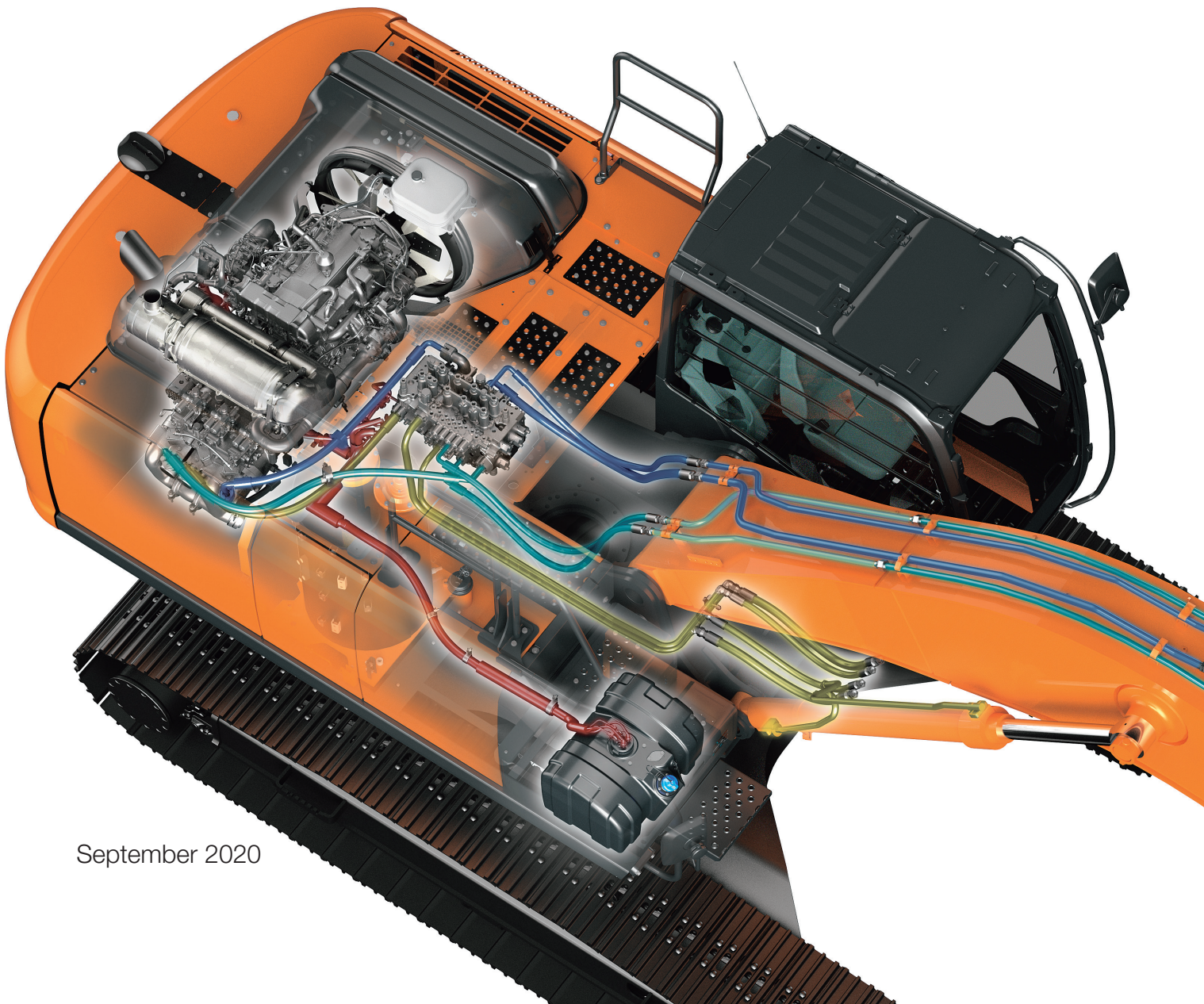


HITACHI

Reliable solutions

TRIAS III hydraulic system

A unique approach to reducing fuel consumption



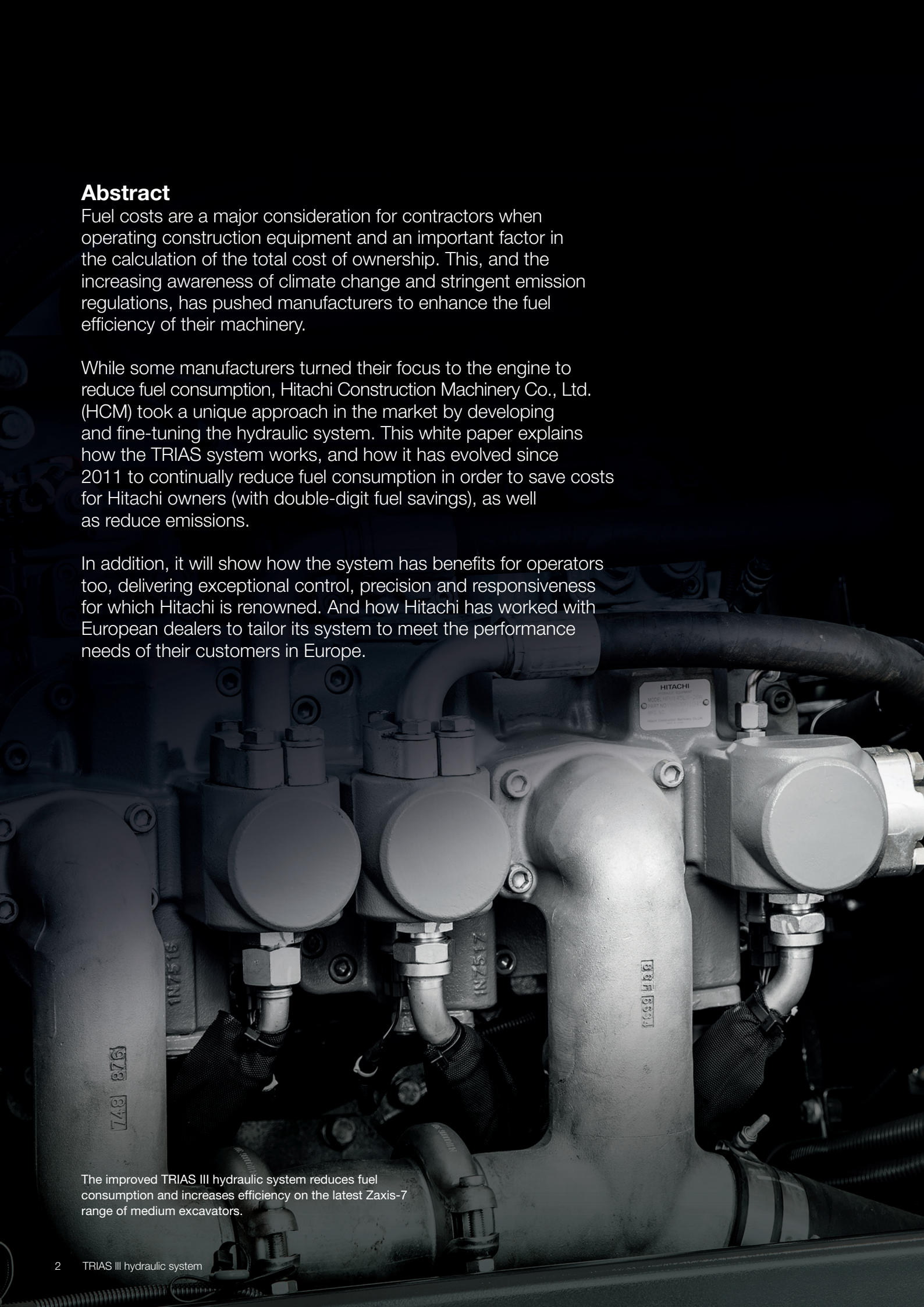
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Abstract

Fuel costs are a major consideration for contractors when operating construction equipment and an important factor in the calculation of the total cost of ownership. This, and the increasing awareness of climate change and stringent emission regulations, has pushed manufacturers to enhance the fuel efficiency of their machinery.

While some manufacturers turned their focus to the engine to reduce fuel consumption, Hitachi Construction Machinery Co., Ltd. (HCM) took a unique approach in the market by developing and fine-tuning the hydraulic system. This white paper explains how the TRIAS system works, and how it has evolved since 2011 to continually reduce fuel consumption in order to save costs for Hitachi owners (with double-digit fuel savings), as well as reduce emissions.

