**Nationaal Lucht- en Ruimtevaartlaboratorium**

National Aerospace Laboratory NLR

## Executive summary

# Certification and operation of a Citation II with large external store


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**Knowledge area(s)**
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**Descriptor(s)**
flight testing

**Problem area**
Cessna Citation (PH-LAB), operated by NLR, is fitted with hard points to enable mounting of external stores. The first store to make use of the hard points was PHARUS, a C-band Synthetic Aperture Radar.

**Description of work**
A certification program was carried out, based on a compliance checklist with respect to FAR 25 regulations.

**Results and conclusions**
It was concluded that the impact of PHARUS on the handling characteristics is nil or insignificant. To cater for the loss of performance due to increased drag during take-off and climb-out, supplementary operational restrictions are proposed. To avoid exceeding the maximum design speed of the store and its attachments in case of an upset, a maximum operating speed in the PHARUS configuration was established.

This report is based on a presentation held at the 45th European SETP Symposium, Madrid, May 22-25, 2013.

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## Summary

In 1993 the Cessna Citation II (PH-LAB) came into service at the National Aerospace Laboratory NLR. The aircraft was fitted with certified hard points to enable mounting of a generic external store with a maximum mass of 200 kg.
The first store to be mounted was PHARUS (Phased Array Universal SAR), a C-band synthetic aperture radar.
In order to obtain formal approval for the installation of and the operation with the radar, a ground and flight test program was required by the Airworthiness Authority of the Netherlands (CAA-NL), in accordance with a Compliance Checklist, as approved by the Authority.
The ground and flight test program comprised of one ground run session, one flight in the clean configuration and five flights with the external store installed. One additional flight with special instrumentation was used in an effort to collect ice on the nose of the pod to evaluate its effect. The flight was not successful, due to the absence of icing conditions. Certification efforts for flight into known icing conditions were then abandoned.

Full use has been made of the FAR 25 certification data in the Airplane Flight Manual as a reference in the analyses. Discussions with Cessna have provided valuable information and guidance on the flight control system, control forces and stall- and stability characteristics.

The overall conclusion of the test and comparison program is that the impact of PHARUS on the handling characteristics is nil or insignificant. To cater for the loss of performance due to increased drag during take-off and climb-out, supplementary operational restrictions are proposed. To avoid exceeding the maximum design speed of the pod and its attachments in case of an upset, a maximum operating speed in the PHARUS configuration was established.

# Contents

## Abbreviations

| | |
|---|---|
| A | Engine intake area |
| AFM | Airplane Flight Manual |
| c | Mean cord |
| C | Centigrade |
| CAA-NL | Civil Aviation Authorities, the Netherlands |
| $C_{dph}$ | Drag coefficient for PHARUS |
| $C_n$ | Yawing moment coefficient |
| $D_{wm}$ | Wind milling drag |
| FAR | Federal Aviation Regulations |
| ft | Feet |
| kg | Kilogram |
| KIAS | Knots indicated airspeed |
| kts | Knots |
| lb(s) | pound(s) |
| m | Meter; minute |
| MCO | Maximum continuous power |
| MTO | Maximum take-off power |
| N | Newton |
| N1 | RPM of low pressure compressor |
| OAT | Outside air temperature |
| PEC | Position error correction |
| RHO | Specific mass |
| RTO | Rejected take-off |
| SAR | Synthetic aperture radar |
| SAT | Static air temperature |
| sec | Second |
| TAS | True airspeed |
| TUDelft | Technical University Delft |
| $V_1$ | Take-off decision speed |
| $V_2$ | Single engine climb-out speed |
| $V_{MCa}$ | Minimum control speed air |
| $V_s$ | Stall speed in relevant configuration |
| TOW | Take-off weight |
| ZFW | Zero-fuel weight |

# 1 Introduction

In 1993, the National Aerospace Laboratory (NLR) and Technical University Delft (TUDelft), acquired a new Cessna Citation II with registration PH-LAB. (See fig. 1).


*Fig. 1: Cessna Citation II (PH-LAB)*

The Citation has been fitted with 6 hard points on the lower left side of the fuselage, forward of the wing to enable the installation of external stores to the aircraft. There are two hard points (upper and lower) on each of the three hard point frames. The store can be attached using any two sets of hard points on the frames located at FS134, FS168 or FS207. These hard points were certified by Cessna to enable the installation of a generic store of 200 kg (440 lbs) mass maximum. Center of gravity can be anywhere between attach points. Wide limits on store center of gravity and attach point configuration allow the entire inertial (gust) load to be applied to any one of the three hard point frames. This is offset in part by the air load, which is applied at the 25 % length station. Load cases considered “long” or “short” length, corresponding to attachment at forward-and-aft hard point locations or at either forward-and-mid or mid-and-aft locations, respectively. Also, the center of gravity could be located at either extreme (forward or aft mount location). Fig. 2 shows the location of the hard point frames.

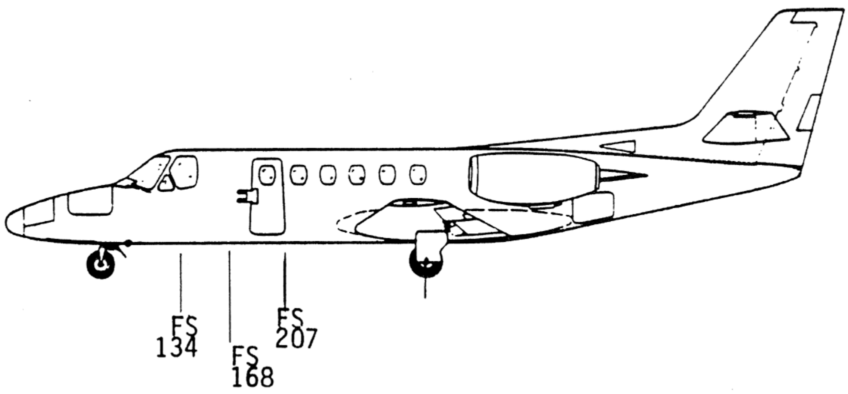


*Fig. 2: Position of the hard point frames*

The hard points were first used for the installation of a Synthetic Aperture Radar (SAR) antenna, called PHARUS (Phased Array Universal SAR). This C-band radar has a cross section of about 45 x 45 cm and a length of 150 cm excluding a nose cone and tail cone of 75 cm length each. The total mass of the radar antenna is 260 kg (570 lbs). Mounting of the antenna is to the upper hard point at FS134 and the two hard points at FS168. Although the antenna exceeds the maximum mass and mounting is to only three of the available four hard points, the maximum load on the three hard points is within limits due to the fact that the center of gravity of the antenna is in the middle between FS134 and FS168. (See Fig. 3).


