ECONOMICALLY IMPLEMENTING

TIER 4 FINAL POWERPLANTS ON TELEHANDLERS

Barry Greenaway, product manager at Skyjack Inc. highlights the major considerations in the company's development of the use of a 74hp unit in its new range of TH series telehandlers and explains why the solution was particularly developed with Rental Companies in mind.

Tier 4 Final Implementation Schedule

Tier 4 Final represents the latest generation of federal air emissions standards established by the U.S. Environmental Protection Agency (EPA) relating to off-highway Diesel powered equipment.

In order allow for an attainable development schedule for engine and equipment manufacturers, this Tier 4 Final generation was implemented one horsepower class at a time. The last horsepower class scheduled for Tier 4 Final regulation (in January 2015) was the one that directly affects the vast majority of telehandlers in the marketplace: 75hp to 173hp.

Emissions Targets and Treatment

The overall directive of the Tiered emission EPA strategy is to drastically reduce the production of the following distinct pollutants: Nitrous Oxides (NOx), Hydrocarbons (HC), Carbon Monoxide (CO) and Particulate Matter (PM). The targets for these pollutants is measured in grams that the engine produces per kilowatt (or horsepower), per hour.

In terms of transition from Tier 4 Interim to Tier 4 Final for the 75hp to 173hp class, the only emissions goal that changes is a large reduction in NOx production targets (see table below).

While various strategies existed for meeting the Tier IV Interim targets for 75-173hp, the majority of North American telehandlers were equipped with engines of horsepower equivalent to their Tier 3 variants. These Tier IV Interim engines typically met emissions targets through the use of Ultra Low Sulfur Diesel (ULSD), Cooled Exhaust Gas Recirculation (EGR) and a Diesel Oxidation Catalyst (DOC).

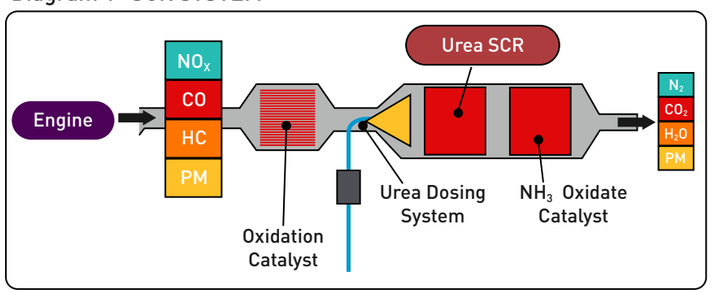
The important bottom line to these Tier 4i emissions control technologies is they require no user intervention (no regen or burn cycles) and no (or negligible) changes to servicing requirements. Equipment prices generally increased approximately 3% to cover the costs of Tier 4i, however the rental rates for machines thus equipped remained static; reducing ROI.

	(NOx/HC)/CO/PM (g/kW-hr)
49-74hp (Tier 4 Interim)	(4.7) / 5.0 / 0.30
49-74hp (Tier 4 Final)	(4.7) / 5.0 / 0.03
75-173hp (Tier 4 Interim)	3.4 / 0.19 / 5.0 / 0.02
75-173hp (Tier 4 Final)	0.40 / 0.19 / 5.0 / 0.02

The Tier 4 Final Challenge

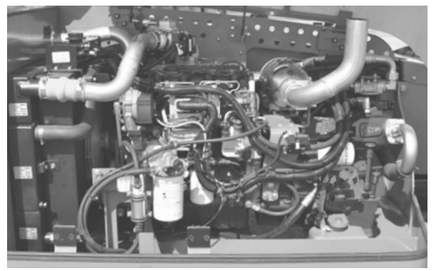
Upon moving to Tier 4 Final, the approximate 90% reduction of the NOx emissions targets in the 75-173hp range demanded more intrusive, expensive and complex emissions controls. The only workable solution is the addition of a Selective Catalytic Reduction (SCR) system incorporating urea based Diesel Exhaust Fluid (DEF) injection, with the result that all engine manufacturers incorporate a SCR system in their 75-173hp Tier 4 Final engines.

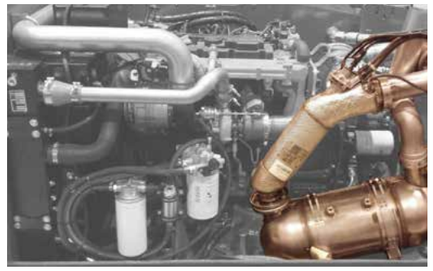
Diagram 1- SCR SYSTEM



The challenge this represents centers around three main issues:

1. Engine complexity
2. End user training (DEF management)
3. Unit cost increase





Engine Complexity

In order to have an SCR system function correctly, a significant amount of additional sensors, computer logic, fluid lines and exhaust piping are needed. While diagram 1 is relatively straightforward, the reality of the difference between a Tier IV Interim and a Tier 4 Final engine is less so:

Sensors are required to monitor the quality of the DEF and emission levels pre/post SCR. This is on top of heated fluid lines, DEF injectors, mixing tube and the SCR catalyst itself. This leads to an increase in complexity of potential failure points on the engine, which, being emissions equipment related, are not user serviceable.

