Scope

- Executive Summary of Flight Test Programme:
  - Background
  - Objectives of Test Programme
  - Scope of Modifications
  - Flight Test Team
  - Conditions Relevant
  - Results and Discussion
  - Conclusions
  - Recommendations
  - Lessons learned and observations
Background

- Designed, developed by Piaggio & Co, Italy, 1953.
- Licence built Focke Wulf: Basic trainer + light utility.
- Retired 1970 from Service.
- Acquired and imported into RSA Werner Heiml.
- Flight test NTCA 2013.
From This!

Piaggio P149D

To This!!

Focke Wulf Piaggio P149D - TP
Objectives

To demonstrate the modified *Piaggio P149D TP* aircraft’s compliance with the requirements of Part 24 of the CAR’s and certain applicable requirements of *FAR-23 Subpart B: Flight*.

The aircraft is a Non-Type Certificated Aircraft (NTCA) Ex-Military in terms of Part 24 of the SA Civil Aviation Regulations (CAR’s).

Proving Authority. The P149D aircraft with registration ZU-SFP (S/N 0060) was operated with a Proving Flight Authority issued by the SA Civil Aviation Authority. ZU-SFP was assigned as the prototype test aircraft.
Aircraft Modifications

- Dorsal Fin
- New engine mounting 600 mm/CG
- Brackets & skin doublers
- FAR23.631 structural compliance = 3.8g

- Canopy
  - Lowered 125mm
  - Streamlined

- Fuel System
  - Outboard
  - Mid span
  - Ferry Tank

- Basic Autopilot
- O₂ System

- ‘Swooplets’

720 shp Walter 601D Turboprop vs
275 hp Lycoming GO-480

- New engine mounting 600 mm/CG
- Brackets & skin doublers
- FAR23.631 structural compliance = 3.8g
Cockpit Modifications
Walter M601D Engine
- designed for remote/rugged operations.
- minimal field maintenance requirements
- Maintenance between overhauls:
  - primarily filter and screen cleaning,
  - compressor wash,
  - oil change,
  - borescope inspection,
  - igniter replacement.
- "hot section inspections" between overhauls not required.
- Recommended (TBO) defined by "cycles"
  - engine starts,
  - flight time, and
  - calendar time.
- TBO interval 2,250 to 20,000 cycles (depending service type/engine series),
- 1,500 to 3,000 hours flight time,
- 5 to 8 years calendar time between overhauls.

### Cost Comparison
Walter RM1.2 vs PT-6 RM 3.5

<table>
<thead>
<tr>
<th>Max. Continuous Rating</th>
<th>657 eshp</th>
</tr>
</thead>
<tbody>
<tr>
<td>N₁ (Gas generator) RPM (100%)</td>
<td>36,293 rpm</td>
</tr>
<tr>
<td>Max. Propeller RPM</td>
<td>2080 rpm</td>
</tr>
<tr>
<td>Max. Inter-Turbine Temperature (ITT)</td>
<td>690°C</td>
</tr>
<tr>
<td>Equivalent Specific Fuel Consumption (ESFC)</td>
<td>0.648</td>
</tr>
<tr>
<td>Max. Fuel Consumption @ 657 eshp</td>
<td>65 gph</td>
</tr>
<tr>
<td>Cruise &quot; &quot; @ 350 to 400 eshp</td>
<td>35-37gph</td>
</tr>
<tr>
<td>Idle &quot; &quot;</td>
<td>25 gph</td>
</tr>
<tr>
<td>Weight (dry)</td>
<td>425 lb</td>
</tr>
<tr>
<td>Height/width/length (inches)</td>
<td>26&quot;-23&quot;-66&quot;</td>
</tr>
</tbody>
</table>
Aeromechanical Implications

• **Mass Re-distribution.** Static margin maintained for standard Piaggio P149D = propeller mounting face forward by 305mm (12 inches).