*Fig. 3: PHARUS installed on Citation*

In order to obtain information on the impact of this relatively large antenna pod on engine behavior, take-off performance, stall characteristics and -speeds, minimum control speed, susceptibility to airframe icing, stability and control and high speed (flutter) behavior, advice has been sought from Cessna. Although Cessna has provided valuable and often reassuring information and guidance in this respect, no definite and conclusive answers were obtained. In order to obtain formal approval for the installation of and the operation with the large radar antenna pod, a ground and flight test program was required by the Airworthiness Authority of the Netherlands (CAA-NL), in accordance with a Compliance Checklist, as approved by the Authority.

## 2 Scope of the flight test program

In the preliminary discussions between CAA-NL and NLR it was mutually accepted that:

- since the Citation being a FAR 25 aircraft, certification basis for the PHARUS store was to be according to FAR 25 as well (Ref. 1).
- NLR should obtain as much information from Cessna as possible, especially about handling and performance issues.
- for those areas where a change in handling and/or performance characteristics could not completely be excluded, a reasonable number of checkpoints needed to be covered during flight tests.
- a compliance checklist was to be made according to FAR25 subpart B, resulting in a list of relevant flight conditions and aircraft configurations to be tested. This list was proposed by NLR and approved by CAA-NL (see Tab. 1).
- in principle, the methods of compliance or demonstration according to the FAA Flight Test Guide (Ref. 2) would be used.

Discussions with the Authority on tests with a higher risk factor, such as the determination of the effect on the minimum control speed, led to the definition of an adapted procedure.

The center of gravity during future PHARUS measurements was estimated to be at 25 % of the range. This position was maintained during the flight test program, if necessary, by balancing.

The flight test program comprised of a ground run session, one reference flight in the configuration where PHARUS was not installed and five flights with the PHARUS store installed (see Tab. 2). One additional flight with special instrumentation was used in an effort to collect ice on the nose of the pod. This flight was unsuccessful due to the absence of icing conditions. After that, efforts to certify PHARUS for flight in known icing conditions were abandoned. This led to a restriction that flight into known icing conditions was not allowed with the store attached.

# 3 Results

## 3.1 Ground runs

Two ground runs / rejected take-offs (RTO) with the PHARUS pod installed were made, obtaining maximum speeds of 80 and 100 KIAS respectively under no wind conditions. A third envisaged ground run was cancelled due to hot brakes. The objective of the ground runs was to obtain information about ground handling, airspeed and altitude indications and Eigen frequencies and loads on the pod and supports. The following observations were made:

1. As to ground handling, no significant difference in response to rudder inputs, throughout the speed range, was noticed.
2. Due to the proximity of the PHARUS pod to the pilot's static ports, a comparison of airspeed and altitude indications of the pilot and copilot systems and the groundspeed (from an inertial source) was made. The left static port of the copilot's static system was blocked; the captain's system was unrestricted. No difference was noticed between the individual cockpit airspeed and altitude indicators and the groundspeed read-out. (See further explanation in the next paragraph).
3. Eigen values and -frequencies and loads on the pod and its supports were obtained. Some excitation was noted at approximately 20 kts groundspeed, during taxying.

## 3.2 General observations during the first flight with PHARUS installed

The main objective of the first flight with the PHARUS pod was to ensure that safe flight was possible over a fair range of aircraft configurations, airspeeds, sideslip angles, engine power settings and power changes.

Woollen tuft was used to visualize and evaluate the flow pattern over the wing and along the fuselage towards the left engine. Pictures were taken from a chase plane (NLR's Metroliner PH-NLZ). See fig.4 for an example of the flow pattern along the left side of the fuselage.

*Fig. 4: Flow pattern along the fuselage*

Figure 5 shows examples of tuft on the upper side of the left wing for a non-stall and stall situation.

*Fig. 5: Flow pattern over the wing for non-stall and stall situation*

The flight was performed with minimum crew and at a low take-off weight. Further, precautions were selection of a 10,000 ft runway at Schiphol and good weather conditions.

Discussions with Cessna could, in advance, not remove the feeling that one or more vortices, originating from the pod, might enter the left engine, affecting its performance or, ultimately, cause engine stall or flame-out. To satisfy this issue a number of qualitative tests were done at airspeeds of 160, 130 and 115 kts in straight and level flight and with left and right yaw and in various aircraft configurations. The left or right engine throttle was closed followed by slam acceleration as soon as N1 approached successively 80 %, 65 % and flight idle. In none of the tests any difference was observed between left and right engine, neither in instrument indications nor in vibration or noise levels. Additional evaluation after flight of the engine recordings did not show any non-normal behaviour.
From these tests, combined with experience from the later stall tests, it is concluded that the presence of the PHARUS pod has no noticeable effect on the engines.

Both captain's and co-pilot's pitot-static systems receive static pressure from a static port on the left side and one on the right side of the fuselage. This concept will tend to correct automatically for effects like angle of sideslip in either direction. The left side static ports are relatively close to the external store. Flow distortion might compromise the validity of the measured static pressure, leading to a change in PEC. To quantify its effect on the flight instrument readings, the left static port of the co-pilot's system was blocked off. The captain's system remained as it was. At 5000 ft and at speeds of approximately 160, 130 and 115 kts, in different aircraft configurations, the left and right indications of airspeed and altitude were compared for three angles of yaw.

The results, presented in Table 3, appear consistent when comparing the direction of the yaw. Yaw to the right results in the co-pilot's airspeed and altitude indications (only right hand static port) to read lower than captain's indications (static ports on both sides of the airplane). This could be caused by relative high pressure on the right hand side. The reverse is true, although less pronounced, for yaw to the left. Nevertheless, the differences are small in all cases.
Additionally, during flight 240 pacer measurements were made with the Swearingen Metro II as a pacer aircraft. No differences were observed between both aircraft in airspeed and altitude indications from 230 kts down to 90 kts.
Based on this, it is concluded that the presence of the PHARUS pod has no significant influence on the airspeed and altimeter indications and the systems continue to provide correct information. There is no further need for blocking the left static ports.

