Tier 4 Bobcat Engine

Andrew Johnson – Product Service Manager, Bobcat Company
Rocky Mountain Asphalt Conference and Equipment Show
Feb. 21st 2018
Overview

• Tier 4 Diesel Engine Technologies
• Bobcat’s Tier 4 Engine Solution
  – Tier 4 Technology Choices
  – Loader Design Impact
  – Overall and Application Specific Benefits
• Making the Most of Your Tier 4 Equipment:
  – Best Practices
Tier 4 – Terms and Acronyms

- HPCR - High Pressure Common Rail
- DOC - Diesel Oxygen Catalyst (no regen)
- DPF - Diesel Particulate Filter (regen required)
- SCR – Selective Catalyst Reduction (desox, no regen)
- DEF – Diesel Exhaust Fluid (urea/water mixture)
- Regulated Tailpipe Emissions:
  - PM – Diesel Particulate Matter
  - NOx – Nitrogen Oxides (NO and NO₂)
  - CO – Carbon Monoxide
  - HC – Hydrocarbons
Emission Regulation Levels

- Interim Tier 4 regulations required a 90% reduction in particulate matter (PM) along with a 50% drop in nitrogen oxides (NOx) from Tier 3.
- Tier 4 regulations = PM and NOx + HC emissions to near-zero levels.

---

**Nitrogen Oxides** - NOx, (g/kWh)

**Particulate Matter** - PM, (g/kWh)
High Pressure Common Rail Fuel System

- Fuel Pressures of up to 45,000 PSI
- Electronic injection control
- Injector nozzles have extremely tight tolerances and clearances to precisely control fuel injection timing and quantity
  - Many use multiple injections per combustion event
  - 2-5 micron tolerances (size of a red blood cell)
  - **Fuel must be extremely clean**
    - Dust or water in the high pressure system will destroy injectors
Diesel Oxidation Catalyst

• Similar to a catalytic converter in your car.
  – NOx, Hydrocarbons, Carbon Monoxide, and some types of PM in the exhaust stream chemically react with the hot catalyst and are converted to Water and Carbon Dioxide.
Diesel Particulate Filter - DPF

- The DPF is an emissions reduction device that removes diesel particulate matter (soot) from the exhaust gasses of the diesel engine.
- The DPF will trap and collect the soot until it is burned off.
- The process of burning off the collected soot is called regeneration.
- Eventually (3000+ hours usually) soot levels reach a point where off machine cleaning or DPF replacement are required.
Selective Catalytic Reduction (SCR)

- An SCR system is needed on engines above 75HP to meet the emissions standards for that HP range.
- SCR systems consist of the Diesel Exhaust Fluid (DEF) tank, controller, pump, dosing injector, and an SCR catalyst.
Step 1:
Urea is injected/atomized into the exhaust

Step 2:
Urea reacts with heat and converts to Ammonia

Step 3:
Ammonia reacts with NOx and passes over the catalyst converting it to Nitrogen and water

Step 4:
NOx levels now satisfy emission requirements
Diesel Exhaust Fluid

- **Diesel Exhaust Fluid (DEF)**
  - Non-toxic fluid that contains purified water and automotive-grade urea
  - 67.5% water – 32.5% urea
  - Nitrogen-based compound that turns into ammonia when heated

- **Proper DEF handling**
  - DEF is nontoxic, non-hazardous, and nonflammable.
  - DEF is corrosive to many materials including most metals, rinse your equipment with plenty of water if DEF is spilled

- **What if something else is put in the DEF tank?**
  - Restoring DEF concentration will require flushing, cleaning, and refilling the tank with clean and pure DEF.

- **Automotive-grade urea is of higher quality than the agricultural urea used in fertilizer and cannot be substituted**
  - Tight tolerances on mixture/quality
  - DEF quality sensor
Bobcat Tier 4 Emissions Solutions

- 25+ HP: “Bobcat Engine”

- All Bobcat Engines feature a non-DPF Tier 4 solution
  - 1.8L, 2.4L, and 3.4L engines

- 3.4L engine rated at 74 HP
  - No DPF
  - No SCR system = No DEF

- All other models with 3.4L engine (75 hp+) will have:
  - Selective Catalytic Reduction (SCR) system
  - Diesel Exhaust Fluid (DEF)
After-treatment Comparison

Diesel Particulate Filter (DPF) vs. Diesel Oxidation Catalyst (DOC)

**Conventional DPF After-Treatment System**

DOC+DPF <75 HP
DOC+DPF+SCR >75 HP

**Bobcat After-Treatment System**

DOC <75 HP
DOC+SCR >75 HP

The conventional DOC/DPF system from the 3.8L iT4 engine we used prior to implementing the T4 Bobcat Engine. It uses a DPF to capture the soot produced by the engine and needs to run a regeneration process to burn this soot out of the filter.

