T-6B Hydraulic System
Objectives

• Identify main sections and components of the hydraulic system
• Understand normal operation of the hydraulic system
• Identify components of the emergency hydraulic system
• Understand operation of the emergency hydraulic system
• Understand operation of the landing gear/inboard gear doors/flaps/speed brake/nose wheel steering

(Utilize hydraulic system schematic while reviewing this slideshow)
References

• T-6B NATOPS Manual
  • Section 1
    • Hydraulic System
      • Normal Operation
      • Emergency Operation
    • Landing Gear System
    • Nose wheel Steering
    • Wing Flaps
    • Speed Brake System
    • Brake System
  • Section 5
    • Figure 5-1 Instrument Markings
    • Wing Flap Limitations
    • Landing Gear Limitations
    • Acceleration Limitations
Hydraulic System Overview

- System Operated by an engine-driven hydraulic pump
- System broken into 3 main areas:
  - Power Package
  - Selector Manifold (Main Side)
  - Emergency Selector Manifold (Emergency Side)
- Powers landing gear/inboard gear doors/flaps/speed brake and nose wheel steering
Hydraulic Pump

- Hydraulic system pressurized to 3000 +/- 120 PSI

- Hydraulic Pump
  - Located in engine accessory section
  - Small but powerful pump
  - Registers pressure on EICAS gauge before prop moves on start and after prop stops turning on shutdown

- Check Valve prevents back flow of fluid into pump
**Power Package**

- **Reservoir**
  - 5 quarts in hydraulic system
  - Holds hydraulic fluid and provides it to pump
  - Contains pressure reducer piston which reduces line pressure from 3000 psi down to 50 psi
  - Ports excess pressure overboard through relief valve
  - A **HYD FL LO** caution message on CAS when less than 1 qt remaining in reservoir
  - With **HYD FL LO** caution message and pressure > 1800 psi there is still sufficient fluid to lower gear & flaps with the main system

- **Hydraulic Fluid Gauge**
  - Located in Hydraulic Service Bay behind right wing
  - Fluid pushes green rod (to left) to indicate amount of fluid in system
  - Green rod must be in one of the green bands depending on the status of the hydraulic accumulator (charged or discharged)
    - If accumulator is discharged (via pressure release handle), more fluid is in the reservoir pushing the green rod farther to the left.
    - If accumulator is charged, some fluid remains in the accumulator versus the reservoir moving the green rod to the right
**Power Package**

- **Firewall Shutoff Valve**
  - Controlled by Firewall Shutoff Handle (front cockpit only)
  - Handle lifts vertically and has pliable clip to hold down in place
  - Used during emergency to cut off hydraulics from going aft of firewall
  - Valve in right side maintenance access bay
Power Package

- Hydraulic Pressure Indications
  - Pressure Transmitter measures pressure after filter
  - Signal sent to EDM and then to EICAS for display on Hydraulic Press display
  - Illuminates a CHK ENG caution when pressure < 1800 psi (consider system unusable)
  - With HYD FL LO caution message and pressure > 1800 psi there is still sufficient fluid to lower gear & flaps with the main system

  **EICAS Hydraulic Pressure Display**
  
<table>
<thead>
<tr>
<th>Pressure Range</th>
<th>Display</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 1800 psi</td>
<td>Amber Arc</td>
<td>Caution</td>
</tr>
<tr>
<td>1800 – 2880 psi</td>
<td>White Arc</td>
<td>Scale</td>
</tr>
<tr>
<td>2880 – 3120 psi</td>
<td>Green Arc</td>
<td>Normal</td>
</tr>
<tr>
<td>3120 – 3500 psi</td>
<td>White Arc</td>
<td>Scale</td>
</tr>
<tr>
<td>3500 – 4100 psi</td>
<td>Amber Arc</td>
<td>Caution</td>
</tr>
</tbody>
</table>

- Hydraulic System Circuit Breaker (CB)
  - On battery bus circuit breaker panel (front cockpit / left side)
  - Pressure display & HYD FL LO caution message on EICAS not available if CB open
  - The EHYD PX LO caution message on CAS still available if CB open