End user training - Diesel Exhaust Fluid (DEF) management

DEF also freezes at 12oF (-11oC), requiring that the DEF tank and fluid lines are heated. The tank needs to not be overfilled so as to allow expansion room for freezing and some engine manufacturers recommend allowing the machine to sit for 60 seconds with ignition on but engine off in order to allow the lines to drain, preventing damage from freezing. This is all difficult to control on a rental piece of equipment.

End users also have to plan logistically for DEF refills (typically at every Diesel tank refill). For many contractors not used to equipment fitted with DEF, this generally results in "machine down" service calls as the engine reduces max RPM to idle only when the DEF is depleted.

Unit Cost Increase

75 to 173hp Tier 4 Final engines typically have an approximate cost increase of 40% over the previous generation of Tier IV Interim engines in order to cover the high costs of the SCR system; this can result in an equipment cost increase of 3% to 7% on typical North American market telehandlers. Unfortunately, this cost increase is typically not counterbalanced by an increased rental rate for Tier 4 Final telehandlers in the market place, resulting in decreased ROI for rental companies.

Solving the Tier 4 Final ROI Problem:

How to dispense with SCR

Ultimately, the above information shows that there is only one way out of equipping a Tier 4 Final telehandler with a DEF/SCR: Equip it with a 74hp engine.

On first impressions, that sounds like an unattractive solution when Tier IV Interim units boast anywhere from 100 to 130hp. However, the restrictions do not require the use of a small engine, only one with a lower horsepower figure. So what is the difference between those distinctions?

Horsepower Limited. Not torque limited.

Engine manufacturers, understanding the challenges placed to OEM's and equipment operators have introduced a whole new class of high torque 74hp power plants in order to provide more flexibility to manufacturers.

Under Tier IV Interim, engines in the 74hp range were typically smaller 2 to 2.5 liter units with around 180 lb-ft of torque. Now, under Tier 4 Final there are 74hp engines available in the 3.5 to 4.5 liter range with torque ratings around 280-310 lb-ft of torque.

Telehandler Performance Metrics

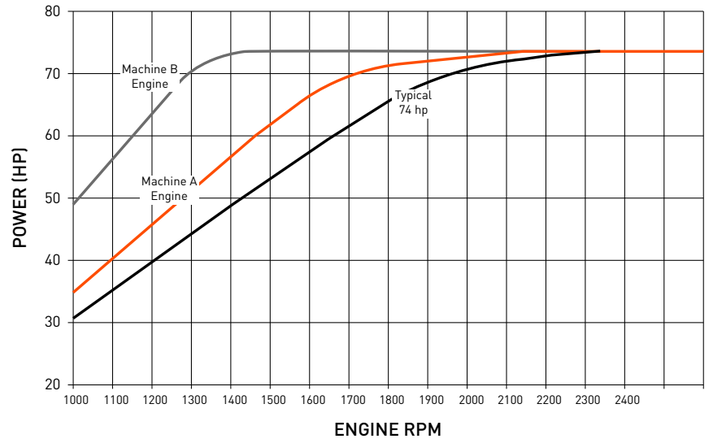
To understand the possibilities of using a 74hp power plant in a telehandler, we first have to identify what performance metrics apply to them and how they are effected by a reduction in horsepower. Key metrics are:

1. Load handling: The unit must be able to comfortably lift the full rated load at idle.

2. Hydraulic function speeds.

3. Rough terrain driving: The unit must develop enough tractive effort to ensure that it can negotiate a combination of grades and soft terrain found at a typical jobsite.

4. Speed maintenance: Attainable acceleration and drive speeds in top gear.



74hp Investigation

Fortunately, for the above, the majority of the requirements of the first 3 metrics require a heavy draw against torque, not engine horsepower.

In order to test this, 74hp high torque engines were installed in two machines:

	Machine A	Machine B
Capacity (lb):	8000	10000
Lift Height (ft):	43	56
Unloaded Weight (lb):	22000	31500
Horsepower (hp):	74	74
Torque (lb-ft):	221	287

Both of the above units previously employed 110hp Tier IV Interim engines with 300 lb-ft of torque.

74hp load handling

In order to be considered acceptable, both units must be able to lift their full capacity at a 24" load center without stalling or lugging at a similar rate to the 110hp Tier IV Interim machines.

Due to the available torque of the lower horsepower engines, no change was noted in the ability to perform this operation when tested back to back with the Tier IV Interim units.

The 74hp units were also tested for their ability to reposition the boom angle while driving with a full load in order to simulate a skilled operator lifting a load from ground height and driving off with it while lifting the load to an approved 20" height for clearance and visibility. No loss of performance was noted.

