Landing Gear 101

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Landing Gear Recycling

• Discussion: Request that Gulfstream provide guidance on the use of recycling the gear to achieve a normal gear configuration

• Action: Will review history of the practice and provide Gulfstream opinion.

• Status:
Landing Gear 101

- **Purpose** – Provide recycling guidance as requested
  - Facts
  - Logic
  - Opinions

- **Recent events justify the request**
  - Landing gear problems increasing in frequency
  - #2 Priority action item for RQAAT

- **Goal**
  - Offer a sound opinion
  - Same success as Brakes 101
Outline

- History
- Gear System Basics
- Failure Modes
- Fleet Examples
- Considerations
- Opinions
History

- 40+ years on the jet fleet
  - Gear nearly same from G-II through G-550

- 2 Nose gear up landings, almost a 3rd
  - GIV packed with frozen slush
  - GV mechanical failure of critical part
  - G-II nose strut wiped with Skydrol rag

- Main gear has always come down
  - Aggressive maneuvering
  - Bounces and Scuffs
  - Improvised emergency procedures
History

• Emergency system has always “worked” (Nitrogen released and routed to actuators)

• Sometimes unable to overpower a mechanical problem
  – Neither was 3000 psi hydraulic pressure

• One case where routed to a ruptured actuator
Recent Trends

- G-1159 through G-VSP gear problems
  - Corrosion
  - Wear
    - Maintenance
  - Rigging and adjustments

- G-IVX, G-V, & G-VSP issues involve the above, plus
  - Electrical control (solenoid)
  - Hydraulic pressure bumps
• Normal system
  – Control is mechanical or electrical
  – Power is Hydraulic
  – Indication is electric

• Emergency system
  – Control is mechanical
  – Power is pneumatic
  – Indication from normal system
Gear Basic Function

• Landing gear handle
  – 2 position, UP/DOWN
  – Controls a Selector Valve
    • Routes hydraulic power to each landing gear

• 3 gear operate independently of each other
  – Operating sequence is controlled by mechanical linkage

• “Gear Down” indication via independent electrical circuits
Gear Basic Function

- Differences between models are minor
  - Landing Gear Selector Valves
    - G-1159 and G-IV are mechanical with sliding spools
    - G-IVX, G-V, G-VSP are solenoid-controlled
  - Dump Valve
    - G-1159 and G-IV have separate dump valve
      - mechanical reset
    - G-IVX, G-V, G-VSP use combined selector/dump valve
      - reset is electric
  - Design operating pressure
    - 1500 psi for G-1159
    - 3000 all others
Gear Basic Function

• Emergency Extension
  – Mechanical control releases Nitrogen
    • Nitrogen pressure shifts dump valve
      – Return path to reservoir for up-side hydraulics
    • Dedicated routing for pressure to each gear
    • Shuttle valves on actuators for door, uplock, and gear
      – Shifted by nitrogen
      – Allow nitrogen to power the actuators open/down
      – Shuttle valves are common to normal & emergency systems
  • No sequencing or timing
    – Gear will push door out of the way
Failure Modes

CONTROL

- Handle or selector valve
  - Mechanical
    - Restricted movement
    - No movement
  - Electrical
    - Safety solenoid
    - Selector/Dump valve solenoid
    - Wiring & connections
Failure Modes

HYDRAULIC POWER

• Pump failure
• Fluid loss

INDICATION

• Only 1 switch per gear for “gear down”
• 2 bulbs per capsule
• Ess DC power
  – Loss is possible but not likely
## Failure Modes

### MECHANICAL SEQUENCING

<table>
<thead>
<tr>
<th>GEAR DOWN</th>
<th>GEAR UP</th>
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</thead>
<tbody>
<tr>
<td>Doors Open</td>
<td>Doors Open</td>
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<tr>
<td>Uplocks release</td>
<td>Downlocks release</td>
</tr>
<tr>
<td>Gear extends</td>
<td>Gear retracts</td>
</tr>
<tr>
<td>Doors close</td>
<td>Doors close</td>
</tr>
</tbody>
</table>
MECHANICAL SEQUENCING