In addition, it will show how the system has benefits for operators too, delivering exceptional control, precision and responsiveness for which Hitachi is renowned. And how Hitachi has worked with European dealers to tailor its system to meet the performance needs of their customers in Europe.



The improved TRIAS III hydraulic system reduces fuel consumption and increases efficiency on the latest Zaxis-7 range of medium excavators.

The challenge: reducing fuel consumption while maintaining performance

Equipment manufacturers have been driven to produce machines capable of less fuel consumption largely to help contractors to be more profitable in their activities: “Fuel is often the biggest cost when operating a piece of construction equipment. In some markets, it can be far greater than labour, maintenance and insurance.” [1]

Fuel efficiency not only helps to protect profit, but also reduces the impact of machines on the environment. Therefore, fuel-efficient equipment also complies more easily with tough industry emissions regulations.

While some manufacturers responded to the need for lower fuel consumption by reducing the engine output of their machines, Hitachi introduced its unique TRIAS hydraulic system with the aim of ensuring contractors could do as much as possible with as little fuel as possible.

All manufacturers had to consider that, while contractors wanted machines that use less fuel and release fewer emissions, they still needed the same or even higher levels of performance, productivity and speed to complete projects in less time and within budget.

This is particularly an issue for customers in Nordic countries, for example, where owner/operators typically use a versatile 20-tonne excavator with a variety of attachments to complete several different activities on one project. To tackle this, HCM's subsidiary, Hitachi Construction Machinery (Europe) NV, has worked closely with its official dealers in Sweden (Delvator) and Norway (Nasta) for several years. Together with other European dealers, they ensure that Zaxis medium excavators can meet the demands of the market for fuel-efficient and highly productive construction equipment.



The history of TRIAS and how it works

Hitachi originally developed the TRIAS system for its Zaxis-5 medium excavators, introduced in 2011. The name TRIAS refers to the three-pump hydraulic system that replaced the previous two-pump system for this size of excavator, which is still commonly used by competitors.

The third pump contributes to several of the main actuators, giving priority to the swing circuit. Fine-tuned control valve spools, multiple pressure sensors and computer-controlled solenoid valves maximise efficiency, and multifunctional productivity without sacrificing fuel economy.

Commenting shortly after the introduction of the Zaxis-5 range, HCM's Manager of Construction Equipment Development Centre at that time, Tsuyoshi Nakamura, said: "The main reason why the TRIAS system was developed was to lower fuel consumption. The only way to achieve this

goal – while maintaining the speed of the machine – was to reduce the loss of pressure in the hydraulic system." [2]

Understanding hydraulic loss

The TRIAS system therefore aimed to reduce hydraulic loss. All hydraulic systems inherently include hydraulic losses – some can be designed purposefully to create lubrication or cooling; other losses occur in spool or valve operation.

When part of the pump flow is directed to an actuator, the other part of pump flow is diverted to the oil tank. The oil flow directed to the actuator results in usable hydraulic power. The oil flow diverted to the oil tank is considered as hydraulic power loss. The hydraulic power loss to tank results in heating of hydraulic oil and reduces fuel efficiency.



“The main reason why the TRIAS system was developed was to lower fuel consumption”

Tsuyoshi Nakamura,
HCM Manager of Construction
Equipment Development Centre

Key components

The key to the TRIAS system is the combination of the three-pump system, the control valve, multiple pressure sensors and computer-controlled solenoid valves. "Tuning the system is vital in the TRIAS system, because without it, there would be no efficiency in the control valve," explained Mr Nakamura. "This technology is unique to the construction industry."

Evolution

In 2015, Hitachi launched TRIAS II in its Zaxis-6 range of medium excavators. This system further fine-tuned the control valve spools, and added additional pump flow limit solenoid valves. This further reduced hydraulic losses in the control valve during less than maximum lever operation. Once again, this led to significant fuel savings of a further 10% (ZX250-6 compared to ZX250-5 in PWR (power) mode).