### 3.3 Stall

Airplane handling at low speeds and stall speeds form an important part of the airplane characteristics, because of the direct impact on safety, take-off and landing performance, and furthermore on the immediate operation. A change in low speed handling could lead to the requirement of additional warning devices, whereas an increase in stall speeds has a direct impact on a number of take-off speeds and thus on the resulting performance.
From preliminary discussions with Cessna it was learned that, if the stall speeds would be affected, it would not be more than a few knots.
The keywords in planning the flight tests for the lower end of the operational envelope were "with great caution". The following steps were taken:

- Stall tests in the configuration without PHARUS, which is the certified configuration as described in the Airplane Flight Manual-AFM (Ref. 3).
- Evaluation of the flow patterns without and with PHARUS, as observed from the Metro and from the cabin of the Citation.
- Approaches to stall and recovery, in the PHARUS configuration, at the first sign of stall warning (aerodynamic buffet), continuously monitoring changes in the flow pattern and comparing left and right wing.
- Fully developed stalls in the PHARUS configuration with continuous evaluation of development of flow patterns over both wings.

Video registrations were taken of both wings to enable evaluation of the flow patterns, after the flight.

In Ref. 2, the flight technique for an acceptable stall test is described. The test pilots are required to aim for a speed decay of 1 kt/sec. The airplane is considered to be stalled if one of the following occurs:

- Elevator control reaches the aft stop.
- Pitch down and/or a wing drop.
- Strong and severe buffet.

The configurations flown in the slow flight part of the program are specified in Table 1, items 1-20. The results of the measurements are given in Table 4.
Recovery in the developed stall, from a flight technical point of view, was on the same indications with and without PHARUS. The stall characteristics in both configurations were essentially the same, e.g. hardly any tendency for a wing drop and immediate response to elevator induced recovery. Aileron control remains effective until in the stall.
Consistently the stall speeds for both configurations (with and without PHARUS) are within one or two knots, but are consistently higher than the stall speeds from the AFM. Most probably it is the flight technique that is accountable for the difference. A distinct aerodynamic buffet serves as a stall warning at a pre-stall speed which is approximately the same in both measured configurations, without and with PHARUS, and typically lies 3 to 7 kts above the stall speed. This and the fact that both measurements result in approximately the same stall speeds (although different from the AFM) leads to the conclusion that the presence of PHARUS has no influence on the stall characteristics and the stall speeds. This is also supported by the development of the flow patterns which are the same in both cases.
Flow separation and its expansion in the direction of the wing root and the wingtip originates just behind the two stall strips and is virtually the same between both wings and between the clean and the PHARUS configuration. The effect of the stall strips is obviously much more pronounced than the effect of the external pod. See fig. 6, showing the onset of flow separation behind the stall strip, visible just outboard of the heated leading edge.

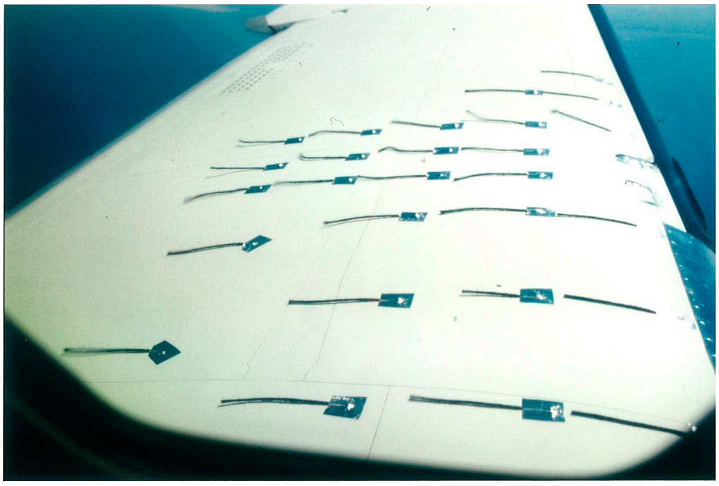

*Fig. 6: Flow separation behind stall strip*

### 3.4 Minimum Control Speed ($V_{MCa}$)

The $V_{MCa}$ of the Citation in the configuration without PHARUS, at practical take-off weights is not limiting because this speed is well below the stall speed in this configuration. For example, for a TOW of 12000 lbs (ZFW = 10000 lbs; fuel 2000 lbs), the $V_{MCa}$ is 77 kts and the stall speed at take-off flaps is 85 kts. For a much more likely fuel load in an envisaged PHARUS measurement configuration of 3500 lbs, the speeds are 77 kts against a stall speed for take-off flaps of 90 kts. To demonstrate compliance a program was flown with and without PHARUS (see Tab. 1 item 64 - 73) that differs slightly from the flight test technique to determine $V_{MCa}$ as defined in AC25.149. For reasons of safety, these checks were flown at 6000 ft with maximum certified take-off power on one engine and flight idle or low power on the other engine. Measurements were conducted at two speeds, 1.1 $V_s$ and 1.2 $V_s$ and in two configurations, flaps 0° and 40°, both with gear retracted. Measurements were flown wings level maintaining a constant heading with rudder.

From the measurements of the engine parameters, the engine thrust of both engines as well as the yawing moments (thrust line at 1.33 m from plane of symmetry) were calculated, using Ref. 4. The resulting moment was balanced in stationary flight by the measured rudder deflection (Table 5). The assumptions in the thrust calculations were zero installation losses and no losses due to bleed pick-off. The yawing moment coefficient $C_n$ was calculated for wing area S = 30 $m^2$ and aerodynamic cord c = 2.057 m. In figure 7 the $C_n$ values for all configurations, with and without PHARUS, are plotted against the measured $\delta_r$ (rudder deflection) and in figure 8 the moment coefficients are plotted against IAS.