![Hydraulic System CB](image-url)
Power Package

- Relief Valve
  - Prevents over-pressurization from damaging system
  - Activates at 3250 – 3500 psi
    - Directs excess pressure to reservoir reduction piston
    - Ports fluid through overboard relief valve if reservoir reduction piston unable to further reduce pressure

- Slide Valve Assembly
  - Activated when emergency gear extension handle is pulled
  - Isolates the main hydraulic system when the emergency system used
  - Can only be reset by maintenance when on ground
Nose Wheel Steering

- **Nose Wheel Steering (NWS) System**
  - Tapped after check valve but prior to Power Package
  - Activated by NWS Button on stick
    - Engages NWS selector valve allowing hydraulic pressure to NWS actuator
    - Illuminates the **NWS ON** advisory light on CAS
    - Connects rudder pedals to nose wheel
  - Actuator assembly has internal centering mechanism and helps prevent nose wheel shimmy
  - Allows 12 degrees of left/right nose wheel deflection
  - Friction collar on nose gear strut to help prevent nose wheel shimmy

- **Ground Operations (steering aircraft)**
  - **NWS**
    - Primary method
    - 12° of left/right nose wheel deflection
    - Ramp speeds only
    - Large turn radius (turns around wing tip)
  - **Differential Braking**
    - Secondary method
    - Free castor of 80° of left/right nose wheel deflection
    - Must center nose wheel with brakes (no automatic centering)
    - Do not use NWS on full deflection, brake turns to prevent wear to NWS and tire
  - **Rudder**
    - Not very effective when little airflow over vertical tail
Selector Manifold

- Main hydraulic side of system
- Operates: Landing Gear, Inboard Gear Doors, SB, & Flaps
- Manifold contains 5 selector valves which direct fluid to various actuators
- After fluid used in actuators it returns through the selector valves to the reservoir
• **Landing Gear**
  - Main landing gear and nose gear operate through gear selector valve as selected by landing gear handle

• **Landing Gear Doors**
  - Inboard gear doors operate through a separate selector valve (electrically sequenced to main gear)
  - Outboard gear doors mechanically attached by rod to main strut
  - Nose gear doors operated mechanically by nose gear strut as it retracts into position
Selector Manifold
(Landing Gear)

- Limitations
  - Max gear extended speed ($V_{LE}$) is 150 kts
  - Max gear extended acceleration limits: +2.5-0.0 Gs (symmetric) & +2.0-0.0 Gs (asymmetric)
  - Max rate of descent at touchdown is 600 fpm (3.7 Gs) with tires serviced to normal pressure (185±5 PSI)
  - Max rate of descent at touchdown is 780 fpm (5.1 Gs) with tires serviced to max pressure (225±5 PSI)
Selector Manifold (Landing Gear)

- Main Landing Gear Parts
- Various parts and names as seen in picture
Selector Manifold (Landing Gear)

- Main Landing Gear Parts (cont)
- Various parts and names as seen in picture
Selector Manifold (Landing Gear)

- Main Landing Gear Parts (cont)
  - Various parts and names as seen in picture
• Main Landing Gear Parts (cont)
  • Various parts and names as seen in picture
Selector Manifold (Landing Gear)

- Nose Landing Gear Parts
  - Various parts and names as seen in picture

- From Power Package to Hyd Reservoir
- From Other Hyd Components to Other Hyd Components

- LH Main Actuator
- RH Main Actuator
- Gear Selector Valve
- Selector Manifold

- Folding Strut (partly shown)
- Gear Door
- Friction Collar (not shown)
- Strut
- Scissors
- Oleo

Selector Manifold

- 6 sec extension/retraction

Various parts and names as seen in picture
• Nose Landing Gear Parts (cont)
  • Various parts and names as seen in picture
Selector Manifold (Landing Gear)

