

Hydrostatic transmission design – Closed loop forestry trailer assist drive

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Abstract The article presents the design, the production and the testing of a heavy duty forestry trailer, equipped with hydrostatic transmission. The aim of the project is to build a heavy duty, highly productive but also compact and user friendly machine which will be able to operate on difficult terrains and can be at the same time driven with a standard agriculture tractor.

To achieve initial requests, the manufacturer of the trailer – company Projernač, closely cooperated with the company Poclain to develop closed loop hydraulic transmission on the trailer. The aim of the trailer transmission is to generate additional tractive effort on terrains where tractive effort of the tractor does not guarantee correct and safe driving conditions. The trailer transmission design is done in a way to provide additional tractive effort when travelling uphill and provides correct hydrostatic braking when travelling downhill. Operation of the transmission is well observed via several sensors and consequently controlled by a micro controller, which is a part of the transmission. That control provides on time speed synchronization between tractor and trailer. The integrated display provides an effective user – machine interface.

To achieve all those functions, Poclain provides components from all product lines covered by Poclain product lines, which means: hydraulic motors, hydraulic pump, several control valves for transmission and auxiliary functions and several electronic components. Some key components come from the so-called “High Performance” pool of Poclain products, which are products that remain at the top of worldwide competition.

After the commissioning, the conclusion can be made that the assist drive in off road conditions is mainly the main drive, which generates the majority of tractive effort.

Key words: hydrostatic transmissions, mobile machines, forestry trailers

■ 1 Aim of the project

On the market there are many systems for transporting wooden logs. There are solutions from very simple winches to classic to more sophisticated forestry machines and at the end to skyline and even helicopter transportation.

The focus on initial log transportation on wheels generally shows two solutions; transportation with tractor trailers and transportation with forestry forwarders. Forwarders are a very effective and comfortable solution, but at the same time also



Figure 1. Several concepts of wood transportation

expensive due to input costs of the complex machine and regular machine operational costs. Transportation with tractor trailers is at the same time inexpensive, but also causing several deficiencies.

On the market there are many different tractor forestry trailer options,

from very simple to very sophisticated solutions. Weaknesses generally stay the same. Normally forestry trailers have to be in combination with heavy and powerful agriculture tractors.

The basic idea of the company Pro Jernač was to develop a forestry

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trailer which can be used also in combination with smaller agriculture tractors and can at the same time reach heavy terrains which are normally reachable only with forestry forwarders.

■ 2 Input requests

The input requests were as follows:

- The trailer solution has to be as universal as possible and usable with any agriculture tractor. The minimal size of the tractor is 4 tons and 90 kW engine power
- The trailer size has to allow loading, transportation and unloading of up to 10m³ of logs in one shoot
- The solution must allow a greater manoeuvrability compared to standard trailer solutions
- The trailer transmission has to be able to transform as much input power in additional tractive effort when composition travelling uphill and at the same time needs to provide a reliable retain torque when travelling downhill

Almost all points above can be, and in the end were reached with proper trailer transmission. This was the point where innovative ideas of Pro Jernač company meet Poclair hydraulic transmission solutions.

■ 3 Transmission solution

Generally trailer transmission is closed loop electronically controlled

hydraulic transmission. It consists of four general type of components; a closed loop hydraulic pump, radial piston hydraulic motors, closed loop hydraulic control valves and an electronic control unit. On the trailer there is also an additional open loop hydraulic system provided by Poclair to control additional functions on the trailer; steering, wheels position control, etc.).

Transmission was designed in a way that trailer can synchronize speed with the tractor and at the same time provide additional tractive effort according to operator demands. To achieve those requests, the so-called constant pressure control principles were used. Also there are several driving modes:

- I. *On road mode*: transmission is completely stopped and transmission need only provides enough energy to provide correct lubricating of the hydraulic motors and ability to operate in freewheeling mode
- II. *Freewheeling mode*: transmission operates, but it is not used to provide any additional torque. Transmission need operates correctly only in freewheeling mode
- III. *Assist mode in forward or reverse*: transmission needs to provide requested torque on trailer wheels to increase moving ability of the composition
- IV. *Retain mode in forward and reverse*: transmission needs to provide the requested hydro-

static braking torque to avoid uncontrolled moving of the composition when travelling downhill