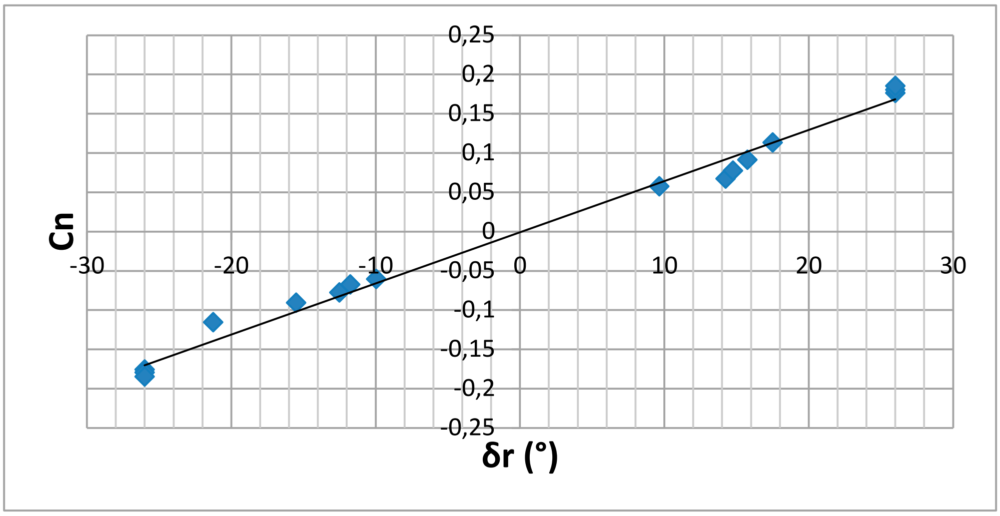


*Fig. 7: Yawing moment coefficient versus rudder angle*

Throughout the thrust range it was shown that the rudder deflection remained linearly correlated with the yawing moment, therefore no non-linear or higher-order effects are introduced with the external store attached.

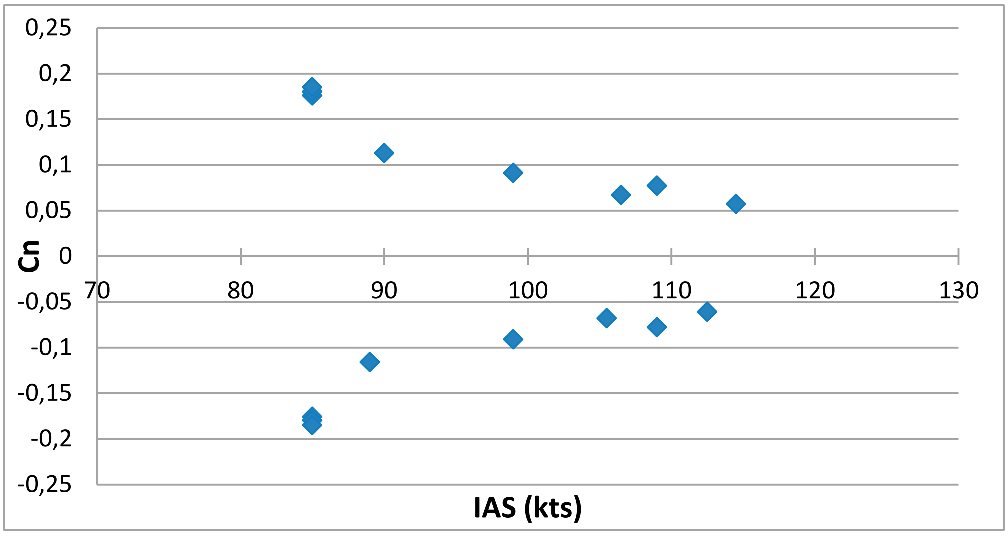


*Fig. 8: Yawing moment coefficient versus IAS*

Similarly, no non-linear asymmetry effects were discovered when comparing the effects of left- and right engine thrust reductions.

As the objective was not to determine a $V_{MCa}$, but to demonstrate that $V_{MCa}$ was not limiting at speeds of 1.1and 1.2 Vs, for safety reasons, the tests were not performed at speeds below 1.1 Vs. The extreme values in figures 7 and 8, at $\delta_r$=±26° and at 85 kts, are therefore calculated and not measured data points. These points represent on the one hand the maximum rudder deflections in both directions (i.e. the maximum capability of the rudder control system) and on the other hand the yawing moment coefficient which needs to be counteracted in case of an engine failure at 85 kts. This is the stall speed in the take-off or approach flap configuration at a weight of 12000 lbs. Three values for the moment coefficient are given for respectively no wind milling drag on the dead engine, wind milling drag due to full stagnation (very conservative) and the more likely wind milling drag due to 50 % stagnation.
Thus the data points in figures 7 and 8 originate from two sources (measured and calculated) and four configurations (left engine; right engine; PHARUS; no- PHARUS). The approximate linearity between "requirement (moment)" and "availability of control (rudder)” for all points, coupled with the possibility to benefit from 5° banking away from the dead engine, justifies the conclusion that the presence of PHARUS does not noticeably change $V_{MCa}$ and that the stall speed remains the determining speed under asymmetrical engine power.

## 3.5 Take-off and landing performance

### 3.5.1 Take-off performance

#### 3.5.1.1 Second segment single engine climb gradient

According to FAR 25 regulations, the second segment single engine climb gradient must be better than 2.4 %. For terrain clearance analysis a nettage factor of 0.8 % must be used to account for certain defined circumstances and to provide some additional safety. In the Citation II AFM (Ref. 3), the published gradient values already include this factor.
Partial climbs were flown to estimate the single engine climb performance in the PHARUS configuration. For both engines, with two repetitions, four different partial climbs are flown (see Tab. 1 items 21 - 36).
The four configurations are:

- Airspeed $V_2$ and $V_2$+10 (kts).
- Gear up/flaps up and gear up/flaps take-off (15°).

The measurements were executed with one engine at maximum take-off power and the other throttled back to flight idle. The measured performance is corrected for flight idle thrust and estimated wind milling drag.
The following corrections are applied to the measurements:

- Flight idle thrust is calculated using the manufacturer's engine computer model (Ref. 4), from recorded and calculated parameters N1, SAT, Altitude, Ambient pressure ratio and Mach or TAS (see Tab. 6). This value for flight idle thrust is conservative because installation losses and bleed air pick off have not been accounted for.
- Wind milling drag is estimated conservatively by loss of impulse to zero in the engine intake according to the following formulae:

  $D_{wm}$ = RHO x A x TAS x (TAS - 0) (in N) where:
  RHO (at 2000 ft) = 1.1549 kg/$m^3$ and A = 0.2003 $m^2$ (engine intake area)
  TAS is the true airspeed in m/s.