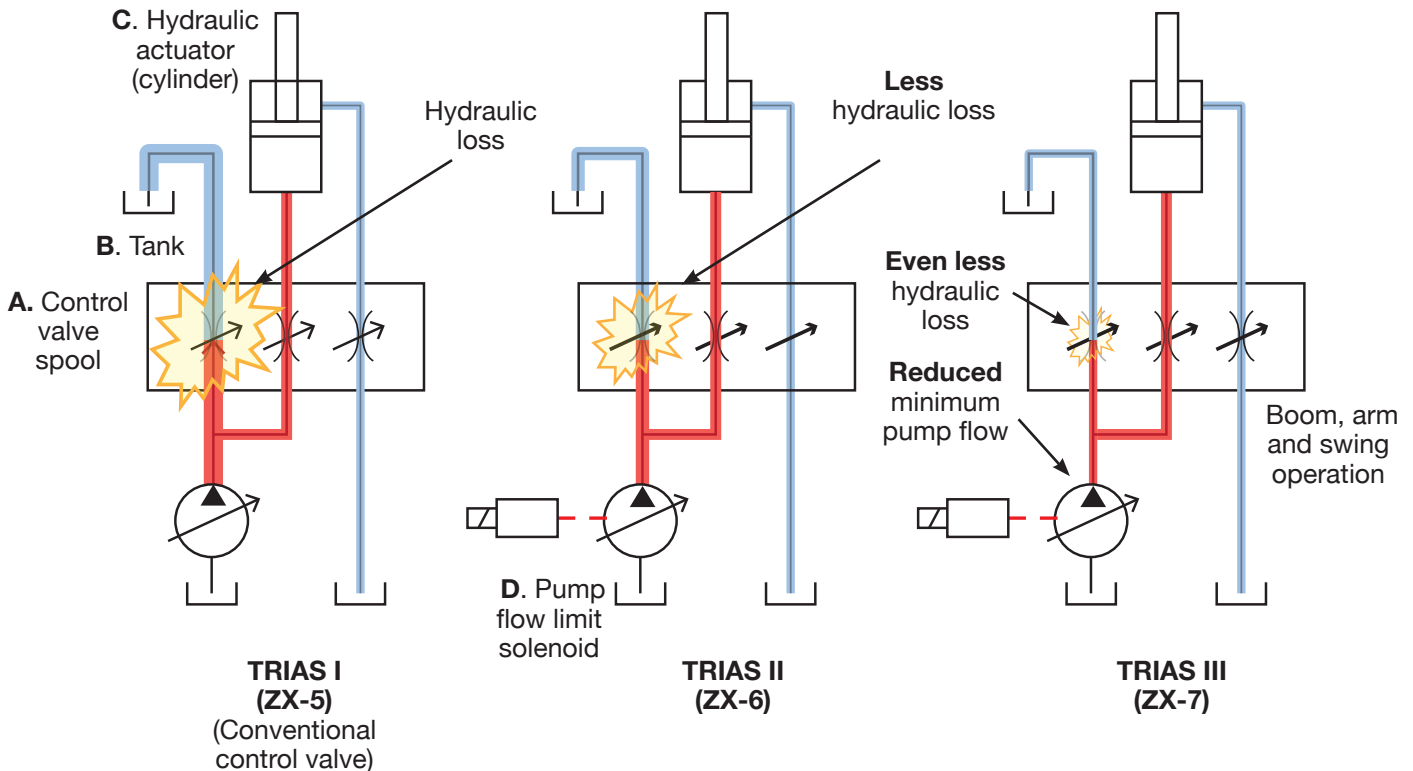
Five years later, TRIAS III was unveiled with the arrival of the Zaxis-7 range. This system benefits from even further fine-tuning of the control valve spools and new features resulting in even less hydraulic losses, greater efficiency and controllability.

The visual below shows the difference between TRIAS I, II and III control valve spools. In a TRIAS I (and conventional) control valve spool [A], there is always a significant return of pressurised oil to the tank [B] during operation of a function, especially at small and medium control lever strokes. This flow of pressurised oil to tank results in hydraulic power loss.

The TRIAS II control valve has less hydraulic loss to tank, which results in reduced fuel consumption. The control valve spools have been tuned to restrict the oil flow to tank during small and medium control lever strokes. To avoid providing too much oil to the actuator (cylinder) [C], pump flow limit solenoids [D] have been added to reduce the pump flow accordingly. The controllability or hydraulic feeling of the machine remains the same.

