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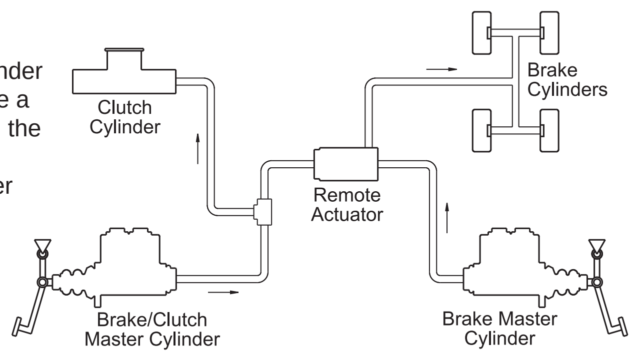
All machines need brakes - some, however, also need the ability to "inch". Selection of the appropriate type of braking/inching configuration is often determined by the machine class and size.

During normal driving, the braking forces on a machine are calculated by adding the force from the service brake system to the retardation effect of the engine through the transmission. Under most conditions, the retardation effect of the engine is desirable, since it allows the machine to slow down without the service brakes being applied, eliminating unnecessary wear as a result. However, when very accurate braking or "inching" is required, it is best to remove the retardation effect from the equation. This is done by automatically disengaging the transmission during service brake application.

Simple mechanical transmissions may require only the actuation of a clutch-release cylinder from the service brake system to disengage the transmission.

Figure 1 shows a simple non-boosted brake/inching system with two hydraulic master cylinders connected through a hydraulic remote actuator to the service brakes. The "brake" master cylinder output passes freely through the hydraulic remote actuator to the service brakes. The "brake/clutch" master cylinder output must first overcome a bypass pressure spring in the hydraulic remote actuator allowing the clutch cylinder to actuate before the service brakes can apply. The bypass pressure spring is sized to allow the clutch cylinder to disengage the transmission before the service brakes can be applied. This type of system can be used on small industrial equipment such as fork-lifts. The non-boosted brake system is a simple, yet suitable system for vehicles with sufficiently small brake volume/pressures.

Figure 1: Non-boosted brake/inching system



More technologically advanced mechanical transmissions use solenoid-operated directional control valves for disengaging the transmission. These solenoid valves can be actuated by an electrical signal from the service brake system.

"The basic operation of this pedal system is right pedal for brake only and left pedal for brake and transmission disconnect (inching)"

Figure 2: Full-power hydraulic brake/inching system

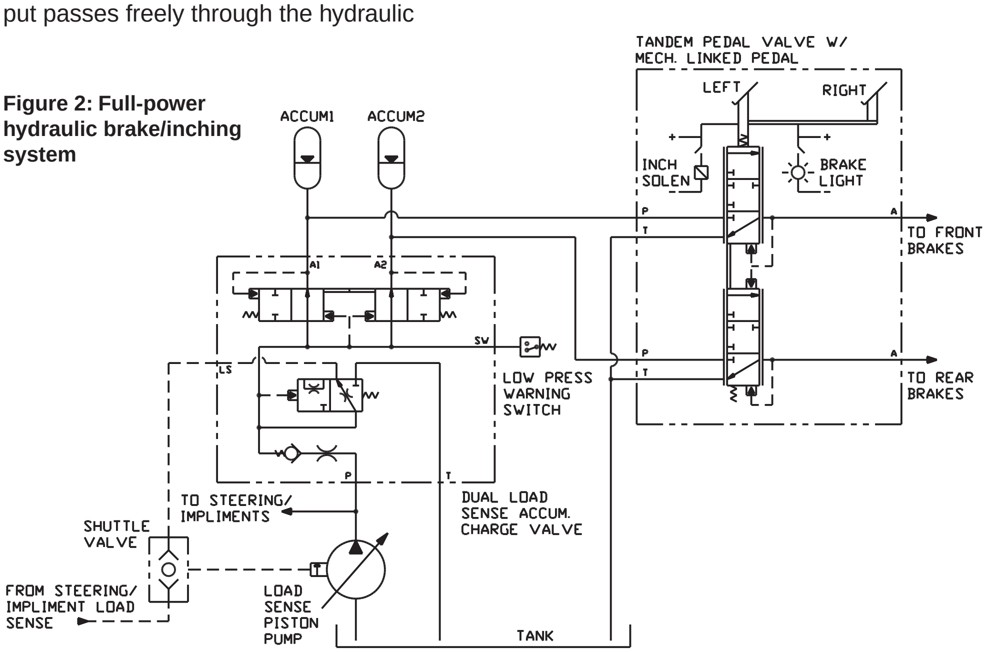


Figure 2 shows a full-power hydraulic brake/inching system with mechanically linked pedals. A tandem pressure-modulating valve supplies hydraulic pressure/volume via an accumulator circuit consisting of two hydraulic accumulators and a

