

BKM Fuel Injection Technology Update

Direct In-cylinder Injection for Gasoline Engines



BKM has developed and demonstrated single cylinder engines using a unique electronic fuel injection system designed for low cost, high production volume engines. The Single Plunger System (SPS) has demonstrated **low exhaust emissions** and improved engine performance. A detailed description of the fuel system and early test results are presented in SAE Paper 1999-01-3312, available at www.sae.org or from BKM.

Several engine manufacturers have secured licenses to this technology, representing the following product categories:

Utility **Outboard Marine**
Moped **Scooter**
Motorcycle **Personal Watercraft**



Compliance has been demonstrated with:

- US EPA 2006 Marine Engine Regulation
- CARB 2000 and subsequent Small Off-Road Engine Standards
- Europe and China (Euro 1) without catalyst

The unique advantages of BKM's SPS system include the following:

- Simple, low cost hardware and design integration into the engine
- High operating speeds: injector charging occurs over a large portion of the engine cycle
- Cycle-by-Cycle control of fuel delivery and injection timing
- Spray quality at starting and low engine speeds is maximized because injection pressure and duration are independent of engine speed
- A non-coalescing "expanding cloud" injection spray results from the decreasing injection rate during the injection event
- Evaporative cooling protects the piston and cylinder from thermal related problems
- Optional: Mechanical injection at cranking speed, for starting without electric power
- Optional: Intermittent cycle injection (skip-fire) provides part load combustion improvement

How It Works:

- ▶ The system involves pressurizing fuel within an injection nozzle and subsequently releasing the pressurized fuel into the combustion chamber on command.
- ▶ The pressurization function occurs over a large percentage of the engine cycle, providing consistent control and eliminating high rate mechanical loads. This concept provides very short injection duration throughout the dynamic operating range of the engine as well as high injection frequency capability.
- ▶ The addition of full authority electronic control provides control flexibility and the opportunity for speed and load dependent calibration of the fuel injection event.
- ▶ The combination of unique components and control schemes has resulted in a flexible electronic direct fuel injection solution, which is applicable to low cost single, and multi-cylinder engines.
- ▶ Components include a single plunger pressurizing pump, a fuel injector, a precise magnetically latching 2-way solenoid valve, a controller and sensors.
- ▶ The control scheme involves both fuel quantity and timing control by means of solenoid valve timing strategy. Skip-injection strategy for improved part load or idle combustion efficiency is optional.

Summary of License Provisions:

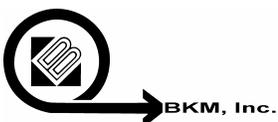
- ▶ Non-exclusive license between engine builder and BKM.
- ▶ A fair and reasonable technology transfer fee, payable to BKM.
- ▶ Licensee has option to make or buy parts. There is no exclusive source for parts, so the engine builder can manufacture or select the best available supplier. Part commonality and high production volume would put best suppliers into a "virtual" exclusive position.
- ▶ Basic technology and BKM improvements are owned by BKM.
- ▶ Ownership of technology & improvements developed by licensee is negotiable.
- ▶ A fair and reasonable royalty based on number cylinders.
- ▶ Demonstration project fees are credited as prepaid royalties.

BKM: founded in 1975, is a product design, research & development, and engineering services company. Our clients rely on us for advanced mechanical, hydraulic, electronic and hybrid solutions to a wide variety of technical challenges.

BKM: has successfully engineered products for manufacturers, service organizations, universities, research institutes, and government agencies. This work has resulted in breakthroughs in internal combustion engine fuel systems and controls.

SERVICES OFFERED:

- Product Design & Development
- Engine Performance & Emissions Testing
- Analytical Simulation
- Fuel System Design
- Computational Fluid Dynamics (CFD)
- Test Equipment Design & Manufacturing
- Precision Prototype Machining
- Electronic Hardware Design
- Solenoid Valve Design and Manufacturing
- Control Software Engineering



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