The TRIAS III control valve has even less hydraulic loss to tank. The control valve spools have been further fine-tuned to restrict the oil flow to tank during small and medium control lever strokes. Together with improved software and a reduction of the minimum pump flow rate, this results in even lower fuel consumption. The controllability or hydraulic feeling of the machine remains the same.

TRIAS comparison



Reducing leaks

A useful analogy for a control valve is that of a garden hose connected to a tap. The hose delivers the water to the garden sprinkler, but if the connection of the hose to the tap is leaking, there is a loss of water.

If you reduce the leak, you can close the tap a bit more and still have the same amount of water coming out of the garden sprinkler. In this way you will save water. TRIAS II and III pump flow limit solenoids are like taps connected to garden hoses in which the water leakage has been reduced.

Impressive fuel consumption reductions

The evolution of the TRIAS system has achieved impressive fuel consumption reductions, as shown in the illustration opposite. This illustrates fuel consumption reduction in PWR (power) mode comparing Hitachi medium excavators (25-35 tonne class) at the same productivity levels: Zaxis-3 (HIOS III hydraulic system), Zaxis-5 (TRIAS I), Zaxis-6 (TRIAS II) and Zaxis-7 (TRIAS III). It has resulted in a total reduction of 26% in the 25-tonne class, 23% in the 30-tonne class and 19% in the 35-tonne class.

Historic TRIAS fuel consumption reduction

Comparison of PWR mode at same productivity

ZX250
PWR MODE



ZX-3 **-26%** ZX-7

ZX250-3 **-9%** ZX250-5B **-10%** ZX250-6 **-10%** ZX250-7

ZX300
PWR MODE



ZX-3 **-23%** ZX-7

ZX280-3 **-9%** ZX290-5B **-10%** ZX300-6 **-6%** ZX300-7

ZX350
PWR MODE



ZX-3 **-19%** ZX-7

ZX350-3 **-5%** ZX350-5B **-7%** ZX350-6 **-8%** ZX350-7



ZX250-3



ZX250-5



ZX250-6



ZX250-7

New in TRIAS III for Zaxis-7 models

The latest evolution of TRIAS has several new features that have contributed to achieving the reductions. These include the arm roll-in meter-out control, which improves fuel efficiency during digging (as pump power for digging operation can be decreased by 5-10%).

In TRIAS III, the arm flow rate control has been optimised. Besides a cost reduction, this results in improved controllability. In TRIAS III the amount of boom priority can be adjusted by the operator. This will be explained further in more detail (see 'Greater control for operators' on page 8).

A further change is the replacement of the arm 3 spool in the pump 3 circuit by a centre bypass shut-out valve. This control aims to reduce hydraulic loss in the boom 3 circuit.

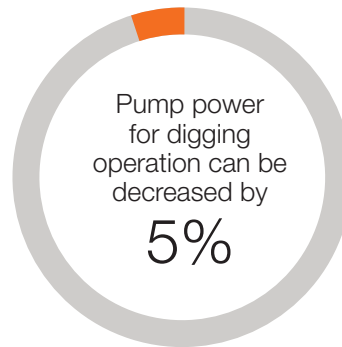
Arm regeneration control has also been enhanced on the TRIAS III system. On Hitachi machines, arm regeneration is applied at low loads to accelerate arm roll-in speed. This guarantees optimum combined operations.

From Zaxis-5, Hitachi uses a regeneration cancel valve for improved controllability. Arm regeneration is active at low loads, until the regeneration cancel valve is activated. This will open a passage to the oil tank and allow oil returning from the arm cylinder rod side to the oil tank. This stops arm regeneration.

In TRIAS III, however, the regeneration valve opening port has been enlarged and the regeneration check valve has also been increased in size. These measures improve efficiency and have a positive effect on fuel consumption.

Another new feature of TRIAS III is pump 3 minimum angle fix control. This improves fuel efficiency during digging. If the pump pressure becomes high during digging, the pump efficiency is improved by fixing pump 3 to no-load/minimum flow rate and using pumps 1 and 2 at high pressure and maximum flow rate. This improves pump efficiency by 2%, reducing fuel consumption.