• **Static Margin.** Net effect = mass redistribution with static margin theoretically unchanged; pitch/yaw inertial moments impacted on the static and dynamic stability characteristics of the aircraft.

• **Inertial Effects.** Increased propeller mass increased rotational inertia by 26% - although rotational speed essentially same as Lycoming, propeller gyroscopic loads changed.

• **Power Effects.** Walter 601D maximum power 2.5x greater than Lycoming GO-480
  – double propeller/engine torque
  – increased helical airflow around fuselage
  – static and dynamic stability characteristics of the aircraft changed.

• **Aircraft Performance.** 32% increase in shaft horse power significantly increased aircraft performance, viz SEP ie takeoff, climb, acceleration, sustained turn pfx.

• **Stability and Control.** Increased shaft horse power significantly increased slipstream, downwash, and mass flow – determine in flight test.
Test Programme Management Team

Test Pilot Class I. Des Barker, military (SAAF) experimental test pilot - 56 types: Piaggio P149 D, total flying hours 7020. 20 hours on Walter 601D turboprop engine and 430 hours Pratt & Whitney turbo-propeller engines.

Test Pilot CAA Class II. Mr Neil Thomas - 30 types: Piaggio P149D, total flying hours 6000. 80 hours experience on Walter 601D turboprop engine + 1300 hours on Pratt & Whitney turbo-propeller engines.

Aircraft Maintenance Organisation. Mr Johan Lok, (Warbirds, (Pty) Ltd).

Flight Test Management. The flight test programme was managed by the programme manager through a Safety Review Board (SRB). The SRB comprised following members:

1. Class I Test Pilot.
2. Class II Test Pilot.
3. Aircraft Maintenance Engineer.
4. CAA Certification representative.
5. Each flight planned + flight test card prepared prior to flight.
6. Hazard analysis conducted per flight – risks minimized through procedure or actions.
Conditions Relevant

• **Aircraft Structural Limitations**
  – Load factor: $N_z = +3.8g$. (Originally +6g/reduced to 3.8g in accordance with static load tests approved by CAA).
  – Negative load factor: $N_z = -1.9g$. (FAR 23 negative limit 0.5 x positive limit, i.e. n = -1.9g.
  – Retained:
    • Maximum speed: $V_D = 204$ KIAS.
    • MTOW (Normal Category): 1820 kgs.
    • Fwd CG limit: 0.42m.
    • Aft CG limit (Normal Category): 0.62 m.

• **Mass and Balance.** CG location each flight adjusted combination of long range fuel tank located aft and 30 kgs lead ballast located in baggage compartment.

• **Test Schedule.**
  – 7 July 2013 to 15 October 2014.
  – 54.9 hours flown; included 28 flight test hours and 10 owner conversion hours.

• **Test Location.** Wonderboom Airport, Pretoria, elevation 4095 feet, main runway 29/11, total distance 5996 ft asphalt surface.

• **Air Traffic Control.** Air Traffic Control and Fire/Emergency response provided by Wonderboom Airport.
Flight Test Programme

- **Build-up to first flight**
  - engine ground runs,
  - ground handling,
  - low speed and high speed taxi tests.
  - Build-up in torque vs handling qualities vs pilot workload.

- **Airframe/engine structural inspections after every flight.**

- **Pitot/Static calibration.**

- **Engine In-Flight Relight.**

- **Stalling characteristics, level +accelerated flight (various flap/CG positions).**

- **Static and Dynamic Stability.** Short Period Pitching Oscillation (SPPO)/Long period ‘Phugoid’/Longitudinal static stability.

- **Lateral Directional.** Dutch Roll/Spiral Stability/Steady Heading Sideslip.

- **Manoeuvre Stability.** Wind-up turns.

No automated flight test instrumentation was provided. Test data manually recorded from aircraft's:
- Flight and engine instruments.
- Stick force gauge to measure stick forces
- Rudder forces estimated
- Sideslip strings to estimate sideslip angle.
- OAT
- Ballast – fuel and 30 kgs lead weights in baggage compartment.
Cradle tested to 2 limit loading cases required by FAR 23.361 and 23.363.

