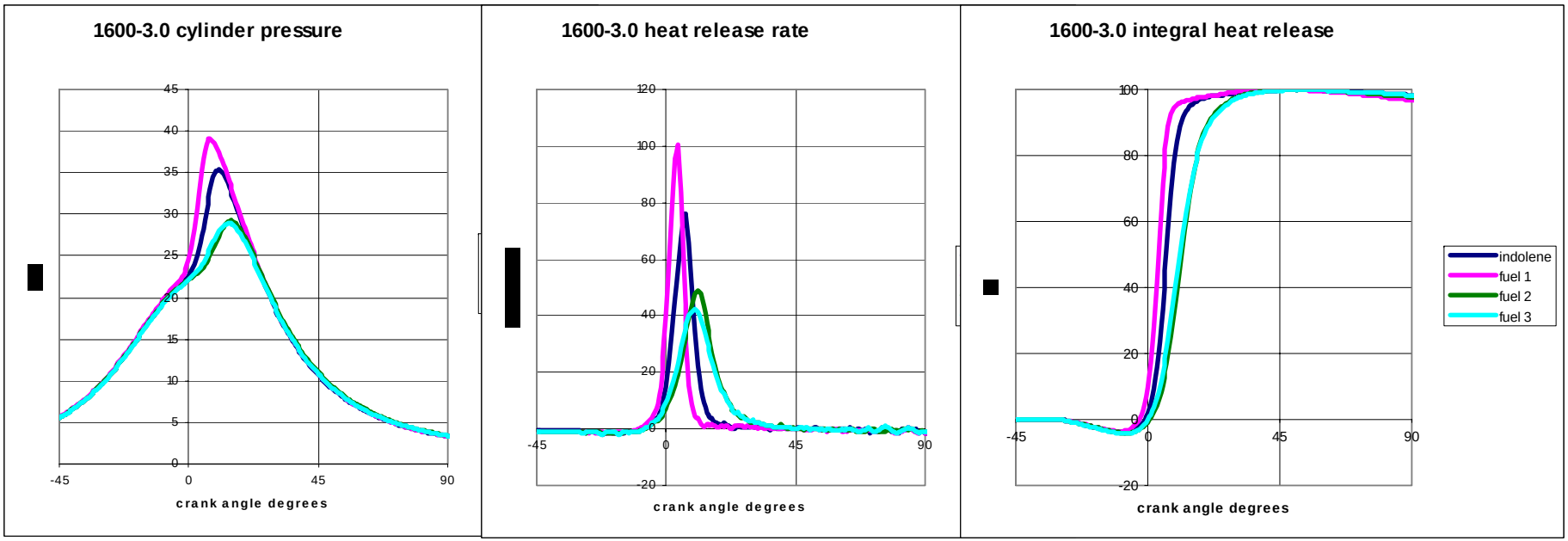
Fuels evaluated

	RON	MON	DENSITY, 60F	RVP, PSI	GROSS HEATING VALUE, BTU/LB	IBP, C	FBP, C	FUEL BLEND
Indolene	96.5	88	0.745	8.3	19550	31	198	full boiling range
Fuel 1	97.4	80.9	0.822	3.8	18867	62	110	4 pure HC
Fuel 2	99.5	86.8	0.76	3.2	19647	72	117	5 pure HC, 50% #1 and #3
Fuel 3	96.3	94.5	0.695	1.9	20487	98	104	2 pure HC - PRF