load sense dual accumulator charging valve. The tandem modulating valve is actuated by a mechanical pedal linkage system. This system consists of two mechanically linked pedals and an integral switch box. Inside the switch box are two switches, one for brake light signal and one for transmission disconnect signal. When either pedal is actuated, the brake light switch engages and the brake pressure increases in direct proportion to pedal force. However, only when pressing the left pedal does the transmission disconnect switch engage. As a result, the basic operation of this pedal system is right pedal for brake only and left pedal for brake and transmission disconnect (inching). This type of system can be used on larger industrial equipment and earth moving/construction equipment such as wheel loaders. It is a simple, yet suitable system for those machines that can accommodate a mechanical linkage in the cab.

Figure 3 shows a full-power hydraulic brake/inching system with hydraulically linked pedals. Hydraulic pressure/volume is supplied by a tandem modulating pedal valve with pilot, single modulating pedal valve and a circuit consisting of two hydraulic accumulators and a load sense dual accumulator charge valve with a priority flow control valve. A hydraulic pilot line and hydraulic pressure switch for the transmission disconnect signal are fitted between the outlet port of the single modulating pedal valve and the pilot port of the tandem modulating pedal valve. When the tandem modulating pedal valve (right mounted) is actuated, only the brakes are applied with a brake pressure directly proportional to pedal force. When the single modulating pedal valve (left mounted) is actuated, the tandem pedal valve is pilot operated to apply the service brakes while the hydraulic pressure switch is also actuated for the transmission disconnect signal. The pilot ration in the pilot section of the tandem modulating pedal valve is 1:1, resulting in near identical brake pressure/pedal "feel" between the two pedals. As a result of this, the basic operation of this pedal system is right pedal for brake only and left pedal for brake and transmission disconnect (inching). this type of system can be used on larger industrial equipment and earth moving/construction equipment such as wheel loaders. It is more complicated than a mechanically linked pedal system, yet suitable for those machines that cannot accommodate a mechanical linkage in the cab due to interference or space constraints. Hydrostatic transmissions often have a rapid deceleration effect that, in most cases, eliminates the need for conventional service brakes. However, depending on the type of machine and/or local regulations, a service brake system may still be necessary. In this case, it is desirable to use a service brake system that will gradually destroke the hydrostatic drive before application of the service brakes begins. If this is not done, the strong deceleration effect of the hydrostatic drive, combined with brake forces from the service brake system, will cause over-aggressive braking. One type of system that destrokes the hydrostatic drive before applying the service brakes is known as a "Hystat" brake system.

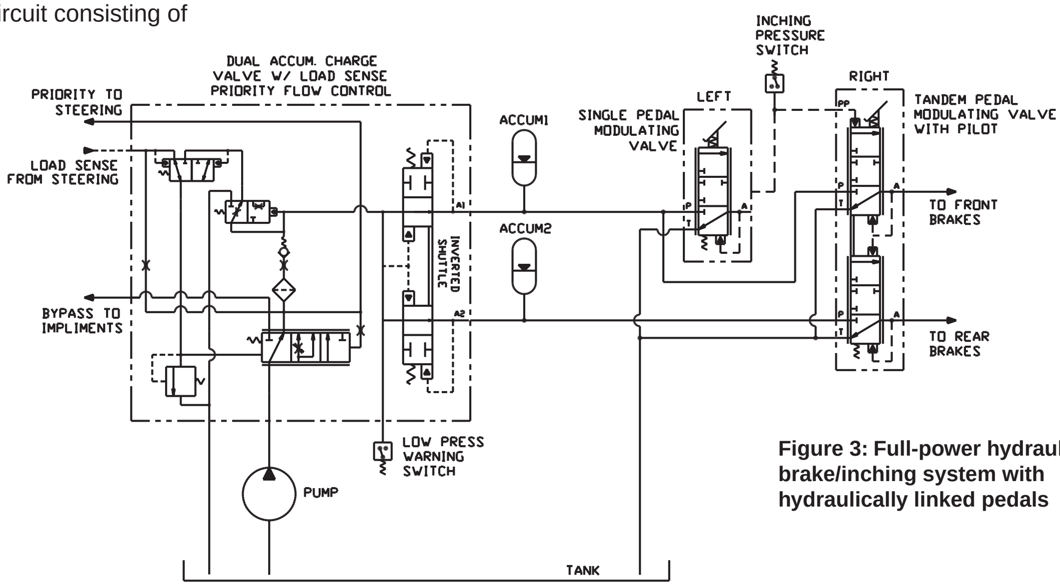
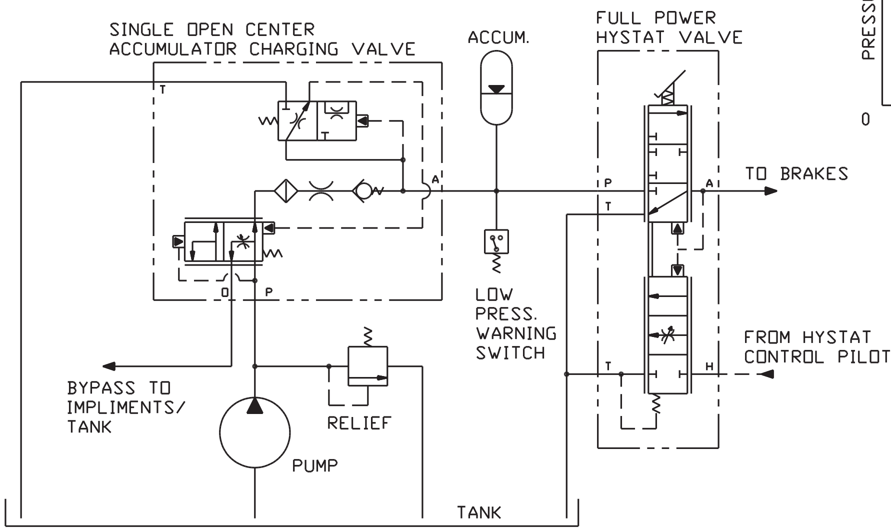