A turbine torque factor of 1.6 and a factor of safety of 1.5 were included in load calcs

Inspections on critical airframe structure viz
- Engine mountings.
- Horizontal tail mounting structure.
- Inspections repeated every 5 operating hours up to 25 hours.
- Structural inspections continued every 25 hours to 100 hours and thereafter during MPI's.
### Mass & Balance

<table>
<thead>
<tr>
<th>MASS (kgs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WEIGH DATA:</td>
</tr>
<tr>
<td>Nose wheel</td>
</tr>
<tr>
<td>L/H main wheel</td>
</tr>
<tr>
<td>R/H main wheel</td>
</tr>
<tr>
<td>SUB TOTALS:</td>
</tr>
<tr>
<td>Fuel inboard fwd tanks (max 68 kg)</td>
</tr>
<tr>
<td>Fuel inboard rear tanks (max 118 kg)</td>
</tr>
<tr>
<td><strong>Fuel centre tanks (max 142 kg)</strong></td>
</tr>
<tr>
<td>Fuel tip tanks (max 60 kg)</td>
</tr>
<tr>
<td>Fuel auxiliary tank (max 56 kg)</td>
</tr>
<tr>
<td>TOTAL FUEL LOAD:</td>
</tr>
<tr>
<td>Pilot</td>
</tr>
<tr>
<td>Co-pilot</td>
</tr>
<tr>
<td>Pax (max 2)</td>
</tr>
<tr>
<td>Baggage (max 70 kg)</td>
</tr>
<tr>
<td><strong>1817,1</strong></td>
</tr>
</tbody>
</table>

**MAXIMUM TAKE-OFF MASS 1820 kg**

**FLYING CG RANGE: 0.424 m to 0.622 m**
Pitot Statics – FAR 23.1323

- Nose extended by 305mm (12 inches).
- Reshaped canopy effects on flow field in vicinity of static ports.

FAR 23.1323 = $\delta V_{pc} < 3\%$ or 5 kts, whichever greater from 1.3 $V_{S1}$ to $V_{ne}$

Graphs showing the change in pressure coefficient ($\delta V_{pc}$) with velocity ($V_{i}$) for different configurations:

1. **PEC Confuration Cruise**
   - Original OEM PEC
   - Graph shows $\delta V_{pc}$ vs $V_{i}$ from 60 to 180 kts.

2. **PEC U/C + Flap III**
   - Graph shows $\delta V_{pc}$ vs $V_{i}$ from 60 to 100 kts.

Equation: $y = -0.0979x + 10.75$
Stalling: FAR 23.207

- Must be a clear and distinctive stall warning, flaps and U/C in normal position, in straight and level and turning flight.

- Stall warning margin of not less than 5 knots and must continue until stall occurs.

- Stall warning of 2 KIAS unsatisfactory.

- FAR Part 23.207 Stall Warning, was not complied with.

- 61 KCAS promulgated in FAR 23.49.c in which Vso and Vs1 at maximum weight must not exceed 61 knots

Stall speeds lower than Piaggio P149D ranging
- 2 KIAS lower in cruise.
- 7 KIAS lower landing configuration (Clmax = 1.9)

Contributory causes considered to be
- Cl from increased mass flow
- ‘swooplets’
Longitudinal Static Stability:
FAR Part 23.173

**Fs vs Vi/CG = 0.55m**

**Config: Land**

**Fs vs Vi/CG = 0.55m**

**Config: Cruise**

\[ y = -0.003x^2 + 0.4868x - 15.938 \]
Manoeuvre Stability/CG = 0.55m

- Wind-up turns + pull-ups during accelerated stalls.
- Stick force/g increase linearly with increase in ‘g’
- Maximum 60 lbs/g at $V_a$ of 160 KIAS/Nz = 4g gradient of 15 lbs per g.
- FAR Part 23, Sec. 23.155 Elevator Control Force in Manoeuvres was complied with
Minimum Control Speed