In Table 6, column "GRADIENT CORR", the corrected and conservative single engine climb gradients are given. The last column in Table 6 represents the single engine climb gradients as given in the AFM (Ref. 3). These values include a reduction of 0.8 % to facilitate use for obstacle clearance purposes (note that in this paragraph "%" means an absolute and not a relative value). Adding this factor and comparing the results with the values measured with PHARUS (column: GRADIENT CORR) shows that PHARUS induces a loss of gradient in the second segment of 1.5 - 2.5 %. If only those checkpoints are taken flown at $V_2$, which represent the correct flight technique after engine failure at $V_1$, then the maximum (conservative) loss of performance with PHARUS and relative to the AFM configuration is 1.8 % (gradient loss).

Another uncertainty which adds to the conservatism is that the measurements were executed during non-ideal conditions (turbulence and Cumulus type clouds).
The second segment take-off net climb gradient tables from the AFM can be used to quantify the effect of a performance loss of 1.8 % on the operating envelope, i.e. the temperature and pressure conditions at which the bottom line of the FAR 25 certification limit is approached. For TOW=14100 lbs; flaps 0°; pressure altitude 1000 ft, no wind conditions, with PHARUS, the second segment take-off net climb gradient is on the lower limit of (2.4 - 0.8) = 1.6 % at an OAT of 35° C. At a TOW of 13500 lbs this occurs at 40°.
With take-off flaps, 15°, selected, the same occurs at respectively 28° C and 32° C.
Operations beyond these constraints should be permitted, providing Visual Meteorological Conditions prevail at take-off.
The operational supplement to the AFM, which accounts for the changed second segment take-off net climb gradient in the PHARUS configuration (i.e. a gradient loss of 1.8 %) can be based, conservatively, on either a take-off weight penalty of 1800 lbs, or an outside air temperature penalty of 18° C, or a combination of both. The combination of a take-off weight penalty and a temperature penalty should be on the basis of 0.1 % gradient loss per 100 lbs take-off weight and 0.1 % gradient loss per degree C until a total of 1.8 %.
Example: An 800 lbs TOW and a 10°C OAT penalty induce the required loss of 1.8 % in climb gradient.

#### 3.5.1.2 Take-off field length

The drag of the PHARUS store is the prime factor affecting the take-off field length. This drag is disadvantageous during the acceleration part of the take-off run. In the RTO phase from $V_1$ until a stop the drag is favourable. The scheme resembles the effect of an up-hill departure on $V_1$ and the take-off field length. The drag of PHARUS at a $C_{dph} = 1$ equals a force of 75 lbs at approximately $V_2$. This is comparable with an up-hill slope of 0.55 % at 14000 lbs take-off weight and 0.65 % at 12000 lbs take-off weight.
The use of an up-hill slope scheme to approximate the effect of a drag force is conservative, due to the fact that drag is speed dependent and the decelerating portion is small in relation to the accelerate-stop distance.

The corrections in the AFM for up-hill slope of the basic aircraft are (Flaps 0° (15°)):

- 2 % up-hill slope: add 2 (4) kts to $V_1$; add 40 (30) % to the take-off field length.
- 1 % up-hill slope: add 1 (2) kts to $V_1$; add 15 (12) % to the take-off field length.

The practical solution in the operational supplement for the PHARUS configuration is to use the conservative correction factors for the 1 % up-hill take-off.

### 3.5.2 Single engine approach climb performance

The requirement in FAR 25 regarding the single engine approach climb performance is a minimum gross gradient of 2.1 % in gear-up and approach flap configuration with one engine inoperative. Assuming a performance loss of 2 % due to PHARUS, then the bottom line of 2.1 % at 1000 ft and at maximum landing weight will be reached at an OAT of 32°C instead of 50°C in the no- PHARUS configuration. It is, nevertheless, proposed to disregard this restriction in this phase of flight.

### 3.5.3 All-engines operating landing climb performance

The requirement in FAR 25 for the all-engines operating landing climb performance is a minimum gross gradient of 3.2 % in gear down and landing flap configuration with all-engines operating. Assuming a performance loss of 2 % due to PHARUS, then the bottom line of 3.2 % at 1000 ft and at maximum landing weight will be reached at an OAT of above 52°C, i.e. still outside the table in the no- PHARUS configuration.

### 3.5.4 Landing performance

The landing speeds in the PHARUS configuration are the same as in the no- PHARUS configuration. Although there is increased drag, the landing roll in the PHARUS configuration is considered equal to the landing roll with PHARUS not installed. Therefore, the landing performance as specified in the AFM is valid and probably conservative for the PHARUS configuration.

## 3.6 Longitudinal control

The adequacy and sufficiency of longitudinal control was checked in a number of different tests at 10000 ft (Tab. 1 items 37 - 51). These tests were:

- Recovery from stalls.
- Selecting flaps from 0 to 40° while maintaining speed; gear down; power flight idle.
- Selecting flaps from 40 to 0° while maintaining speed; gear down; power flight idle.
- Selecting flaps from 40 to 0° while maintaining speed; gear down; power MTO.
- Application of power from flight idle to MTO while maintaining speed; gear down; flaps up.
- Application of power from flight idle to MTO while maintaining speed; gear down; flaps 40.
- Reduction from trim speed at 1.4 $V_s$ to 1.1 $V_s$ then to 176 kts at flight idle; gear down; flaps 40°.
- Application of elevator control to pitch down; gear down; various combinations of speed, flap settings and power.
- Simultaneous application of go-around power and selection of flaps-up while maintaining level flight.

Under all these conditions adequate longitudinal control was available and no problem whatsoever was encountered.

### 3.7 Directional control

Directional control was checked at 6000 ft in gear-up and flaps take-off (15°) configuration. Left and right engines were successively at MCO and one at flight idle power. Abrupt rudder inputs were made into the dead engine, maintaining wings level with aileron, until heading changes to 15°. Configuration was checked with yaw damper on and off. No control was lost and no rudder lock took place. A separate check was made to ensure that sufficient rudder control was available to control a sudden engine failure (Tab. 1 items 52 - 59). In none of these tests any problem was encountered.

### 3.8 Lateral control

Lateral control was checked at 6000 ft and 1.4 $V_s$. Left and right engines were successively at MCO and one at flight idle power (Tab. 1 items 60 - 63). Smooth coordinated turns at 20° of bank into and away from the "dead engine" were made without any problem or difficulty.