• Sequencing linkage
  – Lightly loaded mechanical connection to valves
  – Positions valves to control flow to actuators
    • Doors
    • Uplocks
    • Landing Gear
  – Bungees
    • Spring-loaded units in the linkage
    • Extend to reposition valves
    • Maintain tension on the mechanical links
Failure Modes - Bungee

Bungee Assy, Uplock Linkage, Main Landing Gear

1159LM20256-1 CYLINDER
1159LM20255-5 ROD END
G101-268 SPRING
Figure 20: Photomacrograph of the corroded surfaces of the spring
Failure Modes

MECHANICAL SEQUENCING FAILURES

• Linkage
  – Broken
    • Doesn’t move
  – Binding
    • Moves partially
    • Moves sometimes
    • Doesn’t move at all
  – Rigging out of adjustment
• Result
  • Components don’t operate
  • Operate but interfere with each other
Failure Modes - Sequencing
• “Minor” difference in electrical vs. mechanical control proved to be significant

• Solenoid operation causes rapid spool shift
  – Pressure transients in gear lines
    • Positive (spikes)
    • Negative (suction force)
    • Transients greatest at end of lines (NLG)
      – G-V & G-VSP lines longer than G-IVX
  – NLG uplock actuator may shift toward open
  – Sequencing linkage moves door control valve to blocked ports region
  – NLG “slow to operate” or stays up
NORMAL WEAR

- Bushings, Bearings, and Pins
- Parts move out of alignment and bind
  - Gear slow to extend
  - Gear may not lock down
- Most prevalent with NLG
- Same NLG symptoms as “pressure bumps”
Failure Modes

1 Bushing Undersize

1/3 Liner Missing

Within Limits

1 Bushing undersize
Failure Modes - Wear
Failure Modes - Mechanical

DOOR OPEN HYDRAULICS

SHUTTLE VALVE HOUSING

EMERGENCY AIR LINE

Gulfstream®
Things to Consider

- Cause of the problem
  - Hydraulic
  - Electrical
  - Mechanical

- Recent aircraft maintenance

- Recent gear behavior

- Inflight problems that can’t be duplicated on jacks are usually electrical

- Slow to operate may be binding, rigging, pressure jumps
Things to Consider

- **No response to selection**
  - Electrical – bad solenoid, wiring, or no power
  - Mechanical – dump valve shift or leakage

- **Get any response to gear selection**
  - Problem is not electrical (G-IVX, G-V, G-VSP)
Recycling

• We recycle in the hope things will get better
  – Sometimes they do

• There is an equal chance they will get worse
  – Lately they have

• There is reluctance to use the emergency system because reset requires maintenance action
  – 40 man-hours
  – 1 day

• Aircraft with electrical control of gear selection may get a different hydraulic response by recycling
  – Better or worse
Recycling

• Recycle something that’s binding
  – May be freed
  – May stick in a worse position

• Aircraft with mechanical control of landing gear selector valve (G-1159 series & G-IV)
  – It makes no sense to recycle

• If unsure where some gear component is
  – It makes no sense to recycle

• If you know something is out of sequence
  – It makes no sense to recycle
Recycling

- Gear door OPEN with gear handle UP
  - Something is out of sequence, but
    - The open door is out of the way
  - Put handle back down to recycle
    - Door may interfere with gear
  - If gear goes down but doesn’t lock
    - Bungee likely jammed in extended position
  - Retract gear so door is known to be clear
  - Blow the gear
  - Put handle down for normal indication
Opinion on Recycling Gear

- Sources and their experience
- G-1159 series and G-IV (mechanical gear selection)
  - Do not recycle
- G-IVX, G-V, and G-VSP
  - Recycle once if no response to gear down selection
  - Recycle once if nose gear doesn’t go down but both main gear do
- For all aircraft
  - If any gear does not retract after takeoff select gear down and return to the field for landing and troubleshooting on the ground.
More History

• There have been many cases where recycling has helped.

• There have also been many cases where it made things worse. Recently this is the trend.
  – Recycle to get something up, then not get gear down
  – Recycle to get something down, get less

• For 40 years there have been no cases where an emergency extension made things worse.
Questions