- Controls & Indicators
  - Gear Handle
    - Used to raise/lower landing gear
    - Cockpit handles are linked mechanically (front cockpit is primary)
    - Selecting up/down engages electrical micro-switch and signals activation of valves and sequence
    - Power through LDG GR CONT circuit breaker on batt bus panel
    - Right WOW switch engages downlock pin to prevent handle movement on ground
  - Position Indicator Lights
    - Indicate position/status of gear
    - Green gear lights – specific landing gear is down and locked
    - Red gear lights:
      - Mains – Inboard gear door not up and locked
      - Nose – Gear in transit
    - Red light in handle:
      - Any red gear light is illuminated
      - PCL near idle and gear up
  - Warning Silence Button
    - Silence aural gear warning tone (see position warning slide)
  - Downlock Override Button
    - Mainly a maintenance function
Selector Manifold (Landing Gear)

- Landing Gear Position Warning
  - Aural warning tone sounds 5 times per second
  - Activates when:
    - WOW and gear handle not down
    - Flaps LDG – Gear not down/locked (regardless of gear door/power setting/airspeed)
    - Flaps TO or UP – Gear handle not down (regardless of gear indications) & PCL below mid-range (87% N₁)/airspeed below 120 kts

- Warning Silence Button
  - Used to silence aural warning tone
  - Tone can not be silenced when flaps LDG and gear not down and locked
  - Tone can be silenced when flaps TO or UP
  - Resets when PCL moved above the mid-range (87% N₁) position

Red Light in Handle
- Inboard doors not closed
- Nose gear in transit
- PCL near idle (18-20%) / Gear UP

Gear Warning Tone
- Flaps LDG / Gear UP
- Flaps TO or UP / PCL <87% / <120 KIAS / Gear Handle UP
- WOW / Gear Handle UP

Warning Silence Button
Selector Manifold (Landing Gear)

- Landing Gear Operation/Sequence
  - 6 seconds to retract/extend
  - Inboard gear doors are first & last thing to move in sequence

Red Light in Handle
- Inboard doors not closed
- Nose gear in transit
- PCL near idle (18-20%) / Gear UP

Gear Warning Tone
- Flaps LDG / Gear UP
- Flaps TO or UP / PCL <87% / <120 KIAS / Gear Handle UP
- WOW / Gear Handle UP

From Power Package To Hyd Reservoir
- LH Main Actuator
- RH Main Actuator
- Gear Selector Valve

From Selector Manifold To Other Hyd Components
- Inboard Doors Actuators
- Doors Selector Valve

Landing Gear Retraction

Landing Gear Extension

(click on video to launch)
Selector Manifold (Landing Gear)

- Landing Gear Operation/Sequence
  - Hydraulic actuator moves main gear by pulling/pushing side brace
  - Main Gear mechanically held up
  - Tang on bottom of strut is held by mechanical lock when gear doors close (releases when gear doors open)
  - Once engaged, hydraulic actuator de-powers

Red Light in Handle
- Inboard doors not closed
- Nose gear in transit
- PCL near idle (18-20%) / Gear UP

Gear Warning Tone
- Flaps LDG / Gear UP
- Flaps TO or UP / PCL <87% / <120 KIAS / Gear Handle UP
- WOW / Gear Handle UP

Selector Manifold

From
Power
Package

Selector Manifold

To
Hyd
Reservoir

1 LH Main
Actuator
NG
Actuator
1 RH Main
Actuator
Selector
Valve

Nose gear doors
Actuators

Selec
or
Vale

Selec
or
Va

6 sec extension/retraction

-6 sec extension/retraction

Mechanical
Uplock

Uplock Tang

From
Other
Hyd
Components

From
Other
Hyd
Components

· Landing Gear Operation/Sequence
  · Hydraulic actuator moves main gear by pulling/pushing side brace
  · Main Gear mechanically held up
  · Tang on bottom of strut is held by mechanical lock when gear doors close (releases when gear doors open)
  · Once engaged, hydraulic actuator de-powers
Selector Manifold (Landing Gear)

- Landing Gear Operation/Sequence
  - Main Gear hydraulically held down
  - Main gear hydraulic actuator activates internal down lock keeping pressure in cylinder and locking gear down

Red Light in Handle
- Inboard doors not closed
- Nose gear in transit
- PCL near idle (18-20%) / Gear UP

