Systems

Phil Plumley
SYSTEMS

• Systems forms part of the Aircraft General Knowledge (AGK) exam
• AGK exam is 2 hours in length and consists of:
  - 25 Systems questions
  - 25 Engines questions
  - 18 Electrics questions
  - 8 Emergency Equipment questions

• The topic consists of 48 Systems periods and covers the following subjects:
  - Hydraulics and Pneumatics
  - Pressurisation and Air Conditioning
  - Oxygen (part of the emergency equipment block)
  - Ice Detection and Prevention
  - Aircraft Fuel Systems
  - Landing gear, wheels and tyres
  - Emergency equipment
  - Aircraft Structures
  - Flying Controls
HYDRAULICS

Phil Plumley
Objectives

• State Pascal’s Law
• Solve mathematical problems associated with Brahma Press
• Describe a simple Open Centre Hydraulic system
• State the requirements of a hydraulic fluid
• Name and describe the hydraulic fluids in common usage
WHY HYDRAULICS?

• Light aircraft with relatively small control surfaces and operating at low speeds can be operated by muscle power through cable systems.
• As both speed and control size increase, the force required to move the surfaces increases.
• Eventually the forces involved are either too tiring to overcome for any length of time or simply beyond the capability of a pilot.
• When this point is reached, some form of powered help is required simply to fly the aircraft.
• In addition, other services (undercarriage, flaps etc) may become too difficult to operate manually.
• One of the most common forms of powered help is hydraulic power.
• Note that the terms Power operated and Power assisted mean rather different things.
For an open container of fluid, the pressure exerted by that fluid is dependent only on the depth of fluid.

Hence, varying containers of different sizes will give the same pressure if they contain the same height of fluid.
PRESSURE COMPARISON

OPEN CONTAINER

The pressure within the open container increases with the depth of fluid.
PASCAL'S LAW

- If the container is now closed, and a piston acts on the fluid with a given force, the pressure will be felt instantaneously throughout the container.
- The pressure will be the same value everywhere and will act at 90° to the surfaces.
There are 3 quantities to consider on each side of the press:
- Force (F)
- Cross-sectional Area (A)
- Pressure (P)

These are related by the formulae: \( F = P \times A \) or, \( P = \frac{F}{A} \) or, \( A = \frac{F}{P} \)

Thus, if any 2 of the quantities are known, the third can be calculated.

In addition, as the piston moves, it must displace the same volume of fluid.

Therefore, we can say for both sides of the press, \( A \times \text{distance the piston moves} \) is the same.
The Reservoir holds the fluid.
The pump supplies the pressure.
The actuator jack provides the output.
THE RESERVOIR HOLDS THE FLUID
THE PUMP SUPPLIES THE PRESSURE
THE ACTUATOR JACK PROVIDES THE OUTPUT
THE RESERVOIR HOLDS THE FLUID
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THE SELECTOR VALVE ALLOWS THE SUPPLY AND RETURN TO SWITCH OVER AND REVERSE THE DIRECTION OF THE JACK
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OPEN-CENTRE (PASSIVE) SYSTEM

Open Centre Hydraulic System
Problem - only one service can be operated at a time
PROPERTIES OF HYDRAULIC FLUID

- Lubrication - reduction of friction
- Low viscosity - easily pumped around system
- Wide temp range
- Non-corrosive - will not affect other materials/compatible with seals etc
- Stable - does not quickly deteriorate
- Non-foaming/non-toxic/non-flammable
- Virtually incompressible
- Typical system pressures 1500-4000psi
<table>
<thead>
<tr>
<th>FLUID TYPE</th>
<th>EXAMPLE</th>
<th>COLOUR</th>
<th>SEAL MATERIAL</th>
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</thead>
<tbody>
<tr>
<td>VEGETABLE OIL</td>
<td>LOCKHEED 22</td>
<td>STRAW YELLOW</td>
<td>NATURAL RUBBER</td>
</tr>
<tr>
<td>SYNTHETIC</td>
<td>SKYDROL</td>
<td>GREEN OR PURPLE</td>
<td>BUTYL RUBBER</td>
</tr>
<tr>
<td>MINERAL OIL</td>
<td>DTD 585</td>
<td>RED</td>
<td>SYNTHETIC RUBBER</td>
</tr>
</tbody>
</table>

