



## DISCOVERING HIDDEN ENGINE POWER IN YOUR OFF-HIGHWAY VEHICLE

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### Introduction

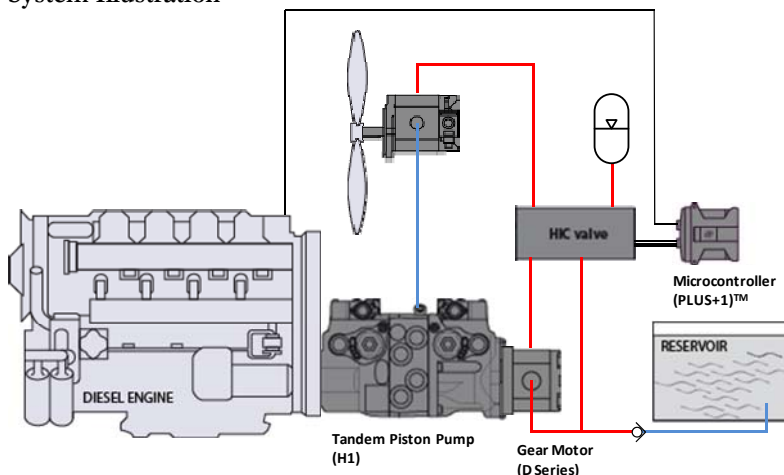
Everybody is talking Tier IV these days; at least we hope so. In 2011 and 2012, the Tier IV interim / stage IIIB emissions regulations for off highway equipment will mandate that new Diesel engines emit significantly lower levels of NOx (nitrogen-oxygen compounds) and PM (particulate matter). The Diesel engine legislation will present a significant challenge to OEMs and suppliers. This change will affect the total cost of the machine, impact the design of the vehicle cooling system, and reduce the available space within the engine compartment, to name a few. If you take a closer look at the legislation and engine power classes, you will discover that the exhaust emission levels for Diesel engines with power ratings below 56 kW (74 hp) are less stringent than power classes above 56 kW (74 hp). This means that vehicles with engine ratings of more than 56 kW will require additional hardware and cost, to meet the emissions mandate. Vehicle manufacturers currently using diesel engines in the 75 – 129 kW (100 – 174 hp) are thus encouraged to down size the engine to the 56 kW class, and investigate alternative methods of delivering peak power requirements.

Sauer-Danfoss has investigated and validated a solution that addresses this issue. This solution utilizes a hydraulic accumulator circuit to provide an intermittent power “boost” to supplement the engine’s power during short periods of peak engine load. This solution enables some vehicles with varying load cycles to use an engine that is below 56 kW but achieve the same power as a 66 or 70 kW engine provides. It simply makes the 56 kW engine feel more powerful. All the users and OEMs out there, that are using 60 kW up to 74 kW, please pay attention to this. The accumulator circuit is projected to cost less than the additional exhaust after treatment hardware that will be required on more expensive engines above 56 kW. The amount of power boost is dependent on the size of components that are selected. This solution is not a Hybrid in the classic sense to improve fuel efficiency. This set up will improve productivity and enables the vehicle manufacturer to utilize a smaller engine.

### Scope

In 2009, Sauer-Danfoss initiated a project to investigate the effectiveness of incorporating a hydraulic accumulator into a vehicle hydraulic circuit with the goal of storing hydraulic energy during lower engine power conditions and then releasing the energy during peak conditions. Sauer-Danfoss integrated a 10 liter accumulator rated for 200 bar into the hydraulic fan drive circuit with fixed displacement pump/motor in order to utilize stored hydraulic energy to boost the engine power. Furthermore, the objective was to develop an electronic control system for sensing engine load conditions to control the charging and release of the stored energy. Besides the scope mentioned above, there are alternative solutions possible. These include the use of a variable displacement pump, a dedicated pump for filling, CAN Bus information for engine load, and could also utilize work functions instead of the hydraulic fan drive.

### System Illustration





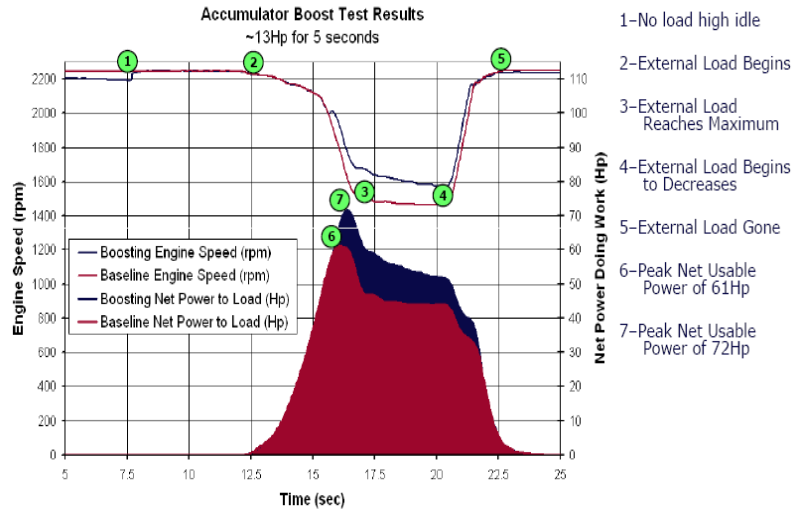
**Test data for 54 kW Test Vehicle Data with a 3.31 Diesel Engine**

Sauer-Danfoss implemented the circuit on a test vehicle. Test validations were done on a dynamometer and in the field. Subjective impressions were collected among expert drivers to round-off this exercise.

**Test Result: Automatic (PLUS+1™) Control**

The engine is set to a ‘no load’ throttle position resulting in 2250 rpm and the external load is ramped from 0 to 80% load in 5 sec (12-17sec). Load dwells for 3 sec (17-20sec) and then is ramped back to 0 % in 3 sec (20-23sec). In the beginning of the test the rpm is dropping because the accumulator is filling. As the load is applied the software decides to boost with the accumulator which results in a higher engine speed compared to the baseline. The power gained when using the boost is the blue shaded area. With decreasing load and increasing speed the software decides to stop boosting at around 22 seconds.

*Notes: Boost helps to keep the engine rpm higher, which allows the engine to produce more power for itself. Therefore, **power gain = boost power + higher engine power***



**Picture of Test Machine / Components**



Off-the-shelf components used:

- Accumulator
- Valves
- Software
- Controller (if one does not exist today)

Timing to implement on prototype:  
4 weeks

Timing for verification:  
4 weeks

Biggest challenge:  
Writing the PLUS+1™ code



### What Value Does This Solution Create?

- It is expected that Tier IV engines will have a lower torque capability at lower rpm compared to current engines. Therefore, it would be beneficial to implement a system as described above to mitigate possible engine stall conditions
- For vehicle manufacturers using engines above 56 kW up to 74kW class, the penalty would be twice: 1) paying for a bigger engine, 2) paying for more after treatment to comply with Tier IV regulations. The hydraulic power boost solution enables the Vehicle Manufacturer to position themselves in the lower engine power class, while still maintaining productivity.
- Since Tier IV is about cost of components and time of implementation, this solution provides more freedom in terms of component cost and 'expensive' real estate on the machine.

### Conclusion

The solution described in this technical article utilizes existing technologies, but applied in a new way. The new piece of the puzzle provides the vehicle manufacturer with a unique solution to meet the challenges presented by Tier IV. The solution was tested, validated and people who drove the machine were impressed about the deliverable of the Power Boost. Sauer-Danfoss is prepared to assist vehicle manufacturers considering alternative, intelligent ways of transmitting and controlling power.