EC Hydraulic Drive Cylinder Relief Valve Test

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Overview:

This engineering note documents the testing of the set pressure of the EC hydraulic drive cylinder relief valve. The purpose of the relief valve is to provide a safety measure in the event that oil becomes trapped in the rod side of the cylinder and pressure is applied to the cap side. The note includes an explanation of the procedure used and a summary of the result of the testing done on February 14, 1991 by Gary Trotter. The result was that the cylinder relief valve relieved at the correct set pressure of 10,500 psig.

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Safety Concern:

The basic concern is for the protection of the cylinder. The pump is capable of providing up to 10,500 psi of pressure to either side of the cylinder. The cylinder is rated for 10,500 psi. Under normal operating conditions, the valves would be open, and the pumping pressure would automatically flow oil into one side, and remove oil from the other side. If, however, the valve for the other side was closed, so that oil could not be removed, then the pressure would build in that side. If the rod side is pressurized to the maximum pump pressure of 10,500 psi, the cross sectional area ratio of 2.29 results in a pressure of approximately 4600 psi in the cap side, which is well under the rated pressure. If, however, the cap side is pressurized to 10,500 psi, the cross sectional area would produce a pressure of approximately 24,000 psi in the rod side, which could damage the cylinder. Therefore, the pressure on the rod side must be limited to the rated pressure of 10,500 psi. In reality, the maximum operating force on the piston would be under 11,000 lbs., which would result in the maximum cylinder pressure being under 8000 psi to the rod side, and under 3500 psi to the cap side. Therefore, the relief is only needed as a safety precaution in the case that oil becomes trapped.

Procedure and Calculations:

The basic purpose of the test was to verify that the relief valve operated at the correct set pressure of 10,500 psig. In order to test the relief in the appropriate situation, oil was intentionally left in the rod side of the cylinder, and the valves were closed so that the oil was trapped. Then pressure was applied by pumping oil into the cap side. Because of the rod, the cross sectional areas acted upon by the oil differ (see Appendix 1), therefore the oil pressures also differ. The calculations are as follows:

let: A_1 = cross-sectional area of rod side,

A_2 = cross-sectional area of cap side,

d_1 = diameter of rod = 1.5 in.,

d_2 = inner diameter of cylinder = 2 in.

Then,

$$A_1 = \frac{\pi(d_2)^2}{4} - \frac{\pi(d_1)^2}{4} = \frac{\pi(2\,\text{in})^2}{4} - \frac{\pi(1.5\,\text{in})^2}{4} \approx 1.374\ \text{in}^2$$

$$A_2 = \frac{\pi(d_2)^2}{4} = \frac{\pi(2\,\text{in})^2}{4} \approx 3.142\ \text{in}^2$$

Since the forces from both sides are equal,

$$F_1 = F_2 \Rightarrow P_1(A_1) = P_2(A_2) \Rightarrow \frac{P_2}{P_1} = \frac{A_1}{A_2} \Rightarrow P_2 = P_1\left(\frac{A_1}{A_2}\right)$$

Setting P_1, the oil pressure on the rod side, to the relief set pressure of 10,500 psi,

$$\Rightarrow P_2 = (10{,}500\,\text{psi})\left(\frac{1.374\,\text{in}^2}{3.142\,\text{in}^2}\right) = \frac{10{,}500\,\text{psi}}{2.29} \approx 4585\,\text{psi}$$

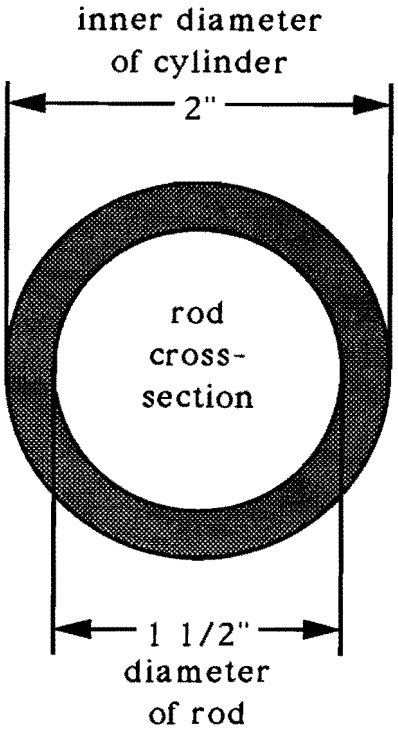
Therefore, in order to produce an oil pressure of 10,500 psi on the rod side, it is only necessary to apply a pressure of approximately 4600 psi on the cap side. A pressure of 4500 psi was used in testing the relief valve.

Results:

The relief valve operated as expected. The cap side was pressurized to approximately 4500 psig, and oil was blown from the relief. The relief valve that was added was a Chicago Jack #CJ160900 high pressure relief, set at 10,500 psi, and with a 3/8 NPT connection. The original drawing of the drive cylinder, #3740.510-MC-279372, was modified in Revision B to add the relief valve.

Appendix 1
Drawings of Cylinder

Rod Side



Cap Side