- Minimum control speed/maximum torque airspeed determination.
- Determine boundary between aerodynamic control power versus asymmetric torque effects.
- Test conducted at 5,000 ft pressure altitude (5690 ft density altitude);
  - \( F_r \) did not exceed 150 pounds.
  - Not necessary to reduce power of the engine to maintain control.
  - Aircraft did not assume any dangerous attitude.
  - Possible to prevent heading change of more than 20°.
- Configuration Cruise. DA = 5690 ft. Max torque 90 psi/100%/1970 RPM.
  - \( V_i = 65 \) KIAS - aircraft fully controllable about all axes
  - 4 units right rudder (50% of maximum)
  - 2 units right aileron trim.
- Configuration Landing.
  - 2 x Compressor blowback @ 60 KIAS/2 due to engine acceleration and unstable intake conditions.
  - Second attempt lower rate - aircraft controllable at 60 KIAS
  - Maximum right rudder
  - 1/2 aileron; rate of asymmetry controllable.
  - Recommended ‘wave-off’ minimum airspeed = 60 KIAS (15 KIAS margin/MAUW)
- Essential: pilots NOT TO SLAM THE POWER LEVER OPEN at low speeds/high angles of attack.
Trimmability: Landing Configuration

Insufficient trim authority to trim the aircraft in pitch with flap settings greater than Flap III.

- Effect of flap extension – CP moves aft,
- Increased nose-down pitching moment requires nose-up trim.
- Decreased tailplane authority due to increased downwash.

Additional trim authority to maximum allowable limit setting provided by increasing the trim motor nose-up deflection.

Approaches > Flap III, residual stick forces approximately 8 lbs pull required for approach.

Unsatisfactory but acceptable; provided tactile feedback for landing flare without excessive pull force required.
## Performance Comparison

### MAUW 1820 kgs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>P149D</th>
<th>P149D TP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Takeoff Distance 50 ft (ISA +13°C)</td>
<td>2420 ft</td>
<td>1180 ft</td>
</tr>
<tr>
<td>Stall Speed (KIAS)</td>
<td>51</td>
<td>45</td>
</tr>
<tr>
<td>Crosswind Limit (kts)</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Climb Time (mins) 5,000 ft – 10,000 ft</td>
<td>7.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Ceiling (ft) ISA* (150 ft/min)</td>
<td>14,000</td>
<td>21,000 (extrapolation)</td>
</tr>
<tr>
<td>Power/Weight Ratio</td>
<td>0.14</td>
<td>0.4</td>
</tr>
<tr>
<td>Fuel Used in Climb</td>
<td>9.1 litres</td>
<td>8 litres</td>
</tr>
<tr>
<td>Descent Best Glide Speed (90 KIAS)</td>
<td>1.2 nms/1000 ft</td>
<td>2.86 nms/1000 ft prop feathered</td>
</tr>
</tbody>
</table>

SEP climb profile airspeed conversion rate of 10 KIAS per 1000 ft
- average rate of climb 2542 ft/min +
- pitch attitude approximately 17°,
- high workload for the pilot.
Level Cruise Performance

Power Required/8000 ft Pressure Alt/ISA/1820 kgs

\[ y = -2 \times 10^{-5} x^3 + 0.0128 x^2 - 1.874 x + 90.802 \]

Endurance
\[ V_{imp} = 90 \text{ KEAS} \]

Range
\[ Vl/d = 118 \text{ KEAS} \]
Vn Diagram

Vn diagram for Piaggio P149D TP.

Vi (KIAS)
Recommendations

Recommended that the Piaggio P149D TP be approved for operations within the mass, CG and airspeed limitations as stipulated in the original certification conditions & limitations EXCEPT for the changes to the flight envelope and operating limitations as presented.
Thank You!

The happy owner

Werner Heiml