Figure 3: Full-power hydraulic brake/inching system with hydraulically linked pedals

"It is desirable to use a service brake system that will gradually destroke the hydrostatic drive before application of the service brakes begins"

Figure 4 show a full-power hydraulic Hystat brake/inching system. A Hystat brake valve supplies hydraulic pressure/volume by an accumulator circuit consisting of one hydraulic accumulator and a single open center accumulator charging valve. The Hystat brake valve

Figure 4: Full-power hydraulic Hystat brake/inching system



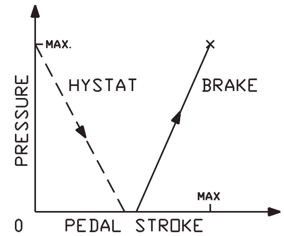


Figure 5: Graph showing brake pressures versus valve actuation

consist of two valve sections in a single housing. The bottom section controls the pilot pressure to the hydrostatic drive control and the top modulating valve section controls service brake pressure. When the Hystat brake valve is actuated, pilot pressure to the hydrostatic drive control decreases to destroke the hydrostatic drive before the service brakes are applied. The brake pressure is proportional to pedal force. Figure 5 shows brake pressures versus valve actuation. The Hystat brake valve is typically optimized for each machine application, and this type of system can be used on hydrostatic-driven earth moving/construction and industrial machines. Applications include wheeled excavators, small wheel loaders and forklifts with hydraulic pilot control of the hydrostatic drive. It should be noted that machines with low brake pressure and/or volume could possibly use a non-boosted version of the above valve with a master cylinder in place of the brake modulating valve section.

Figure 6 shows a full-power electronic/hydraulic hybrid Hystat brake/inching system. A single modulating brake valve is mounted to an electronic pedal with a potentiometer (variable resistor). the single modulating brake valve supplies hydraulic pressure/volume through an accumulator circuit consisting of one hydraulic accumulator and a single open center accumulator charge valve. When the Hystat brake valve is actuated, the potentiometer sends a signal to the electrohydraulic hydrostatic drive control (not shown) before the service brakes are applied. When the service brakes are applied, brake pressure is directly proportional to pedal force. This type of system can be used on hydrostatic-driven earthmoving/construction and industrial machines with electrohydraulic pilot control of the hydrostatic drive, with applications including small wheel loaders and telescopic handlers. In addition, the system can also be designed as a "split" front/rear brake system by using a tandem modulating brake valve. As before, machines with small brake pressure and/or volume could possibly use a non-boosted version of the above valve with a master cylinder in place of the brake modulating valve section.