### 3.9 Static Longitudinal Stability

In order to get insight into the static longitudinal stability of the aircraft with PHARUS a number of turns were made with angles of bank of up to 45°. A progressively increasing pull force was needed to maintain level flight in the turns (Tab. 1 item 75).
The static longitudinal stability for cruise conditions was demonstrated, starting at a trim speed of 180 kts, with a reduction of the speed by a pull force (no retrimming); stabilization at 170 and 160 kts. Then a stick-free return to trim speed conditions was executed. The reverse with a push force was done, stabilizing at 190 and 200 kts. In both cases the free return speed was 180 kts, the trim speed (Tab. 1 item 76 - 77).
Measured longitudinal control forces at control column, with zero force at trim speed of 180 kts are: a pull force of 18 N at 170 kts; a pull force of 36 N at 160 kts; a push force of 16 N at 190 kts; a push force of 25 N at 198 kts.

### 3.10 Lateral Directional Stability

The lateral and directional stability in two different steady sideslip manoeuvres was checked at 30000 ft and at 6000 ft. (Tab. 1 items 78 - 87):
The sideslip was induced by slow rudder inputs, while maintaining wings level with aileron input. Positive directional stability was demonstrated if, after releasing rudder the aircraft returned to the starting condition.
The sideslip was induced by rolling bank with aileron and maintaining heading with rudder. Releasing aileron should tend to roll off the bank or at least maintain bank angle, thus

demonstrating indifference.
The speeds during the tests ranged from IAS=235 kts at 30000 and 6000 ft (maximum operating speed with PHARUS via approximately 176 kts (maximum for landing flaps) to 1.2 $V_s$.
The first check demonstrated, without exception a positive directional stability. No indication of rudder locking was noticed (Tab. 7). The second procedure demonstrated positive lateral stability in all gear up and flaps up cases. However, in the gear-down and landing flaps (40°) configuration, the lateral stability is clearly indifferent in both directions.

### 3.11 Dynamic Longitudinal Stability
The dynamic longitudinal stability was checked at 10000 ft. at all flap settings and speeds at the high and low end for the configuration. The aircraft was excited by short pulsed doublets (Tab.1 items 88 - 93). Damping of the short period oscillation was excellent.
During the measurement of the static longitudinal stability the period of the phugoid was 42 sec. and damped in 4 to 5 oscillations.

### 3.12 Dynamic Lateral Directional Stability
The dynamic lateral directional stability concerns specifically the dutch roll characteristics. The tests were performed over a fair-sized range of the operational envelope of the aircraft and for all flap settings (Tab. 1 items 94 - 101). The test was done with yaw damper off. Some runs were repeated to evaluate the effect of the yaw damper. The general conclusion is that the dutch roll is reasonably well-damped (Tab. 8). The yaw damper is very effective.

### 3.13 High speed

#### 3.13.1 High speed buffet
The behaviour of the PHARUS store at high airspeeds was checked during runs, starting at 200 kts and increasing in steps of 10 kts until the maximum design speed of the pod of 250 kts was reached (Tab. 1 items 102 - 106). On-line evaluation of accelerometer data on a scope showing signals of pick-ups on the PHARUS store and absence of vibration, buffeting or unusual noise determined continuation with the next step. No problems were encountered. Analyses of the pick-up signals after flight have been reported in reference 5.

#### 3.13.2 Maximum speed in PHARUS configuration
One of the limiting flight conditions is the requirement that in case of a high speed upset the design speed of the Citation including PHARUS of 250 kts is not exceeded. This requirement would set the value for the maximum operating speed with PHARUS. The procedure used for this test is to pitch down 6° from steady level flight, roll to a bank angle of 15°, wait 3 seconds and recover (Tab. 1 items 107 - 111). If the procedure was started at 235 KIAS, the maximum

speed remained below 250 kts. Based on this outcome the maximum operating speed with PHARUS is proposed at 235 KIAS. The recordings showed that the timing was always somewhat longer than 3 sec which incorporated some conservatism in the limiting speed.

### 3.13.3 High altitude 45° bank turns at maximum (PHARUS) operating speed

A fair-sized margin to high speed buffeting was demonstrated in 45° bank turns at 235 kts and 30000 ft. No vibrations or buffeting were noticed (Tab. 1 items 112 - 113).

## 3.14 Trim

A general requirement according to FAR 25 is that sufficient trim authority is available over the full speed, altitude and aircraft configuration envelope. No dedicated flights were made on this subject. However, in the measurement program the aircraft could always be trimmed hands- off.

## 3.15 General manoeuvrability

During the test program, advantage was taken to manoeuver the aircraft in turns up to 45° of bank, throughout the speed, altitude and aircraft configuration envelope. No dedicated flights were made on this subject.

# 4 Flight in icing conditions

Ice accretion on the PHARUS pod was considered to be a potential problem. Ice breaking loose may enter the left engine causing flame out and/or damage to the engine. In addition, ice may hit parts of the wing, fuselage and tail.
Since the available power from the aircraft electrical system was insufficient to install anti-icing features on those PHARUS parts vulnerable for ice accretion, a study was made in order to:

- design a nose cone for PHARUS that minimizes the amount of ice accretion
- obtain information on the trajectories of ice, once broken loose, for various speeds, configurations and nose cone geometries.

Based on water droplet impingement studies (Refs. 6 through 8) it was concluded that the optimal shape of the nose is a cone with cone angle of 30 degrees and spherical top with radius 0.5 cm, rather than a half sphere with radius of 20 cm. However, a limited amount of ice accretion cannot be ruled out.

Once ice has been built up and separation occurs, the trajectory of the ice may also be an issue. Fig. 9 shows an example of ice trajectories for speeds ranging from 64 to 128 m/s. Other parameters that were looked at were: shape and size of the lump of ice and nose cone angle. The study of the ice trajectories revealed that it could not be excluded that ice enters the left engine.