Gear Warning Tone
- Flaps LDG / Gear UP
- Flaps TO or UP / PCL <87% / <120 KIAS / Gear Handle UP
- WOW / Gear Handle UP

From Power Package
To Hyd Reservoir

From Other Hyd Components
To Other Hyd Components

Actuator Bar
Pivot Point
Side Brace

Actuator internal downlock

Hydraulic Actuator
Selector Manifold
(Landing Gear)

- Landing Gear Operation/Sequence
  - Hydraulic actuator moves nose gear by the nose leg actuator which moves the folding strut
  - Nose Gear hydraulically held up & mechanically held down
  - Nose gear hydraulic actuator activates internal up lock keeping pressure in cylinder and locking gear up
  - Spring strut forces folding strut over-center to mechanically hold the gear down

Red Light in Handle
- Inboard doors not closed
- Nose gear in transit
- PCL near idle (18-20%) / Gear UP

Gear Warning Tone
- Flaps LDG / Gear UP
- Flaps TO or UP / PCL <87% / <120 KIAS / Gear Handle UP
- WOW / Gear Handle UP

Selector Manifold
(Hydraulic Actuator)

Actuator internal downlock
(not visible)

Spring Strut

From
Other Hyd Components
To
Selector Manifold

Hydraulic Actuator

From Power Package
To Hyd Reservoir

- 6 sec extension/retraction
- RH Main Actuator
- NG Actuator
- LH Main Actuator

Selector Manifold

- Selector Valves
- Actuator Internal Downlock
- Spring Strut

Other Hyd Components

From
Other Hyd Components
To
Selector Manifold

Selector Valves
Selector Manifold
(Speed Brake)

- Single ventral plate located on belly of aircraft between flaps
- Actuator
  - Pushes plate into Windstream (70° extension from stowed position)
  - Internal uplock keeps SB retracted with loss of hydraulic pressure
  - Should blow up (and lock) if airborne, SB out, and hydraulics fail

Red Light in Handle
- Inboard doors not closed
- Nose gear in transit
- PCL near idle (18-20%) / Gear UP

Gear Warning Tone
- Flaps LDG / Gear UP
- Flaps TO or UP / PCL <87% / <120 KIAS / Gear Handle UP
- WOW / Gear Handle UP
Selector Manifold
(Speed Brake)

- Controls & Indicators
  - Three-position, guarded switch on PCL activates selector valve
  - Switch spring loaded to center position
  - SB is IN or OUT but no intermediate positions
  - Switch Forward – SB retracts
  - Switch Aft – SB extends
  - A SPDBRK OUT CAS advisory light illuminates when SB extended

Red Light in Handle
- Inboard doors not closed
- Nose gear in transit
- PCL near idle (18-20%) / Gear UP

Gear Warning Tone
- Flaps LDG / Gear UP
- Flaps TO or UP / PCL <87% / <120 KIAS / Gear Handle UP
- WOW / Gear Handle UP

From Power Package
To Hyd Reservoir

4 sec extension/retraction

Selector Valve

LH Main Actuator
NG Actuator
RH Main Actuator

Spd Brake Actuator
Selector Valve

Speed Brake Actuator
Selector Valve

From Other Hyd Components
To Other Hyd Components

SB Switch

SB Switch
Selector Manifold
(Speed Brake)

- Speed Brake Operations
  - No speed restriction for use
  - Used to decrease speed or increase descent rates (without increasing speed)
  - Automatically retracts when:
    - Flaps moved out of the UP position
    - PCL moved to the MAX position
- Pitch Compensation
  - Linked to elevator trim tab
  - Counteracts some (not all) pitch change tendency when extended

Red Light in Handle
- Inboard doors not closed
- Nose gear in transit
- PCL near idle (18-20%) / Gear UP

Gear Warning Tone
- Flaps LDG / Gear UP
- Flaps TO or UP / PCL <87% / <120 KIAS / Gear Handle UP
- WOW / Gear Handle UP
Selector Manifold
(Flaps)