This control is only activated at small boom-up lever inputs. As soon as larger boom-up lever inputs are given, this control is cancelled and pump 3 is also used for boom raise.



Fuel efficiency is further enhanced with the latest Zaxis-7 range of excavators

Greater control for operators

One of the most significant updates in TRIAS III is that the operator can now fine-tune the performance of their machine by adjusting settings on the monitor menu. There are two parameters: Boom Priority and Front Speed Adjustment for Heavy Load.

Boom Priority

Boom Priority is an attachment setting, allowing the operator to give boom raise speed priority when performing combined operations involving boom raise, swing and arm roll-in.

There are three options for the operator to select: Off, Auto 1 and Auto 2. Both Auto 1 and Auto 2 increase boom-raise speed for combined operations involving boom-raise, swing and arm roll-in.

'Off' maintains normal boom raise speed. This setting is used for light digging work, low-density materials, or for grading and levelling.

Auto 1 increases boom raise speed for combined operation and gives arm roll-in priority until start of swing. This setting is used for digging high-density materials, loading a truck, or earthmoving using a heavy front attachment or crusher.

Auto 2 also increases boom raise speed for combined operation, but gives less priority to arm roll-in until start of swing. This setting is used for digging high-density materials in a ditch or deep hole, loading a truck, or earthmoving using a heavy front attachment or crusher.

Front Speed Adjustment for Heavy Load

This attachment setting enables the operator to increase or decrease pump flow for heavy loads. Operators can choose anywhere in between three settings: MIN, STD and MAX.

The MIN setting reduces the speed of the front attachment, with reduced pump torque at high loads, for reduced fuel consumption. The STD setting in the middle is the standard setting for regular operations. And the MAX setting leads to increased front speed at heavy load (pump torque at high loads is increased).



OFF, AUTO 1 and AUTO 2 are default settings. Additional settings can be enabled upon request. For example Semi Auto 1 (4sec) behaves the same as AUTO 1, except when pressing the Power Boost switch it gives Boom Priority for 4 seconds under any condition.

Feedback from Sweden and Norway

This possibility to fine-tune the machine's performance on the monitor is one of the results of the close cooperation between HCM, HCME and Nordic dealers, Delvator (Sweden) and Nasta (Norway), since 2012. Delegates and customers from both Sweden and Norway have worked with Hitachi engineers in Japan to test the settings of Zaxis excavators with several front attachments.

Their input over the years has helped Hitachi to continually improve the TRIAS system and develop it for the next generation of machines. Crucially for customers, it has enabled them to utilise TRIAS to increase performance.

This was necessary because although the first version of TRIAS successfully reduced fuel consumption, customers noticed a reduced output in certain operations, which was less than ideal for use with heavy attachments. Thanks to the cooperation with Nordic dealers, HCM was able to adjust the trigger level of the machine, and how it balances the three pumps in its hydraulic system.

Delvator Product Manager Magnus Hansson explains: "The operator settings are priority settings, and these basically adjust how the three pumps in the hydraulic system balance the load. If you lift a heavy bucket load, for example, the excavator measures how much you are moving the lever – it can tell how eager you are to lift it and will give you more power if required.

"Now the machine settings are pre-set for our customer needs, mainly dependent on the weight of the attachment, for the performance and output of the machine. When an operator makes these adjustments on the Zaxis-7 model, they will notice the difference. It's like switching to sport mode in a car – it has a huge impact on performance."

Magnus believes HCM's hydraulic system makes Hitachi stand out from the crowd, even in the land of one of its

major competitors. "TRIAS is an excellent system for preserving the power of the machine. All the manufacturers make machines capable of less fuel consumption. One particular manufacturer, for example, has a large variable engine and two large pumps. Hitachi has a smaller engine and a three-pump variable hydraulic system.

"The other manufacturer's operator saves fuel with lowering engine speed in light/normal operations, then increases the engine speed to increase production. Hitachi is the opposite, with a suitable engine and a few preset engine modes (ECO and Power), and a hydraulic system that determines if you use full or low performance.

"The competitor reduces engine output, but Hitachi TRIAS hydraulic system automatically optimizes the performance to minimise the load, loss and fuel consumption. While the other machine can reach low fuel consumption by lower idle, it is relatively slow. Hitachi on the other hand is renowned for the outstanding speed of the front attachment compared to the competition."