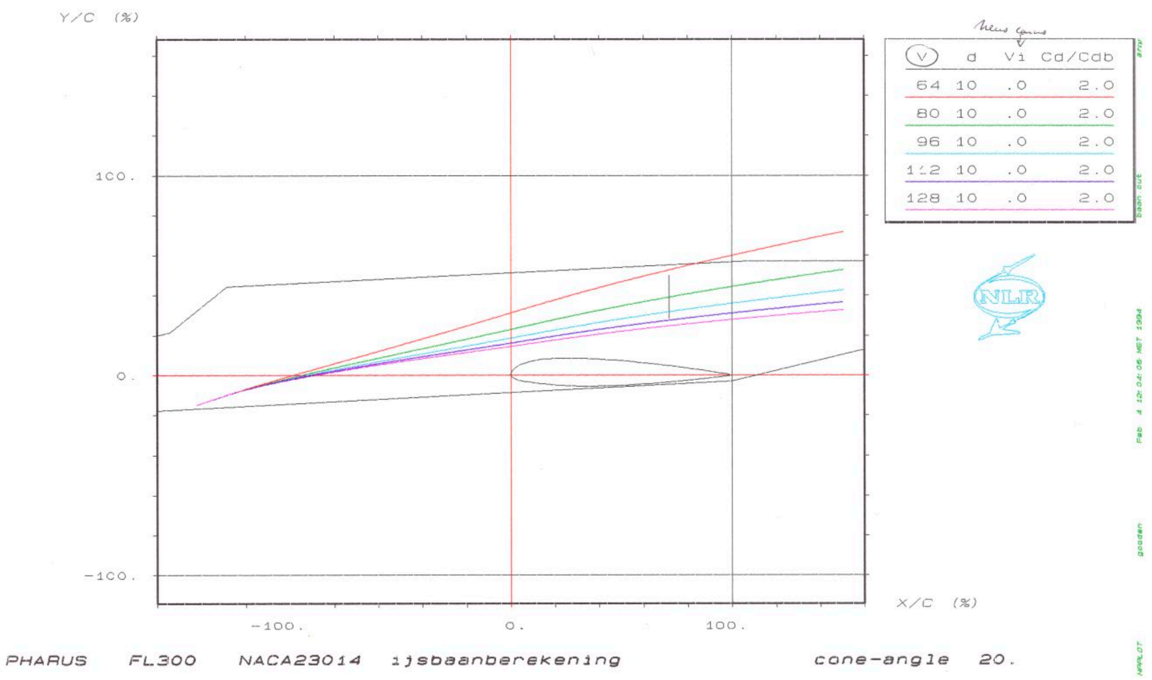


*Fig. 9: Trajectories of ice lumps as a factor of airspeed*

During one of the test flights with PHARUS, an effort was made to collect ice on the nose cone. This was unsuccessful because no icing conditions were encountered during the flight. Given the fact that ice accretion can occur and ice lumps can subsequently enter the left engine, further certification efforts for flight into known icing conditions were abandoned.
Icing issues have never caused operational restrictions during the planning phase nor during subsequent PHARUS flights.

# 5 Conclusions

- The ground and flight test program in the PHARUS configuration was based on the compliance checklist as approved by the CAA-NL.
- FAR 25 certification data for the Citation II were used as a reference where deemed appropriate.
- The methods in the FAA Flight Test Guide were used in the test program.
- Center of gravity during the tests is maintained at the approximate position for the future PHARUS measurements.
- The Citation PH-LAB is certified in the normal category, but can also be operated in the restricted category.
- Discussions with Cessna provided valuable information and guidance but no real conclusive answers.
- No data have been collected which verify that the aircraft can be safely operated in icing conditions. In an early stage of the certification process, certification for flight into known icing conditions was abandoned.
- The presence of the PHARUS pod has no influence on the airspeed and altimeter indications and the systems provide correct and reliable information.
- There is no need for blocking-off the left static ports.
- The presence of the PHARUS pod has no noticeable effect on engine performance and behaviour.
- The presence of the PHARUS pod has neither influence on the stall characteristics, nor on the stall speeds.
- There is no reason to increase stall speeds in the PHARUS configuration.
- Take-off and landing speeds in the PHARUS configuration can remain the same as in the no- PHARUS configuration.
- The presence of the PHARUS pod does not change the minimum control speed air.
- Single engine take-off climb performance is influenced by the presence of the PHARUS pod, by reducing the achievable climb gradient by a gradient of 1.8 %.
- A practical solution is proposed to account for the loss of performance on the single engine climb gradient and the take-off field length.
- Values are given for OAT, weight and configuration at 1000 ft pressure altitude, where the aircraft in the PHARUS configuration can just maintain bottom line FAR 25 requirements in the single engine second segment climb gradient and the approach climb gradient.
- Take-off operations beyond these values should be permitted, providing visual meteorological conditions prevail at take-off.
- The restrictions on the approach climb can be disregarded.
- The minimum requirements for the all-engines operating landing climb are not

compromised in a normal operational environment.

- Landing field length performance is not adversely affected by the presence of the PHARUS pod.
- Longitudinal, lateral and directional control is not adversely affected by the presence of the PHARUS pod.
- Static and dynamic longitudinal and lateral-directional stability are still adequate in the presence of the PHARUS pod.
- No high speed vibration and buffeting is noticeable up to the maximum measured speed of 250 KIAS.
- A maximum operating speed of 235 KIAS provides adequate margin with the maximum PHARUS design speed of 250 kts.
- No buffeting was encountered in turns with 45° of bank at the maximum operating speed of 235 KIAS at 30000 ft.
- The presence of PHARUS does not deteriorate the trim possibilities in comparison with the basic clean aircraft.

## 6 References

1. Anon., Code of the Federal Regulations FAR Chapter 25.
2. Anon., Flight Test Guide for certification of Transport Category of Airplanes. Advisory Circular AC 25-7; U.S. Department of Transportation: Federal Aviation Administration, 4/9/86.
3. Anon., Airplane Flight Manual Model 550 Citation II. Date of Approval 16 February 1990 (latest revision 4 20 January 1995).
4. Anon. JT15D-series engine thrust model P1591. Pratt & Whitney Aircraft of Canada Ltd. 1993.
5. Persoon, A.J.; Geurts, E.G.M., Vibration test at the nacelle "PHARUS". NLR TR 95621 L; 951213.
6. Bruin, R.J.; Mergler, H.W., Impingement of water droplets on a cylinder in an incompressible flow field and evaluation of rotating multi cylinder method for measurement of droplet size distribution, volume median droplet size and liquid water content in clouds. NACA TN 2904, 1953.
7. Dorsch, R.G.; Saper, P.G.; Kadow, C.F., Impingement of water droplets on a sphere. NACA TN 3587, 1955.
8. Lewis, J.P.; Ruggeri, R.S., Experimental droplet impingement on four bodies of revolution. NACA TN 4092, 1957.