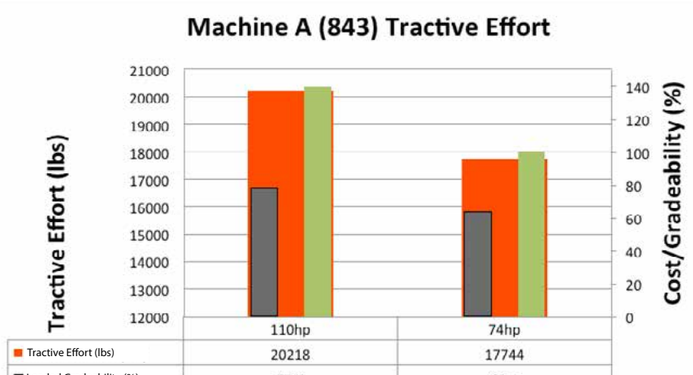
Hydraulic function speeds

Due to the absence of a performance loss on the above test, it was unnecessary to reduce the flow on the main hydraulic pump. With the flow rate identical, function speeds were predictably unaffected.

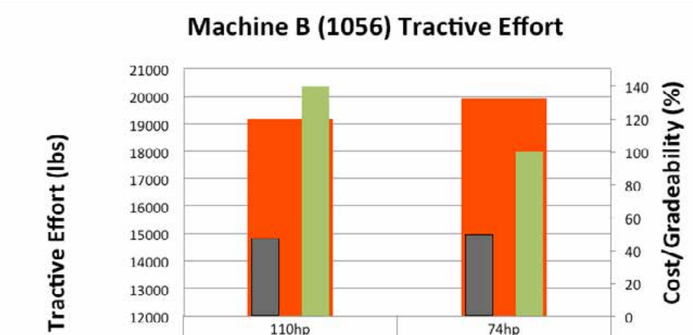
Rough terrain driving & speed maintenance

In order to deliver the tractive effort requirements for rough terrain driving, the axle gearing ratios on the 74hp units were increased from the 110hp units. This resulted in a reduction of maximum drive speed from 19mph on the 110hp units to 15mph on the 74hp units. The positive aspect, however, was that the tractive effort was only slightly reduced on Machine A, while it actually increased on Machine B.

As a matter of note while maximum drive speed was minimally reduced and number of customers actually see this as a benefit due to decreased wear and tear incurred through high speed rough terrain travel.



	110hp	74hp
Tractive Effort (lbs)	20218	17744
Loaded Gradeability (%)	77.6	63.4
Engine Cost (% of Tier IV Interim)	140	100



	110hp	74hp
Tractive Effort (lbs)	19187	19950
Loaded Gradeability (%)	46.8	49.3
Engine Cost (% of Tier IV Interim)	140	100

Rough Terrain Test Notes

Live, head to head testing between the 74hp & 110hp units was performed on a soft mud surface with several varying grades. All machines carried theirfull rated loads for the duration of the test and were tested in their heaviest configuration (foam filled tires, largest carriage, etc.)

Both 74 & 110hp variants of Machine A were able to traverse all the same grades (up to 50%) in the soft mud while fully loaded. They used the same gears to tackle the same obstacles. There was no observable distinction between their drive speeds on the test course, but the 110hp unit was observably faster when tested on a long asphalt roadway.

For Machine B, both variants could traverse all the grades up to 45% on the test course fully loaded, using the same gear on each machine. The 110hp unit was observably faster on longer flat sections between grades where 3rd gear could be employed. The same difference was noted on the asphalt roadway, with acceleration in 3rd slower on the 74hp unit.

Conclusions

Testing shows a 74hp Tier 4 Final telehandler can perform all the load lifting and rough terrain functions that job sites currently employ with 100+hp Tier IV Interim. A trade off in maximum travel speed is required, but minimally effects how the units are actually used.

The upside is a negation of the above noted ROI, service and downtime issues associated with SCR/DEF systems, protecting the revenue stream of Tier 4 Final telehandler fleets. With this in mind, Skyjack launched the concept as SMARTORQUE. As such, the all new Skyjack TH range is engineered to require NO DPF, NO DEF and NO other active exhaust after treatment on standard engines for Tier 4 Final. By utilizing improved gearing, high torque engines and a simplified, high efficiency hydraulics package, the TH range is able to employ 74hp engines to deliver the same on-site job performance as higher power units. In addition this allows for improved residual value as a simple more reliable machine competes positively with active emission controls.

www.skyjack.com

When NO!...is a good thing.

Skyjack has consistently approached the issue of emission compliance with the knowledge that rental rates don't just go up with emissions standards cost increases. The all new Skyjack TH range is engineered to require NO diesel particulate filter (DPF), NO diesel exhaust fluid (DEF), NO additional engine and exhaust sensors, NO complicated engine programming and computer logic, NO selective catalytic reduction (SCR) and NO other active exhaust after treatment on standard engines for Tier IV Final.

Simple, Serviceable, Reliable….Skyjack

SKYJACK
simply reliable

FLEXCAB™
READYHOOK™
SMARTORQUE™

SJ643 TH | SJ843 TH | SJ1044 TH | SJ1056 TH