On the Bobcat engine soot generation is minimized during combustion: a DPF is not needed. A DOC is used for NOx and Hydrocarbon reduction.
No DPF?

A non-DPF solution was achieved with engines designed bottom up to meet the T4 requirements as efficiently as possible. Key technology advances include:

**Ultra Low Particulate Combustion (ULPC)**

The ULPC system utilizes a highly engineered piston bowl shape that maximizes air/fuel disbursement in the cylinder. When combined with improved injector calibration this enables precise control of combustion timing, duration, and efficiency, reducing PM.

**C3I Injector Calibration**

A typical HPCR engine used 8 fueling parameters to calibrate injections. This has been increased to 20 parameters enabling more precise injection quantity, reducing unburned hydrocarbons.

![Combustion Bowl](image1)

- **Soot Simulation for DPF version**
- **Soot Simulation for ULPC version**

Red : High Soot  
Green : Low Soot
LOADER DESIGN IMPACT
T4 Engine Impact on Bobcat Loader Design

• All machine sizes:
  – Maintaining excellent serviceability was a key factor.
  – Fuel filtration requirements for HPCR engines in T4 applications are extremely stringent.
  – Fuel cooling is required due to high volume of hot fuel returning to tank.

• 75+ HP machines:
  – HEAT: SCR and DPF after-treatment solutions can add significant heat to the engine compartment
    • Bobcat’s solution maintains serviceability, visibility, and machine size targets
      – Addition of cooling fans to air-cool the SCR
Maintain Excellent Serviceability
T4 Design Changes

Fuel Cooler:

Fuel filter size:
Maintain Excellent Visibility

- Additional air inlets
- Additional air outlets
Rear of machine

- Air outlet structure adds minimal height
- Metal cover plate protects internal components
Inside Rear Door

• Electric air inlet fans
Engine compartment

- DOC
- SCR

Bobcat
One Tough Animal.
BOBCAT ENGINE BENEFITS
Bobcat Engine Benefits

• Engine designed specifically for Bobcat Compact Equipment
  – Demanding applications with constantly varying load and engine speed requirements
  – HPCR and custom calibration allow us to control combustion pressure – less noise and improved fuel efficiency when peak torque is not required.

• HP/Torque Optimized for each machine
  – Very wide peak torque curve:
    • Even inexperienced operators are able to use most of the available engine torque.
  – Peak torque is achieved at higher RPM

• The Result: More power where you need it most.
  – 3 to 12% more HP at Max Torque depending on model
Bobcat Engine Benefits (cont’d)

- **No-DPF = less operator confusion regarding regeneration**
  - Operator confusion can lead to a plugged DPF needing Parked or Service Regen and associated downtime.

- **Cold start protection**
  - Electronically controlled HPCR engine allows us to protect vital engine components after cold starts:
    - Reduce torque and RPM until oil is warmed and oil pressure is stable (3-4 min.)
    - Prevent component wear / keeps turbo speed low

- **Cold weather operation:**
  - High efficiency / low micron rating fuel filtration can lead to issues with filter plugging due to fuel cloud point in cold weather
  - Bobcat utilizes the Bobcat Fuel Recirculation Valve to keep fuel above cloud point and ‘melt’ wax from the fuel filter
3.4L Engine Customer Feedback

- Machine performance evaluations
  - 74, 85, 92 & 100 horsepower settings
  - S740, T740, T750, T770, S850, T870
  - Over 250 customers & dealer staff evaluated the machines
  - Side by side “demo” evaluations Bobcat SSL/CTL with Bobcat 3.4L vs. Bobcat SSL/CTL with Kubota 3.8L at similar horsepower
  - Long term “in the field” evaluations also completed

- S740/T740 Customer comments:
  - Lower power than 750 but adequate for some applications
  - Will meet the needs for loading and lifting.
  - Would buy higher HP unit for digging/pushing use
  - Customers like lower purchase price and lack of DEF use/costs.