While speed undoubtedly has a positive impact on productivity, the TRIAS hydraulic system has a further benefit for operators by bringing a user-friendly feel and responsiveness to the controls. Magnus adds: "Hitachi excavators have the best operator feeling in terms of controllability. Anyone can sit in the cab and feel instantly that they are in full control."

This has been the case since the initial development of TRIAS in 2011, when Mr Nakamura commented: "Hitachi places great emphasis on controllability, which is a vital feature in today's construction equipment. Some of our competitors might be able to produce control valves and pumps, but we are the only one to have this level of expertise in tuning – and none of our competitors can easily copy this level of technology."

"TRIAS is an excellent system for preserving the power of the machine"

Magnus Hansson,
Delvator Product Manager



TRIAS in practice

The Hitachi TRIAS hydraulic system is clearly essential to the performance of its excavators and the operator experience. Following its launch in Europe in 2012, Finnish contractor Maaperustus Saarinen Oy noticed the advantage of the Zaxis-5 over previous generations of Hitachi excavators.

“The most important development with the Zaxis-5 range is the hydraulics package,” said the company’s co-owner Kari Saarinen [3]. “The ZX225USRLC-5 operates perfectly thanks to the TRIAS system.

“The flow of oil is distributed more evenly and therefore the machine is more responsive and precise in comparison to the previous model. The same level of performance is achievable with less engine speed, and the power mode is only required for tougher jobs.”

The improved TRIAS II in Zaxis-6 models has also been well received by customers across Europe. In Germany, Richard Schulz Tiefbau tested four different brands of 20-tonne excavators and assessed operator opinions before deciding to invest in two new models. Workshop Manager Markus Winkler explained how TRIAS was decisive: “They liked the precision of the Hitachi hydraulic system and that led to the purchase of two new Zaxis machines.” [4]

One of the company’s experienced operators, Andreas Maul, was impressed by one of the new Hitachi machines, a ZX300LCN-6, when using it for earthmoving, loading trucks and spreading chalk with a different attachment: “It is really precise for removing topsoil. The power and capacity are strong points, and it is also fast and easy to operate... I’ve been particularly impressed by the low fuel consumption – this is the best machine that I’ve operated in the past 20 years!”

The speed and precision of the TRIAS system have also been highly valued on job sites in France. Operator Bruno Lourenco of demolition and earthmoving company Millot TP used a Zaxis-6 excavator following experiences with two Zaxis-3 machines. “I really like the ZX300LCN-6, because it is more powerful than the ZX280LC-3,” he explains.

“Overall, it’s an excellent machine: smooth and fast, and the loading cycle is very good. For example, there is no problem in working with around ten trucks per day on this site. The most impressive feature is the way in which I am able to work with this new machine, especially with the precision offered by the hydraulic system.” [5]



“I’ve been particularly impressed by the low fuel consumption”

Andreas Maul, operator,
Richard Schulz Tiefbau GmbH



Conclusion

The unique hydraulic system within Hitachi excavators was developed to significantly lower fuel consumption by reducing hydraulic loss. The initial TRIAS I and subsequent II and III versions (introduced in 2011, 2015 and 2020 respectively) have achieved a total fuel consumption reduction of 26% in the 25-tonne excavator class. This has resulted in significant total cost of ownership savings and vital emission reductions to comply with stringent environmental regulations.

In addition, the TRIAS system ensures an efficient swing operation and an exceptionally fast front attachment speed. This, coupled with high levels of controllability and precision, contributes to excellent productivity and further enhances the profitability of customer operations.

To ensure consistently high levels of performance, Hitachi has worked closely with its Nordic dealers over several years to further enhance the TRIAS system so that it meets the needs of customers. The latest version installed in the ZX-7 series, TRIAS III, also allows operators to fine-tune the performance of their machines using the machine monitor, according to the weight of the attachments they are using.

HCM's approach with TRIAS, namely to preserve the power of the machine and ensure that as much as possible can be done using as little fuel as possible, is more important now than ever with the optimum use of resources under the spotlight. Efficiency and environmental concerns will only increase in the future, and while zero-emission electric equipment is still in the early stages of development, exceptionally fuel-efficient machines – and their skilled operators – will bridge the gap.

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