- **Selector Manifold (Flaps)**
  - Flap Benefits
    - Decrease takeoff and landing roll
    - Reduce stall speed
  - Split Flaps
    - Flaps split away from wing form (position cannot be seen from cockpit)
    - Two flap panels on each side (4 total)
    - Provide good lift in TO position (23° deflection)
    - Provide good drag in LDG position (50° deflection)
    - TO & LDG positions have a separate selector valve
  - Limitations
    - Max flaps extended speed ($V_{FE}$) is 150 kts
    - Max flaps extended acceleration limits: +2.5-0.0 Gs (symmetric) & +2.0-0.0 Gs (asymmetric)

Red Light in Handle
- Inboard doors not closed
- Nose gear in transit
- PCL near idle (18-20%) / Gear UP

Gear Warning Tone
- Flaps LDG / Gear UP
- Flaps TO or UP / PCL <87% / <120 KIAS / Gear Handle UP
- WOW / Gear Handle UP

![Split Flaps](image-url)
Selector Manifold
(Flaps)

Red Light in Handle
- Inboard doors not closed
- Nose gear in transit
- PCL near idle (18-20%) / Gear UP

Gear Warning Tone
- Flaps LDG / Gear UP
- Flaps TO or UP / PCL <87% / <120 KIAS / Gear Handle UP
- WOW / Gear Handle UP
Selector Manifold (Flaps)

- **Controls & Indicators**
  - **Flap Selector**
    - Three-position flap selector in each cockpit (mechanically linked together)
    - Detents for UP/TO/LDG (No intermediate positions)
    - Located under PCL
    - When flap position selected, respective selector valve (TO or LDG) moved to allow hydraulic power to actuator. Hydraulic actuator then pushes the flap actuator strut which rotates the torque tube and attached flap segments

- **Flap Indicator**
  - Flap indicator in each cockpit
  - Positions marked for UP/TO/LDG & indicated by pointer
  - Located above gear indicators/right side of Ldg Gr Emer Handle
  - Pointer moves to intermediate position between marks during extension/retraction

- **Gear Warning Tone**
  - Flaps LDG / Gear UP
  - Flaps TO or UP / PCL <87% / <120 KIAS / Gear Handle UP
  - WOW / Gear Handle UP

- **Red Light in Handle**
  - Inboard doors not closed
  - Nose gear in transit
  - PCL near idle (18-20%) / Gear UP

- **Flap Position Indicator**
  - TO - 23° deflection
  - LDG - 50° deflection

- **Selector Manifold Diagram**

- **Power Package to Hyd Reservoir**

- **Selector Valve**

- **Flap Actuator**

- **Selector Manifold (Flaps)**

- **Gear Handle UP**

- **Red Light in Handle**

- **Gear Warning Tone**

- **Flap Position Indicator**

- **Flap Selector**
Selector Manifold (Flaps)

- Controls & Indicators
  - Power through FLAP CONT circuit breaker on batt bus panel (normal operations)
  - Power through EMER FLAP circuit breaker on hot batt bus panel when Emergency Gear Extension Handle pulled (actuation of emergency hydraulics)

Red Light in Handle
- Inboard doors not closed
- Nose gear in transit
- PCL near idle (18-20%) / Gear UP

Gear Warning Tone
- Flaps LDG / Gear UP
- Flaps TO or UP / PCL < 87% / < 120 KIAS / Gear Handle UP
- WOW / Gear Handle UP
Emergency Selector Manifold

- Emergency side of system
- Charged by main hydraulic system to 3000 +/- 120 psi
- Pressure stored in emergency accumulator
- Allows one-time operation of landing gear and flaps
- System can only be reset by maintenance on ground
- Uses independent lines from main system
Emergency Selector Manifold

- **Hydraulic Fuse**
  - Prevents leak in emergency system from depleting all the system fluid
  - Fluid flow to emergency system limited to 0.25 GPM
  - If flow > 0.25 GPM fuse closes to isolate main system
  - Maximum fluid loss of 0.5 qt (20-30 cubic inches)
  - Check valve prevents fluid back-flow through fuse