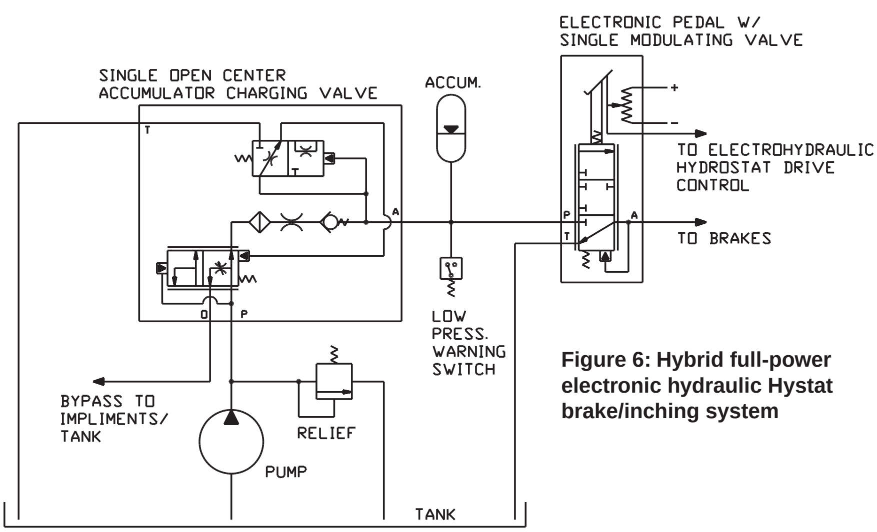


Figure 6: Hybrid full-power electronic hydraulic Hystat brake/inching system

Figure 7: Full-power electrohydraulic Hystat brake/inching system

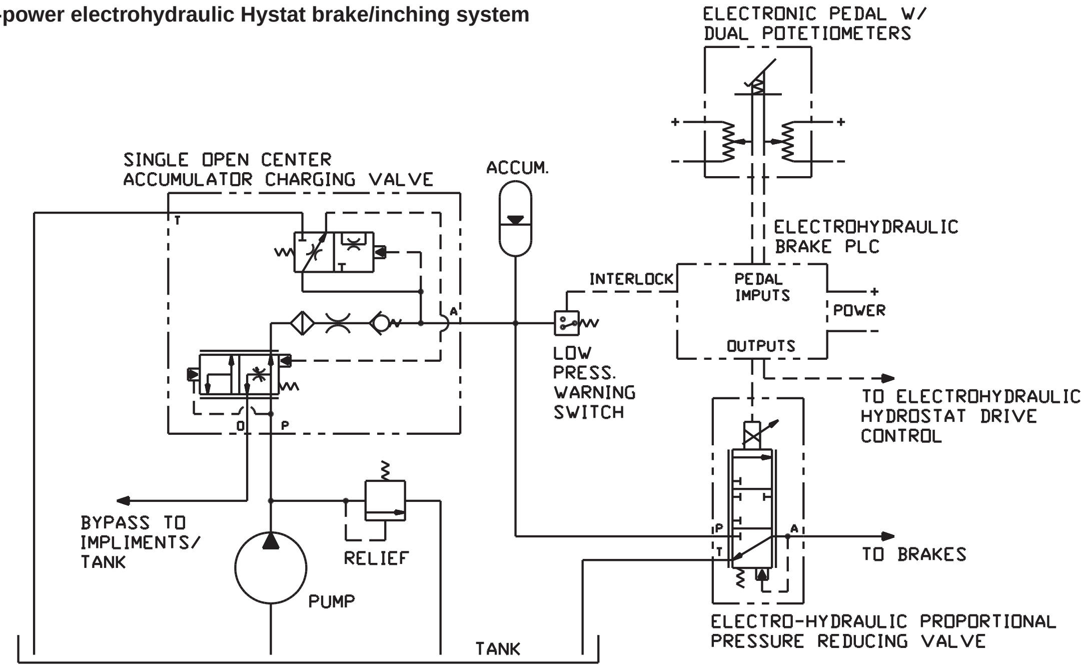


Figure 7 shows a full-power electrohydraulic Hystat brake/inching system. An electrohydraulic proportional pressure reducing (EPPR) brake valve supplies hydraulic pressure/volume through an accumulator circuit consisting of a hydraulic accumulator and a single open center accumulator charge valve. The EPPR brake valve is controlled by an electronic pedal and pulse width modulated (PWM) current drive electronics. The electronic pedal has multiple potentiometers. One potentiometer provides a signal to the electronic control of the EPPR brake valve, with another potentiometer providing a signal to the electro-hydraulic hydrostatic drive control (not shown). This type of system can be used on large hydrostatic-driven equipment with unusual geometries and/or large distances between cab and brakes, such as aircraft pallet loaders. Through the use of this system, machines can realize large cost savings in piping and installation labor, etc. Once again, this system can be designed as a split (front/rear) brake system by using two EPPR brake valves and an electronic pedal with three potentiometers.

Operating parameters can be easily adjusted through software on this type of system. This will reduce development costs and adjustments when the machine is being built. Additional diagnostics built into the electronics reduce maintenance expenses.

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