Closed vs. Open Loop Safety Considerations

General Background

High pressure, variable displacement piston hydraulic systems provide the best performance, efficiency, and component life for use in high duty cycle offshore cranes. Piston hydraulic circuits are available in two configurations, closed circuit and open circuit. The following information details the safety and ramifications of closed and open circuit hydraulic systems as applied to hoisting and slewing operations of offshore cranes.

Closed Circuit Hydraulic Systems

The pump in a closed hydraulic circuit discharges directly to the hydraulic motor, and flow exits from the opposite port of the motor directly back to the pump. The hydraulic fluid moves in a closed loop from which it does not escape. With a closed circuit system, the pump has a rotating swashplate. The position of this swashplate selects the direction and volume (volume determines hoisting speed) of pump flow or, if the swashplate is vertical, then no flow occurs (neutral).

The best application for closed circuit hydraulic systems is on equipment with horizontal, reversing loads. For example, by far the most common application for closed circuit hydraulic systems is vehicle ground drives, such as crawler mounted earth moving equipment, off-road construction and agricultural equipment.

Closed Circuit Hoisting

Hoisting on a crane is not a horizontal, reversing load. When hoisting vertically (lifting) in the up direction, the pump builds pressure until great enough to lift the load or the boom. When lowering, the same side of circuit is under pressure.

Dynamic braking, controlling the vertical descent of a load or the boom without them running away, with a closed circuit hydraulic system is accomplished by back driving the pump. The pump and diesel engine control the vertical descent of the load and combined are the dynamic brake.

Safety Problems with Closed Circuit Hoisting

The diesel engine in a closed circuit hoisting system must develop sufficient power to drive all three primary crane motions at full load and full speed at the same time. Otherwise loss of dynamic braking
capability can occur because of engine overload while lowering the **boom and the hook** at the same time.

- If sufficient power is not available at the **engine** for **dynamic braking** during simultaneous operations, the **engine** will back drive just as it would on a mechanical crane, and loss of control of the load will occur. The **diesel engine** must run at high throttle at all times during heavy lifting operations with a **closed circuit hoist** equipped cranes to keep the power level up for **dynamic braking**.

- The high kinetic energy from vertically suspending heavy loads and the weight of the **boom** often make it impossible to **dynamically brake** simultaneous operations with a reasonably-sized **engine**, even at full **engine** speeds.

- As a result of running the **diesel engine** and **pumps** at high speeds, controllability while safely moving heavy loads by small increments is reduced. In addition, **prime mover** failure, for any reason, can result in loss of control of the load.

**Closed Circuit Hoisting Complexity**

Extremely complex and difficult to maintain **ancillary electronic** and **hydraulic control circuitry** is added to closed **circuit hydraulic vertical hoisting systems** in an attempt to reduce the risk of the basic safety flaws inherent with **closed circuit hoisting** and **dynamic braking**.

*(PHOTOS SHOW COMPETITOR’S HYDRAULIC SYSTEM)*

**Open Circuit Piston Hydraulic Hoisting Systems**

The **piston pump** in an **open hydraulic hoisting circuit** draws fluid from a **storage tank** or **reservoir** and then discharges it through a **directional control valve** which is used to select **up**, **down** or **neutral**. Flow from this valve goes to the **motor** and then back to the **tank** (**up** or **down**) or goes directly back to the **tank** when in **neutral**. The position of the **rotating pump swashplate** selects the volume of **pump** flow (volume determines hoisting speed).

**Open circuit dynamic braking** is accomplished by means of a **dynamic brake** or **counterbalance valve** which is fitted directly to the **hydraulic motor**. The energy of vertically lowering the load and **boom** at a controlled speed is converted into heat in the **hydraulic fluid** by forcing it to effectively flow through a small orifice at high pressure. The full volume of fluid exchanges with the tank (it is not trapped in
a closed circuit), so it is a simple matter to maintain cooling via a full flow heat exchanger and tank baffling.

**Open Circuit Hoisting**

When hoisting vertically (lifting) in the up direction, the pump builds pressure until great enough to lift the load. The hoisting speeds are controlled by the pump and diesel engine speed. The dynamic brake valve is bypassed in the up direction.

**Open Circuit Dynamic Braking**

Dynamic braking (controlling the vertical descent of a load or the boom without them running away) with an open circuit hydraulic system is accomplished by applying positive pressure in the downward direction to slightly pilot open the dynamic brake valve. In other words, the dynamic brake valve controls the descent of the load rather than the pump and diesel engine.

**Advantages of Open Circuit Hoisting Systems**

The open circuit hoisting configuration overcomes the inherent safety problems associated with using closed circuit systems to handle vertical loads as described below.

- The open circuit diesel engine plays no role in dynamic braking of vertical loads. This means that the prime mover need not be sized based on the potential full power requirements of the three primary crane motions. It is NOT possible for the engine to back drive resulting in a loss of control of the load.

- For this reason, a failure of the prime mover cannot and will not result in loss of control of the load.

- It is not necessary to run the diesel engine at high speed. Full rated loads, on both the boom and the hook, can be lowered under full control with the engine operating at idle speed.

- Since the diesel engine and pumps can safely operate at low or high speeds, controllability while
safely moving heavy loads by small increments is greatly enhanced by modulating the pump AND engine speeds.

**Open Circuit Hoisting Simplicity**

Open circuit hoisting does NOT require complex and difficult to maintain ancillary electronic and hydraulic control circuitry. The basic arrangement is inherently safer in its basic design. This allows for a safe, easy to maintain high performance arrangement for handing of vertical loads.

( PHOTOS OF SEATRAX ARRANGEMENT)

**Closed Circuit Slewing Systems**

When slewing a crane, the loads are horizontal and reversing, so a closed circuit hydraulic arrangement provides the best service. Because of the lower horsepower demand of the slew system, the engine does not always have to run at high speed to ensure dynamic braking. Since the diesel engine and pumps can safely operate at low or high speeds, controllability while safely slewing heavy loads by small increments is greatly enhanced by modulating the pump and engine speeds.

**Closed Circuit Slewing**

A closed circuit slew system is arranged with a conventional closed circuit hydraulic system. Loads are horizontal and reversing rather than vertical and suspended.

When the slew joystick is released, the crane automatically decelerates in a smooth manner without consuming excessive power. This operating characteristic is especially useful on cranes mounted on floating and listing installations.
Seatrax High Pressure, Piston Hydraulic Systems

Seatrax combines the most favorable safety-in-design, fail-safe hydraulic arrangements available for offshore cranes. For hoisting of suspended, vertical loads and the weight of the boom, open circuit hydraulic systems are used. For handling the reversing, horizontal loads associated with the slew system, closed circuit hydraulic systems are used. Each hydraulic system type has distinct operating advantages depending on the crane operation type, and Seatrax utilizes these advantages to the fullest by combining the system types.

The fully closed hydraulic circuit was used by Rexroth, the hydraulic equipment supplier for many offshore cranes, before the combined approach was available. Rexroth agreed to develop the combined closed/open piston hydraulic system because customers such as BP, Shell, Kerr McGee, Chevron Texaco, Conoco-Phillips, Petrobras and many drilling contractors had expressed a strong interest in an arrangement that had safer operating characteristics than the fully closed circuit, without the associated complexity and high operating costs associated with the fully closed hoisting hydraulic circuits.

The Seatrax combined closed/open hydraulic system is the successful result of years of joint development between Rexroth and Seatrax, which includes development, detailed design, testing and refinement. Dozens of these systems are operational throughout the world, providing a safer, more dependable solution for hydraulic marine cranes.