HYDRAULICS

Capt. M.P. "Pappy" Papadakis

Many airplanes of the more sophisticated variety utilize hydraulic systems to accomplish a myriad of operations in aircraft. Among typical hydraulic functions are:

1. Gear, up and down.
2. Flight control boosted movements. (power steering)
3. Flaps, down and up.
4. Speed brake.
5. Ground spoilers.
6. Yaw damper.
7. Brakes.
8. Rudder augmentation.
9. Some doors and stairs.

The more sophisticated the aircraft the more such systems are employed, and the more complex each is. An investigator must know the type and variety of system on each aircraft by referring to the particular system manuals.

Most hydraulic systems on aircraft are rated at 3,000 lbs pressure plus or minus 200, with low pressure systems at 1,500 lbs. system pressure. Since some systems are critical to flight it is usual that redundant systems are provided so that loss of the system will not result in loss of the airplane. A hydraulic system usually consists of the following components: A fluid reservoir, lines, pumps, (engine driven or electric) and actuators. Work is accomplished by pumping fluids under high pressure.

Three principles of hydraulic operation are:

1. Fluids are not compressible.

and

2. Force = Pressure times Area.

and

3. Work = Force times Distance.

Actuators are of varying designs, but in general their purpose is to change hydraulic flow into some sort of powerful linear motion. The system may operate an actuator device that acts as a pump in reverse (in reality a motor). By this, it is meant that the flow of high pressure fluid drives a hydraulic pump (motor) and this motorizes a shaft in the direction consistent with the flow. Reversing the flow will reverse the shaft rotation. The shaft in turn may rotate jack screws that position and retract flaps or other devices. When these jackscrews fail they remain where they were last positioned.

The system may move an actuator that simply moves a piston in or out by direct application of hydraulic pressure on a movable piston face. If this system loses pressure and it is otherwise untouched the actuator will remain in its last position. However, if the actuator is influenced by outside crash or aerodynamic forces then the actuator may move after fluid / pressure loss. For instance the hydraulic prop dome is designed so that at fluid / pressure loss the spring drives the propeller to feather.

You may remember the design of the hydraulic system of the DC-10 that crashed at O'Hare was such that when hydraulic pressure was lost the wings leading edge devices were blown up due to wind forces. The point is that if the actuator system is such that at pressure loss the fluid evacuates the cylinder, then it may move. In such a design wreck damage may move the piston.

Within the cockpit the pilot or engineer is usually provided three indications of hydraulic system health. He will have a quantity gauge that tells reservoir quantity. He will have a system temperature gauge and a pressure gauge. These may have warning lights as well. The pilot or engineer will have switches so he can turn off a bad pump or system.

Thus within the cockpit the investigator has some clues as to operation of the system. They are:

1. Switch position.
2. Ac powered gauge readings.
3. Light bulb analysis of warning lights and associated component enunciator lights.

Outside the cockpit the investigator will have some other clues. Depending upon crash damage he may have intact reservoirs. If these have fluid remaining then there probably wasn't a leak causing loss of system. (When a severe leak occurs a three thousand pound system evacuates almost faster than a pilot or engineer can react) Leak areas can sometimes be identified by color stains in the area. Old fluid and military mil5606 fluid is bright red.

The investigator can examine hydraulic pumps. If they are seized or overheated they may have been run dry. The investigator can flow check and bench check the hydraulic pumps to see they operate normally, and he can disassemble them to ascertain internal condition thereof. Next the investigator will examine the actuators themselves to ascertain position at time of crash.

The system that is composed of a hydraulic motor driving a jackscrew device is the easiest position determination an investigator can make. The jackscrew will remain where it was during impact. This device, because of its screw thread design, will break rather than unscrew or otherwise move.

Much more difficult is trying to determine the position a piston type actuator was at impact. Equally frustrating is trying to determine what it was commanded to do prior to impact.

This piston variety of actuator is usually comprised of a piston in a cylinder filled with hydraulic fluid. One side of the piston is attached to a shaft that protrudes out the end of the cylinder. As the cylinder is pressurized with metered hydraulic fluid the piston moves to a new position and the shaft extends from or retracts into the cylinder. The shaft may move a flight control, or it may apply brakes.

Some more sophisticated varieties apply hydraulic pressures to both sides of the piston so movement is determined from a neutral mid position. In cases like this the actuator will only move when fluid is ported to one side of the piston and fluid is simultaneously evacuated from the opposite side. Thus powering the system on one side and the evacuation on the other allows movement. The metering valve opens one side to allow fluid in and an exit valve simultaneously opens on the other side letting fluid out.

In some systems the piston movement is determined by the fluid pumped into one side (A) while being evacuated simultaneously from side (b). The shaft movement will move a flight control in either direction.

In a system such as this, it requires three things for movement of the shaft. They are:

1. Hydraulic pressure available at the input metering valve.
2. Opening of an input valve on one side.
3. Opening of an evacuation valve on the other side.

A system such as this is “fail safe” or at least “fail passive “design. A failure of either one input or one exit valve will not cause uncommanded movement of the system. This is true since fluid is incompressible. Thus if an input valve opens it can't move the panel since the opposite exit valve is still closed. Conversely, if an exit valve fails one side evacuates but there is little movement since there is no fluid entering the system. This system is designed to fail passive and remain where it was except for natural slow leakage. If the hydraulic system fails the system reverts to manual reversion and both hydraulic chambers are evacuated and a secondary system takes over rudder control.

An investigator has many clues to aid him in determining what the piston type actuator was doing at impact. The clues are:

EXTERNAL

a. Determine from positions of valves and clamps if the device was powered or manual.

b. Examine length of polished shaft. If measurements show extension or retraction beyond limits, it was probably wreck damage.

c. Measure length of polished shaft for measurement that correlates to a position within normal limits. If this correlates positively to expected positions then it may be a valid indication of position at impact.

d. Examine polished shaft for impact or witness marks. If they exist them shaft has moved after impact.

e. If such witness marks occur on shaft, then the one farthest from the as found position may be the valid first impact mark.

f. If the polished shaft is clean and of a length showing maximum limit extension it may signify an unusual condition, manual reversion or crash induced pull through.

g. If a hydraulic actuator is bulged, has exploded walls, or has seals blown out then the system was powered and filled by hydraulic when the piston tried to move at impact. (This is because hydraulic fluid is incompressible thereby causing the bulging.)

h. Such a system can only move at impact or post impact if the hydraulic cavities within are evacuated. Thus it is a clue of pre existing failure or manual operation if there is post impact movement without bulged cylinders or blown seals.

TESTING

If a system seems intact, and after a complete external non destructive examination is concluded, the actuators can be bench tests to see if they work and if they meet all performance specifications.

INTERNAL

If the system has been tested or if it is damaged such that testing can not be tested the part should be disassembled and examined. Internally the investigator is looking for ground impact witness marks between the cylinder wall and the piston. More than one set shows piston potion and movement as a result of ground impact.

You should remember that the discussion was for a generic actuator with hydraulic fluid on both sides of the piston. An investigator must have control drawings of the actual actuator so as to have correct rigging measurements and to be sure of the functioning of the actuator. You may have varieties of actuators that are vastly different in design concept and construction.

As in the prop you may have springs loading in one direction / hydraulic force movement in the other. Some systems have a compressed air preload on one side and hydraulic the other. In these cases impact damage may be free to move one direction but not the other.