The operational principle is as follows:

- The composition starts to move; tractor demands speed of composition.
- One of the trailer wheels is equipped with a speed sensor which independently detects and measures the speed of the composition
- A dedicated software calculates pump displacement according to the wheel speed. An electronic control unit provides on time adjusting of pump displacement regarding the speed variation
- At the same time the operator sets the requested additional torque – on the control panel the operator directly sets the percentage of additional torque
- A software recalculates the requested torque – regarding the wheel size and motors displacement – in needed pressure level
- An electronic control unit sets the pump to maintain calculated pressure in the high pressure lines of the system and at the same time maintains the requested speed of the composition
- The retain mode is done in the same way, the only difference being that the opposite lines are pressurized

■ 4 Hydraulic system

a) Hydraulic motors

There are two low speed, high torque radial piston wheel hydraulic motors. The motors are used on the trailer front wheels due to increased gradeability of the wheels with ground. The first wheels normally (in case of equal weight distribution) generate a greater tractive effort in comparison with rear wheels. The motors on the trailer are the most common Poclair product.

The motors used are 2340 ccm radial piston motors with stepped piston technology. Stepped tech-



Figure 2. Pro Jernač prototype trailer

nology allows higher displacement inside the same overall dimensions. At the same time, the maximal pressure for those motors is limited to 410 bars, which is enough in the trailer assist case.

The motors are of a wheel type with a dedicated bearing unit which can handle a complete weight load of the trailer. The ends of the motors are equipped with an additional drum brake. That kind of braking system complies with all regulatives for on road use in the area of the European Union. The brakes can be hydraulic or pneumatic controlled. The braking energy is provided and controlled by the main tractor braking system.

One of the motors is equipped with an additional rear gear pump, which provides necessary hydraulic energy when the main hydrostatic pump is stopped (road use of the trailer). The pump is driven by the motor which is driven by the wheel. Additional energy is needed for motors lubricating and to mainta-

in the freewheeling state of the motors. The freewheeling state means light pressurization of the motor case (~ 2 bars) to avoid uncontrolled movement of motor pistons.

b) Hydraulic pump

Initially the Poclain medium duty PM50 pump was used. But based on the results of the first tests, the decision was made to switch over to the Poclain heavy duty PW096 pump. PW096 is a closed loop axial piston pump. The high development of this product provides an effective and reliable product which can be used in several mobile and industrial applications. The key point of the pump is its unique piston – a sliding plate joint which provides less wear of the key pump components, a higher response time due to lighter components and less temperature dependence.

The pump is a 96 ccm electro proportional controlled unit with an integrated 22 ccm gerotor charge

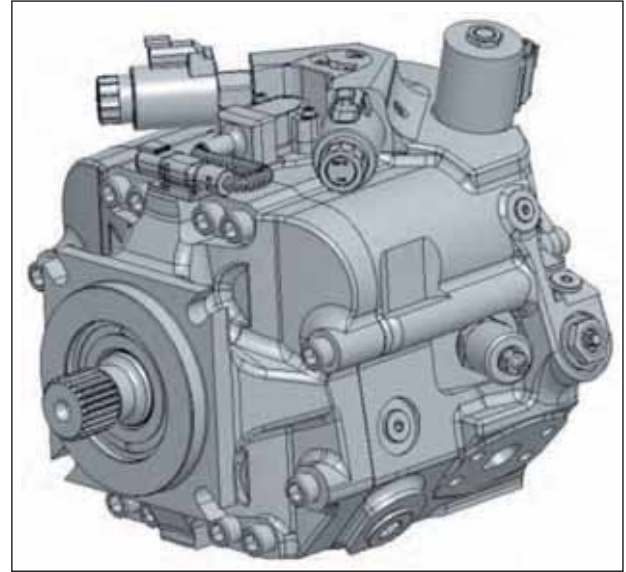


Figure 5. PW096 pump closed loop hydraulic pump

pump. The integrated and closed loop flushing valve importantly decreases piping which still – based on the machine complexity – remains heavy. The integrated pump speed sensor on the time monitor pump speed and transmits information to the main electronic control unit. The pump speed is also important information to adjust its displacement.