- nb Skydrol is a phosphate ester based synthetic oil and is an irritant to both skin and eyes (Flash Point 6-700°C so NOT considered a fire hazard)
Mineral oil flammable

Oil types must not be mixed under any circumstances
SIMPLE CLOSED CENTRE SYSTEM

- Pump
- Reservoir
- Filter
- Accumulator
- Gas
- Oil
- NRV
- Ground Test Couplings
- Automatic Cut-out
- Pressure relief valve
- Selector valve
- NRV
- Hand pump
- Common return
- Via Selector Valves
- To other Services
- Jack
- Jack
Objectives

Identify the main components of an Active system and describe their working principles and functions
RESERVOIR

Functions:

• To hold hydraulic fluid

• Provide sufficient space for changing volume of fluid

• Purge gas from return fluid

• Correct fluid is shown on the label
FILTERS

• Removes fine particles from fluid to prevent damage to seals and moving components, especially pumps

• Two basic types
  - paper filament (replaceable)
  - metal filament (cleanable)

• Named after position in circuit (pressure/suction/return)

• May have a bypass (relief) system as dirty oil is better than no oil (red pop out button shows if relief valve has operated)
FILTERS
FILTER CAPABILITIES

HUMAN HAIR IS ABOUT 100 MICRONS IN DIAMETER

40-MICRON PARTICLE  10-MICRON PARTICLE  5-MICRON PARTICLE
PUMPS

• Two main types:
  - **Constant volume** (requires ACOV); delivers a fixed quantity of fluid to system
  - **Constant pressure**, variable volume; reduces flow by changing the angle of a swash plate when system pressure is reached

• Purpose is to provide a flow of hydraulic fluid at a given pressure

• Driven by:
  - Engine (most common)
  - Electric motor (AC or DC)
  - Air Driven Motor
  - Ram Air Turbine
  - Power Transfer Unit
  - Hand (used for emergency backup, ground servicing)

• In a 2 pump system, the loss of one pump will mean that system pressure remains the same, but flow rate will halve. This will result in increased service operating times.
CONSTANT VOLUME PUMPS
Axial piston pump

Quill drive shaft

Piston on outward stroke

Universal joint

Piston on inward stroke

Outlet

Inlet
CONSTANT VOLUME PUMPS

Radial piston pump

- Piston on fill stroke
- Piston on power stroke
- Inlet
- Outlet
- Quill drive shaft
- Eccentric crankshaft
CONSTANT PRESSURE, VARIABLE VOLUME PUMP

- Inlet
- Outlet
- Control piston
- Lubrication drain
- Drive shaft
- Non-rotating swash plate
- Piston
- Non-rotating port plate
- Rotating cylinder
- Outlet
- Inlet
CONSTANT PRESSURE, VARIABLE VOLUME PUMP
CONSTANT PRESSURE, VARIABLE VOLUME PUMP

Non-rotating port plate

Rotating cylinder

Non-rotating swash plate

Inlet

Outlet

Drive shaft

Control piston

Piston

Non-rotating port plate
HYDRAULIC PUMP
SYSTEM REDUNDANCY (MULTIPLE PUMPS)

Each pump delivers 3000 psi and 10 gals/min

If one pump fails:
- NRV prevents one pump feeding the other
- Pressure stays the same
- Flow rate halved and services operate slower

Pump 1

Amber Warning Light

Pressure Switch

Pump 2

Amber Warning Light

Pressure Switch

3000 psi and 20 gals/min
AUTOMATIC CUT-OUT VALVE (ACOV)

- Directs the excess fluid back to the reservoir in a hydraulic system using a constant volume pump.
- Reduces pump wear, consumption of engine power and helps prevent the fluid from overheating.
- Operates by sensing the demand (downstream) system pressure; services selected, pump flow to system; no services and correct pressure, excess fluid to reservoir.
- System operates on a cycle time as pressure drops and then is recharged each few minutes (cuts out at about 3200 psi, cuts in at about 2800 psi).
ACCUMULATORS