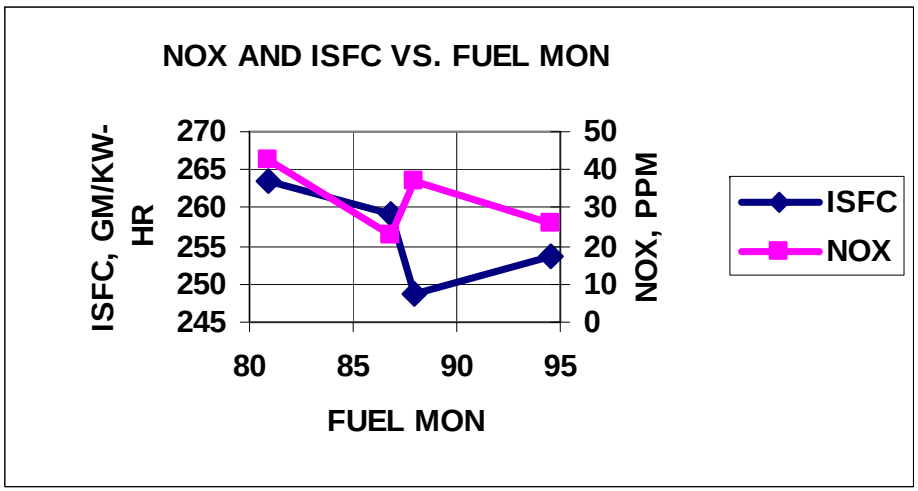
Test fuels composition

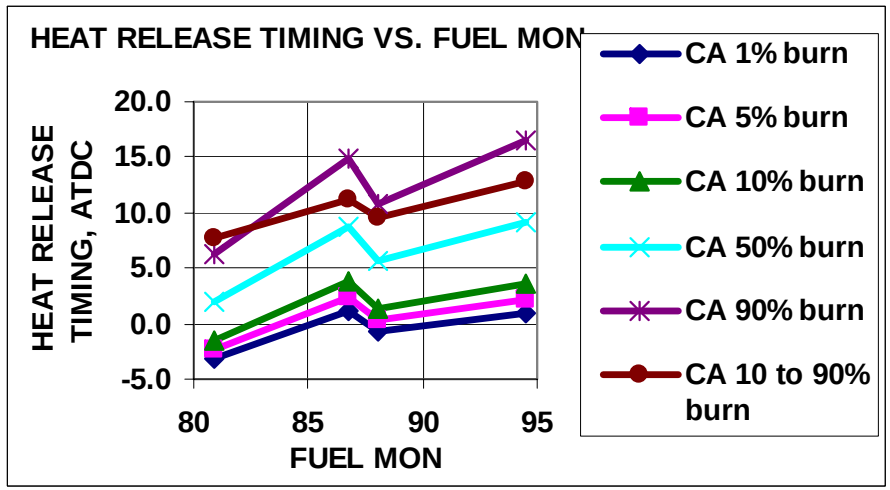
	INDOLENE	FUEL 1	FUEL 2	FUEL 3
Toluene	xxx	60.0%	30.0%	
Cyclopentene	xxx	20.0%	10.0%	
Cyclohexane	xxx	10.0%	5.0%	
n-Heptane	xxx	10.0%	5.8%	1.5%
Iso-octane	xxx		49.3%	98.5%

Comparison of fuels at 1600-3.0

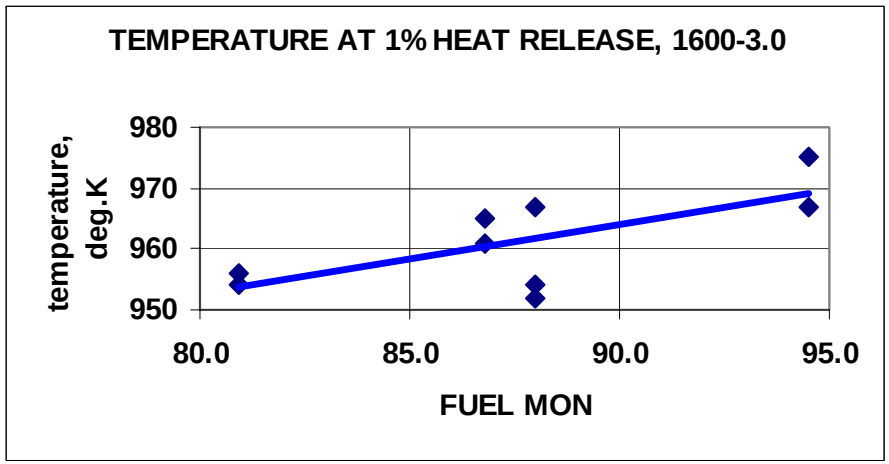


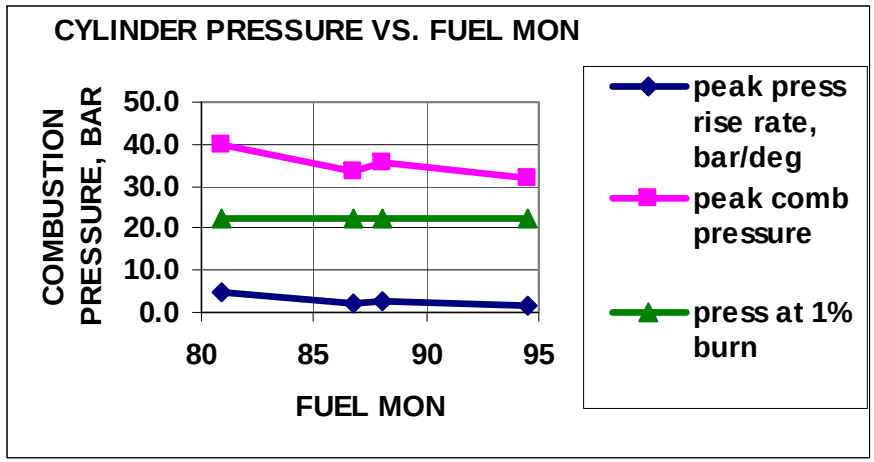
Performance vs. MON, 1600-3.0





Performance vs. MON, 1600-3.0





Summary

- **Data demonstrates advantages of HCCI combustion over conventional throttled operation**
  - **Better fuel economy**
  - **Lower NOX emissions**
- **Spark assist can help transition to HCCI combustion and extend operating range and stability**
- **Spark assist can remain 'on' in HCCI mode since influence of spark can be varied by spark and valve timing**
- **Fuel properties (in this case – MON) have a large effect on HCCI operation**
- **Chemistry or volatility effects may also exist**

Future work

- **Second fuels matrix**
  - **8 fuels**
  - **Constant RON and MON**
  - **Chemistry and volatility differences**
- **Further explorations of combustion transitions, mixed mode operation, and methods of HCCI control**

Acknowledgments

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