The pump is driven by a 3:1 multiplier which is driven by the tractor PTO. This allows the pump to operate in a most optimal speed frequency. The crane pump is mounted directly on the rear of the closed loop pump.

c) Closed loop hydraulic control valves

An additional hydraulic control (beside the control provided with the pump) consists of a freewheeling valve, a traction control valve and a motor case pressurization valve.

The freewheeling valve is a high pressure, high flow electro controlled hydraulic valve, its function is to enable freewheeling of the motors. At the same time its function is to engage and disengage the transmission when the pump is running. The freewheeling valve also provides quick transmission disengaging in case of emergency. Large internal sections provide low pressure drops through the valve.

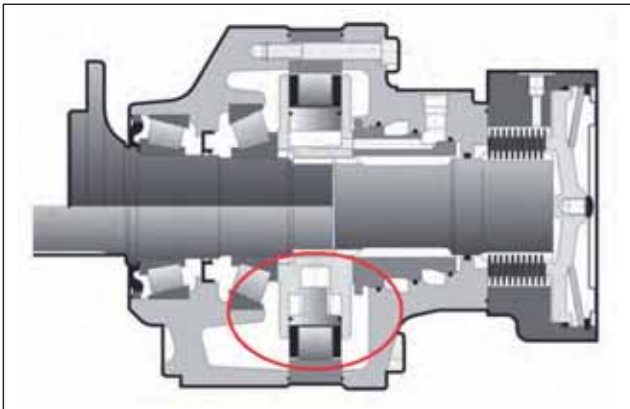


Figure 3. Stepped piston technology



Figure 4. Wheel type hydraulic motors

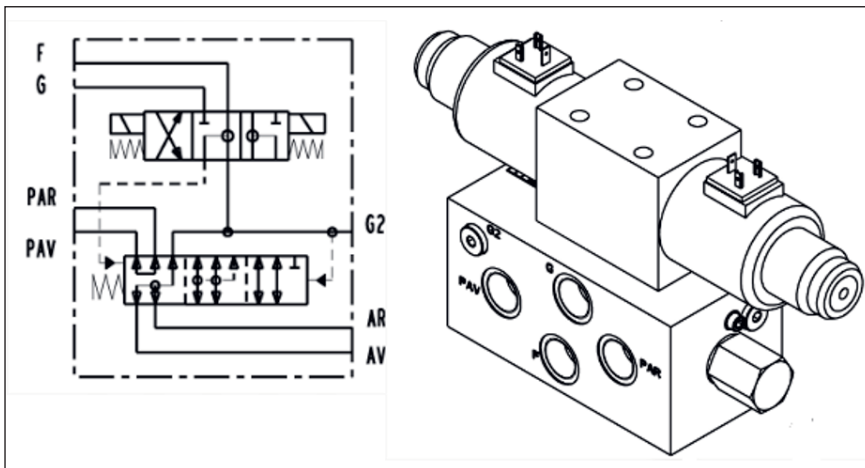


Figure 6. Freewheeling valve VDF-H15

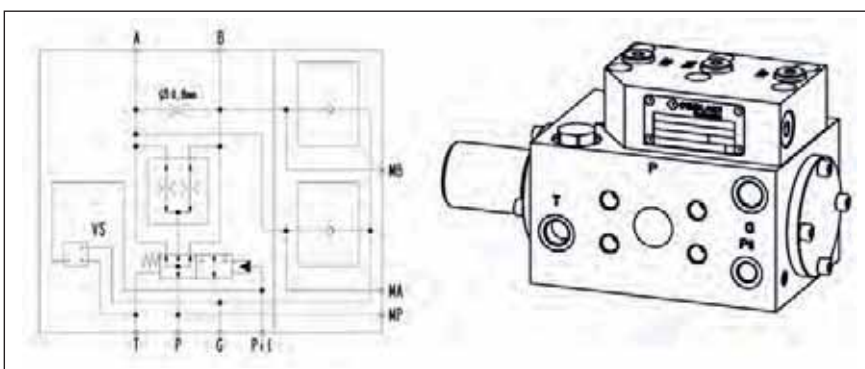


Figure 7. Traction control valve FD-H2

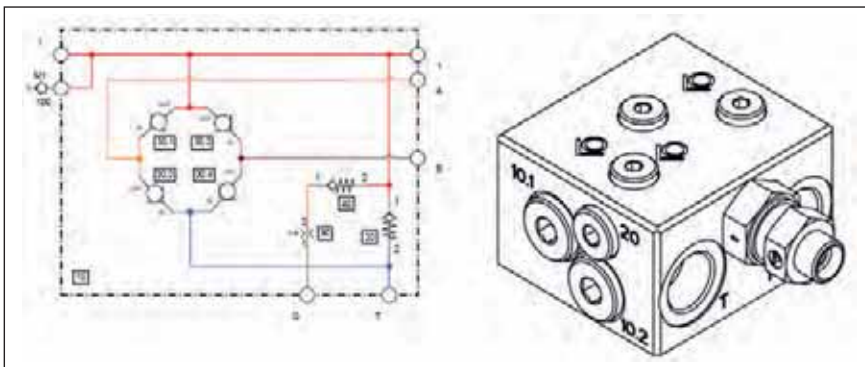


Figure 8. Case pressurization valve

The traction control valve is basically a high pressure flow divider, equipped with a bypass and a control system. It is FD-H2 type, a new product of Poclairn and its first OEM use. The valve split pump flows into two independent ways to independently supply each motor. In the reverse way it combines flow to supply the return line of the pump. The demand when to use the function is given from the operator via the control panel.

The case pressurization valve is hydraulic wheatstone bridge and it is used in combination with an addi-

tional gear pump driven by a hydraulic motor. The motor can run in both directions and consequently the pump suction and pressure line must change according to the pump rotating direction. This is provided by the case pressurization valve.

d) Electronic control components

The electronic control components exist of four main units; the electronic microcontroller with high power outputs, the dedicated software,



Figure 9. Electronic control unit

the control panel and several sensors integrated in the hydraulic system.

The electronic control unit is the Poclairn SMARTDRIVE EASY programmable module with several high power outputs to control hydraulic pump and several electro-controlled hydraulic valves.

The software was dedicated and developed for the trailer. Generally the code is locked but it can be adapted via several parameters. The parameters also allow to control global trailer modifications like the final speed of the transmission, tyre size, etc.

There are two control panels for the trailer – one for trailer transmission and the second for trailer auxiliary functions. The trailer transmission control panel is a programmable display with several control buttons where the required functions can be set. Pressure command is given by a rotatable potentiometer. On the display the chosen function is graphically shown. Also important parameters like trailer speed or hydraulic liquid temperature are shown.

On the trailer there are three types of sensors: speed sensors, pressure sensors and temperature sensors. The outputs are used to provide correct system control and necessary safety functions like power or pressure limitation.