- T750, T770, S850, T870 Customer comments:
  - Power is better
  - Has more torque
  - RPM recovery is faster
What about my application?

• Asphalt and Paving
  – All the benefits previously discussed
  – For clean up machines:
    • Non-DPF Bobcat Engine provides peace of mind knowing multiple short operation cycles won’t plug a DPF due to lack of passive regen
    • HP/Torque and Hydraulic Flow is optimized to maximize performance in each size class
  – For Planers or other High Hydraulic HP attachments:
    • Hydraulic flow and pump sizing is optimized for each machine size and HP to ensure maximum performance for the engine power available.
Proper Maintenance and Care makes Dollars and Sense

BEST PRACTICES FOR TIER 4
Maintenance

Protect your investment with good maintenance practices!

• Air filtration is even more critical than before
  – Tier 4 engines are designed to consume very little oil – oil ring or cylinder wall damage due to dust can quickly contaminate after treatment systems.
  – Use genuine OEM filters

• Engine oil: Follow manufacturers recommendations carefully
  – Proper oil viscosity for expected temperatures is critical! DO NOT ASSUME 15W-40 is correct!
    • Too heavy oil in the winter prevents proper component lubrication and destroys vital (and expensive) engine components
    • Too thin in the summer leads to overheat, oil degradation, and engine damage

• Fuel Filters:
  – Keep spares on hand
  – Use Genuine OEM replacements
Maintenance – Fuel Quality

- Why is fuel cleanliness so important?
  - Damage from contamination is by far the most frequent root cause of problems attributed to fuel injectors
  - Preventing contamination is critical
    - Damaging particles are smaller than the eye can see
    - Filtration: When a micron doesn’t = a micron?
      - Efficiency ratings on filters are critical

[Diagram of fuel filter comparison]
Maintenance – Fuel Quality

• Fuel quality:
  – ULSD fuel has lower lubricity than previous fuels
  – Fuel storage, handling, and selection are critical
    • Fuel quality in North America has declined steadily
    • The most expensive place to filter fuel is on the machine!
      – Use bulk tank filtration and careful handling
  – Additional information:
    • Attend the Certified Labs session on Friday of this show
    • Contact your local dealership
    • AEM CLEAN Fuel information at aem.org/clean
    • Bobcat.com > Search > Fuel Quality
Biodiesel Facts:

- Higher lubricity 😊
- Fuel injection component corrosion risks: 😞
  - Acid formation, hygroscopic: will carry entrained water, biodiesel properties make water separation difficult
- Biodiesel quality properties vary widely 😞
  - Biodiesel quality degrades in storage
- Biodiesel in unexpected places: 😞
  - Suppliers can legally sell 5% Biodiesel without labeling requirements
  - Fuel survey data: more than 5% in several areas with no labeling present

What to do about it? 😊

- Fuel storage:
  - Never store biodiesel in machine or bulk tanks for more than 3 months
- Read your manual
  - Oil change intervals may be impacted
- Machine storage:
  - Follow manufacturer’s recommendations prior to storing machines or periods of disuse
  - Usually includes draining tanks, refilling with 100% petroleum diesel, and running the engine for 30 minutes.

Bottom Line: **Time is NOT on your side!**

- Rust, corrosion, acid formation, and fuel degradation all take time to occur
Cold Weather Fuel Issues

• Fuel “clouding/gelling” cause premature fuel filter plugging issues
• Fuel blends have not matched ambient temperatures
• The most important property to look for in winter fuel suitability is Cloud Point
  • Clouds due to filtration requirements of HPCR engines
    • Cloudy fuel represents wax chains forming
    • Rule of thumb: If its visible, the filter will catch it.

• Bobcat recommends #1 diesel or blends or #1 and #2:

<table>
<thead>
<tr>
<th>TEMPERATURE</th>
<th>GRADE 2-D</th>
<th>GRADE 1-D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above -9°C (+15°F)</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>Down to -21°C (-5°F)</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>Below -21°C (-5°F)</td>
<td>0%</td>
<td>100%</td>
</tr>
</tbody>
</table>
Questions?

Thank You!