• Accumulators are always used in a constant delivery system and in the brake system on large aircraft
• Maintains a store of hydraulic fluid under pressure and hence, gives a reasonable idle time for the pump
• Functions are:
  - To give an initial impetus to the system when a service is selected
  - Dampens pressure fluctuations
  - Gives a reserve of pressure should the pump fail
• Gas is normally Nitrogen but can be air
• To charge an accumulator, first dissipate all normal system pressure
• Usually charged to half system pressure
ACCUMULATORS

[Diagram of an accumulator with parts labeled: top, separator, filter gauze, washer, filter assembly, single seal, system connection, end fitting, piston, non-vented seal, vented seal, flapper ring, backing ring.]
ACCUMULATORS
TYPICAL HYDRAULIC BAY
DISTRIBUTION MANIFOLD
NON-RETURN VALVE (NRV)

Purpose is to allow flow in one direction only

Normal flow

Reverse flow
NON-RETURN VALVE (NRV)

NRV Closed

NRV Open
NON-RETURN VALVE (NRV)
MANUAL SELECTOR VALVES

- Purpose is to direct hydraulic flow; dependent on the pilot selection.

4-Way rotary valve with blocked neutral
4-Way rotary valve with open neutral
4-way slide valve with blocked neutral

P = Pressure
R = Return
A = Actuator
ELECTRICAL SELECTOR VALVE (2-WAY)

Diagram showing the components of a 2-way electrical selector valve, including manual selector, supply, solenoid, pilot valve, and connections to small and large pistons and reservoir.
ELECTRICAL SELECTOR VALVE (2-WAY)
ACTUATORS

Also called **Hydraulic Jacks**
Convert pressure energy into linear motion

**Single-acting**
- Pressure to one side
- Spring returns piston when pressure released
- Undercarriage door locks

**Double-acting**
- Pressure to either side
- One side has greater area - more force going one way
- Landing gear and flaps

**Balanced**
- Pressure to either side
- Equal areas
- Nose wheel steering - equal forces required on both sides
RELIEF VALVES

- Purpose is to relieve excess pressure in the system back to the reservoir and usually operate at about 3800 psi (full pressure relief valves)
- Thermal relief valves relieve excess pressure caused by the expansion of trapped fluid as temperature increases
- However, they sense pressure not temperature and usually operate at pressures around 3350 psi
- A Blowback valve is a form of pressure relief valve fitted in spoiler and flap circuits to prevent overpressure causing damage to the aircraft because of aerodynamic forces (if inadvertently selected at high speeds)
RESTRICTOR VALVE

- Purpose is to control rate of flow

- Normally fitted in the return lines and Restricts flow in one direction only (marked by a dotted arrow on the valve body)

- Restricts flow in the flap down line and creates a restriction during up flap selection

- Restricts flow in landing gear up line and creates a restriction during gear down selection
In the event that system supply reduces, the priority valve ensures pressure is provided to primary (essential) services (operates at around 2500 psi)

Undercarriage lowering is classed as a secondary system and has (for exam purposes) 3 systems for lowering.

These are:

Primary hydraulic
Secondary hydraulic
Mechanical (free fall)
Pressure reducing valve reduces pressure for subsystems.
SEQUENCE VALVES

- Purpose is to ensure that components operate in the correct, pre-determined, order/sequence (e.g., undercarriage doors and undercarriage)
Feed from undercarriage jacks

Return feed

When gear is down, back-pressure overcomes spring pressure

Feed to undercarriage door

SEQUENCE VALVES
SHUTTLE VALVE

- Purpose is to provide a method of splitting 2 different supplies (normal and emergency) to a single service

- CAA sometimes say to supply 'best' pressure to a service
SERVO CONTROL UNIT

- Piston is fixed and the body of the unit moves under differential pressure
- Loss of pressure causes the interconnecting valve to open and another servo unit would now be able to operate the control surface
SERVO CONTROL SEQUENCE