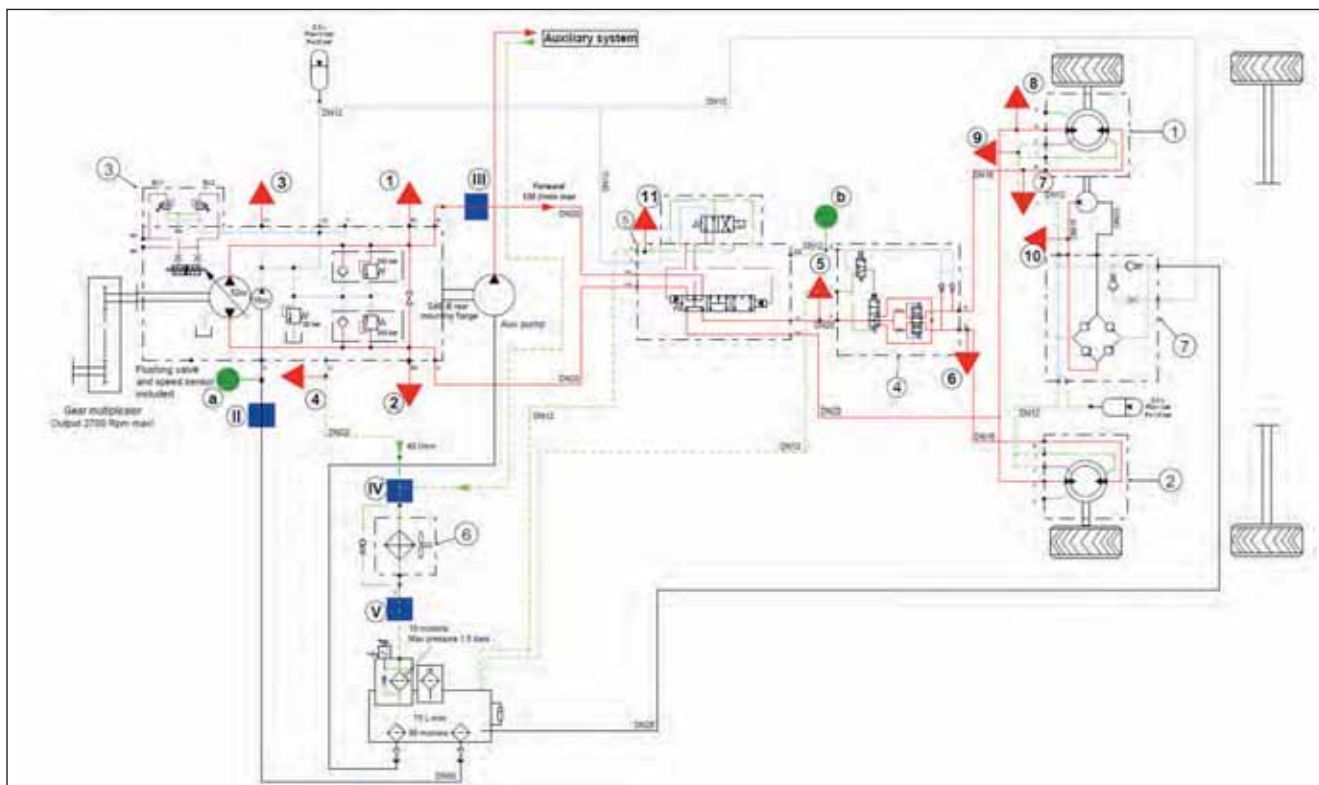


Figure 10. Trailer hydraulic schematic

e) System hydraulic schematic

■ 5 On field testing

Intensive on field setting and testing shows many trailer transmission advantages as well as many advantages of the trailer as a complete unit. Trailer transmission can be used till 7 km/h and can provi-

de up to 2.75 tons of tractive effort per wheel. Those findings show that trailer transmission in many cases is not an additional transmission, but has become a main transmission. The tractor in that case only provides the power to run the pump. It is also a fact that a loaded trailer can weigh up to 18 tons, when the weight of the tractor is 4 tons.

A system can operate up to 410 bars. Temperature stabilization is 82.5 °C. The system provides performances according to initial calculations. Special care was put on retain mode. After a fine tuning also this function was fine adapted, especially with the use of a heavy duty hydraulic pump. That was also one of the general conclusions of testing; the machine is proper to be equipped with the best components that can be found on the market.

Commissioning also exposes some weak points of the transmission. One of the main disadvantages are the hydraulic pipes. After a longer high pressure testing mainly all of them started to leak and needed to be replaced.

■ 6 Conclusions

Generally speaking, hydrostatic transmission is a proper solution for that kind of applications. Energy transition via hydraulic pipes allows a complex architecture of the machine, which at the end allows many others functionalities.