- **Pressure Relief Valve**
  - Prevents over-pressurization from damaging accumulator
  - Activates at 3250 – 3500 psi
  - Directs excess pressure to reservoir reduction piston
  - Ports fluid through overboard relief valve if reservoir reduction piston unable to further reduce pressure
Emergency Selector Manifold

- **Emergency Accumulator**
  - Stores hydraulic pressure for emergency use
  - Helium pre-charge of 3000 psi on one side of accumulator diaphragm (pushes pressure against stored fluid)
  - Continuously charged when main hydraulic system is pressurized
  - Excess fluid from accumulator charging returns to hydraulic reservoir

- **Manual Pressure Release Handle**
  - Discharge handle in hydraulic access bay
  - Releases accumulator pressure
  - Fluid returns to reservoir for more accurate system measurement
Emergency Selector Manifold

- **Controls & Indicators**
  - **Emergency Gear Extension Handle**
    - Located above landing gear control unit & flap gauge
    - Used for one-time lowering of landing gear and flaps
    - Releases emergency accumulator
    - Pushing silver button (in middle) allows handle to be pulled
    - Handle pulls out approximately ¾ of an inch
  - **CAS Messages**
    - A **EHYD PX LO** caution illuminates at 2400 +/- 150 psi
    - The **EHYD PX LO** will normally illuminate after emergency gear extension when flaps are selected
    - A **EHYD PX LO** caution coupled with a **HYD FL LO** caution indicates a leak and the fuse did not close to isolate the main system thus possibly depleting hydraulic fluid
Emergency Selector Manifold

- **Operation**
  - **Landing Gear Emergency Extension**
    - Pulling EMER LDG GR handle releases emergency accumulator pressure
    - Pressure ported thru landing gear emergency extension selector valve to:
      - Slide valve assembly to isolate main hydraulic side
      - Landing gear actuators
      - Inboard gear door actuators
    - Inboard gear doors open & gear extends (regardless of landing gear handle position)
    - Inboard gear doors remain extended
    - Three green & three red indications after actuation (see picture)
    - Landing gear emergency extension selector valve ports remaining fluid to flap emergency extension selector solenoid
Emergency Selector Manifold

- Operation
  - Emergency Flap Extension
    - Flap selector powered through EMER FLAP circuit breaker on hot batt bus panel (vice FLAP CONT circuit breaker on batt bus panel) when Emergency Gear Extension Handle pulled
    - Allows selection of TO or LDG flaps (not automatic extension like landing gear)
    - Do not use flaps until after the landing gear are down
    - Flaps cannot be raised using emergency system
Wheel Brakes

- Not part of the hydraulic system
- Parts of wheel brake system
  - Toe brakes (top of each rudder pedal)
  - Two master cylinders (fwd of aft instrument panel)
  - Brake Reservoir Indicator (by front seat canopy rail)
  - Fore/Aft disk brake units
  - Brake wear indicator
  - Parking break handle
Wheel Brakes

• Controls & Indicators
  • Brake Reservoir
    • Located near rear part of front seat along canopy rail
    • Green band with red bands on top and bottom
    • Canopy rail flush with any part of green band means reservoir is good
    • Top red band means reservoir over-serviced & lower red band means reservoir under-serviced

• Toe Brakes
  • Located on top part of each pedal
  • Pushing forward on top part of pedal pushes fluid from master cylinders to brake units

• Parking Brake Handle
  • Only in front cockpit
  • On lower right side of instrument panel
Wheel Brakes

- Operations
  - Pushing forward on the top part of pedal to activate wheel brakes
  - Differential braking is possible using more/less pressure on an individual brake
  - No real feedback/feel on the amount of brakes being applied
  - Whichever pilot is applying the most pedal force determines the amount of braking

- Setting Parking Brake:
  - Apply toe brakes
  - Pull parking brake handle and rotate clockwise 90°

- Releasing Parking Brake:
  - Turn parking brake handle 90° counterclockwise
  - Release parking brake handle
Conclusion

- Identified main sections and components of the hydraulic system
- Discussed normal operation of the hydraulic system
- Identified components of the emergency hydraulic system
- Discussed operation of the emergency hydraulic system
- Discussed operation of NWS/Landing Gear/SB/Flap systems