System at rest

Control is moved allowing pressure fluid to be applied to servo piston

Body moves, as piston is fixed
Control surface moves
System returns to rest
HYDRAULIC JETTISON VALVES

Used to relieve fluid pressure from behind the actuator when an 'Air bottle' type emergency gear lowering system is used
PRESSURE RELAY

- Used in older systems with long distance from hydraulic bay to pressure gauge in the cockpit
- Purpose is to cut off the supply to the gauge in the event of a leak from the pipe to the gauge
- Normally there is no flow through the relay and the relay merely transmits pressure. If there is a leak, then the flow through relay cuts off the supply to preserve pressure for the services (gauge lost but services still operate)
HYDRAULIC FUSE

- If flow rate too high, the fuse moves to shut off supply to affected system
- System lost but pressure remains for other services
Hydraulic Fuse

No pressure

Flow towards brake

Return from brake

Closed due to Excessive flow
FLOW CONTROL VALVE

- Purpose is to smooth the flow to a system/dampen out surges in system pressure
BRAKE CONTROL VALVE

Complex valve; the important points are what capabilities it is required to provide.

These are:

- Progressive braking
- Differential braking (for nose-wheel steering)

MAXIMUM BRAKE PRESSURE - 1900psi/3000 psi
MODULATOR

- Basically a flow control valve
- Specific to brake system
- Speeds up operation of the anti-skid system
DOUBLE-ACTING HAND PUMP

- Normal type of hand pump fitted in an aircraft
- An emergency device
- Can be used to charge brakes before engine start

Piston moving in

Piston moving out
RAM AIR TURBINE (RAT)

- Primarily used to provide hydraulic power for flying controls
SEALS

Fitted to prevent leaks

• ‘O’ rings/Square section
  - Hydraulic pressure in both directions
  - Slight leakage accepted
  - Backing rings to prevent extrusion

• Chevron seals (‘V’ seals)
  - Effective in one direction only
  - Oil and pressure to the inverse side, air to the pointed side
  - If internal to the hydraulic system, need to be fitted in pairs/back-to-back

• Wiper rings
  - Clean rams and protect seals from damage and contamination

• Static seals
  - Crush washers/bonded rings; seal between hose fittings and actuators
Material for seals is important; butyl rubber for synthetic fluid (Skydrol)
SEALS

- Washer
- Retaining nut
- "V" seals
- Packing
- Wiper ring
- Retaining nut
- Backing rings
- O-rings
- Backing ring
HYDRAULIC POWER PACK

- Motor Switch
- Gas Charging Valve
- Switch Operating Collar
- Selector Lever
- Electric Motor
- Drive
- Pump
- Filler
- Filter
- NRV
- Accumulator
- Selector Valve
- Actuator
# DIAGNOSIS OF SYSTEM MALFUNCTIONS

- Flight Deck indications of hydraulic system are:
  - Temperature
  - Pressure
  - Contents

- Look at indications for different types of system leaks

<table>
<thead>
<tr>
<th>CONTENTS</th>
<th>SLOW EXTERNAL</th>
<th>FAST EXTERNAL</th>
<th>INTERNAL</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Slowly decrease</td>
<td>Rapid loss</td>
<td>No change</td>
</tr>
<tr>
<td>PRESSURE</td>
<td>No change</td>
<td>Nil</td>
<td>No change</td>
</tr>
<tr>
<td>TEMPERATURE</td>
<td>No change</td>
<td>N/A</td>
<td>Increase</td>
</tr>
</tbody>
</table>
GROUND SERVICING

• Air in the system
  - can give problems of pump overspeed, damage, cavitation and erratic service operation
  - Remove by dynamic bleeding (moving services) that takes air back to reservoir or normal bleeding (eg brakes) via bleed nipple

• Replenishing N₂ in accumulator
  - Must discharge system pressure
  - Can then read accumulator pressure on gauge (roughly half system pressure)

• Reservoir Low?
  - Discharge system (reservoir will now rise as accumulator discharges fluid back to reservoir)
  - Services also need to be at pre-set positions because of fluid displaced by actuator pistons
  - Can now refill with CORRECT fluid