Figure 11. On field trailer testing

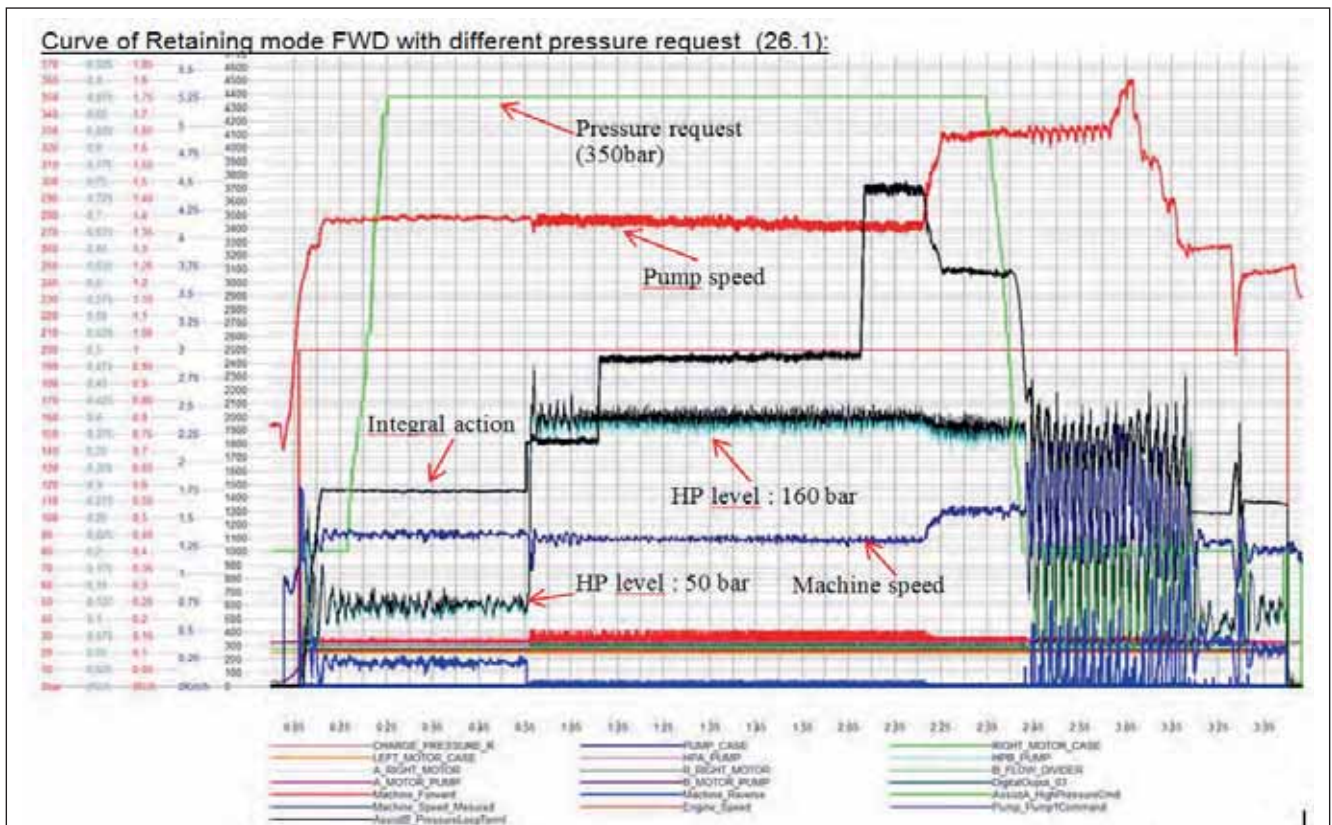


Figure 12. Measurements during commissioning

Also some further development steps can be defined: increasing end speed of the transmission using two speed hydraulic motors, integration of several components (hydraulic valves) into one group to simplify piping and some other improvements on the trailer geometry and auxiliary hydraulic system.

Literature

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Razvoj hidrostatičnih transmisij – Hidrostatična transmisija v zaprtem hidravličnem krogotoku na gozdarski prikolici

Izveček: Članek predstavlja razvoj, izdelavo in testiranje hidravlične transmisije na zelo produktivni traktorski gozdarski prikolici. Cilj projekta je bil razviti in izdelati zelo produktivno, hkrati pa tudi kompaktno in uporabniku prijazno gozdarsko prikolico, ki se bo lahko uporabljala skupaj s standardnim kmetijskim traktorjem.

Proizvajalec prikolice, podjetje Projernač s. p., je zato tesno sodelovalo s podjetjem Poclain Hydraulics d. o. o., ki je dobavilo potrebne komponente in znanje s področja razvoja hidravličnega in tudi upravljalnega (elektronskega in programskega) dela pogonskega sistema.

Rezultati zaključnega testiranja prikolice so pokazali, da na konfiguraciji kmetijski traktor – gozdarska prikolica, hidrostatični pogon na prikolici v delovnih razmerah tako rekoč prevzame vlogo glavnega pogona kompozicije (main drive) in ne le pomožnega pogona (assist drive), kot je bilo sprva zamišljeno.

Ključne besede: hidrostatične transmisije, mobilni stroji, gozdarske traktorske prikolice

Avtor prispevka se zahvaljuje podjetju Projernač s.p., ki je omogočilo in dovolilo objavo njihovega imena in produkta.

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