*Table 1: Compliance checklist and flight test program*

| NUMBER | FAR | SUBJECT | DESCRIPTION OF TEST | REFERENCE FLIGHT AND CONFIGURATION | | | ALTITUDE (FL OR FT) | IAS (KTS) | GEAR | FLAP | POWER | WEIGHT (LB) | YD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | FLT | REC | PHARUS | | | | | | | |
| 1 | 25.103<br>25.201<br>25.207 | STALL | STALL IN STRAIGHT FLIGHT | 238 | 6.7.23 | NO | 10000 | | UP | 0 | FI | 12990 | OFF |
| 2 | | STALL | STALL IN STRAIGHT FLIGHT | 238 | 69 | NO | 10000 | | UP | 0 | FI | 11590 | OFF |
| 3 | | STALL | SLOW TO BUFFET | 240 | 48 | YES | 10000 | | UP | 0 | FI | 12543 | OFF |
| 4 | | STALL | STALL IN STRAIGHT FLIGHT | 240 | 50 | YES | 10000 | | UP | 0 | FI | 12513 | OFF |
| 5 | | STALL | STALL IN STRAIGHT FLIGHT | 238 | 9 | NO | 10000 | | UP | 15 | FI | 12930 | OFF |
| 6 | | STALL | STALL IN STRAIGHT FLIGHT | 238 | 71 | NO | 10000 | | UP | 15 | FI | 11570 | OFF |
| 7 | | STALL | SLOW TO BUFFET | 240 | 52 | YES | 10000 | | UP | 15 | FI | 12488 | OFF |
| 8 | | STALL | STALL IN STRAIGHT FLIGHT | 240 | 54 | YES | 10000 | | UP | 15 | FI | 12468 | OFF |
| 9 | | STALL | STALL IN STRAIGHT FLIGHT | 238 | 13 | NO | 10000 | | DWN | 0 | FI | 12880 | OFF |
| 10 | | STALL | STALL IN STRAIGHT FLIGHT | 238 | 73 | NO | 10000 | | DWN | 0 | FI | 11550 | OFF |
| 11 | | STALL | SLOW TO BUFFET | 240 | 56 | YES | 10000 | | DWN | 0 | FI | 12438 | OFF |
| 12 | | STALL | STALL IN STRAIGHT FLIGHT | 240 | 58 | YES | 10000 | | DWN | 0 | FI | 12398 | OFF |
| 13 | | STALL | STALL IN STRAIGHT FLIGHT | 238 | 15,17 | NO | 10000 | | DWN | 15 | FI | 12820 | OFF |
| 14 | | STALL | STALL IN STRAIGHT FLIGHT | 238 | 75 | NO | 10000 | | DWN | 15 | FI | 11540 | OFF |
| 15 | | STALL | SLOW TO BUFFET | 240 | 60 | YES | 10000 | | DWN | 15 | FI | 12363 | OFF |
| 16 | | STALL | STALL IN STRAIGHT FLIGHT | 240 | 62 | YES | 10000 | | DWN | 15 | FI | 12348 | OFF |
| 17 | | STALL | STALL IN STRAIGHT FLIGHT | 238 | 19.21 | NO | 10000 | | DWN | 40 | FI | 12700 | OFF |
| 18 | | STALL | STALL IN STRAIGHT FLIGHT | 238 | 77 | NO | 10000 | | DWN | 40 | FI | 11540 | OFF |

*Table 1: Continued*

| NUMBER | FAR | SUBJECT | DESCRIPTION OF TEST | REFERENCE FLIGHT AND CONFIGURATION | | | ALTITUDE (FL OR FT) | IAS (KTS) | GEAR | FLAP | POWER | WEIGHT (LB) | YD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | FLT | REC | PHARUS | | | | | | | |
| 19 | | STALL | SLOW TO BUFFET | 240 | 64 | YES | 10000 | | DWN | 40 | FI | 12308 | OFF |
| 20 | | STALL | STALL IN STRAIGHT FLIGHT | 240 | 66 | YES | 10000 | | DWN | 40 | FI | 12268 | OFF |
| 21 | 25.101 through 25.125 | SINGLE ENGINE CLIMB PERFORMANCE | PARTIAL CLIMBS: ONE ENGINE MAXIMUM TO AND ONE ENGINE FLIGHT IDLE | 243 | 8 | YES | 1000-3000 | V2 | UP | 0 | MTO/FI | 13000 | OFF |
| 22 | | SINGLE ENGINE CLIMB PERFORMANCE | PARTIAL CLIMBS: ONE ENGINE MAXIMUM TO AND ONE ENGINE FLIGHT IDLE | 243 | 10 | YES | 1000-3000 | V2 | UP | 0 | FI/MTO | 12950 | OFF |
| 23 | | SINGLE ENGINE CLIMB PERFORMANCE | PARTIAL CLIMBS: ONE ENGINE MAXIMUM TO AND ONE ENGINE FLIGHT IDLE | 243 | 12 | YES | 1000-3000 | V2 | UP | 0 | MTO/FI | 12900 | OFF |
| 24 | | SINGLE ENGINE CLIMB PERFORMANCE | PARTIAL CLIMBS: ONE ENGINE MAXIMUM TO AND ONE ENGINE FLIGHT IDLE | 243 | 14 | YES | 1000-3000 | V2 | UP | 0 | FI/MTO | 12860 | OFF |
| 25 | | SINGLE ENGINE CLIMB PERFORMANCE | PARTIAL CLIMBS: ONE ENGINE MAXIMUM TO AND ONE ENGINE FLIGHT IDLE | 242 | 103 | YES | 1000-3000 | V2 | UP | 15 | MTO/FI | 11750 | OFF |
| 26 | | SINGLE ENGINE CLIMB PERFORMANCE | PARTIAL CLIMBS: ONE ENGINE MAXIMUM TO AND ONE ENGINE FLIGHT IDLE | 242 | 105 | YES | 1000-3000 | V2 | UP | 15 | FI/MTO | 11700 | OFF |
| 27 | | SINGLE ENGINE CLIMB PERFORMANCE | PARTIAL CLIMBS: ONE ENGINE MAXIMUM TO AND ONE ENGINE FLIGHT IDLE | 243 | 16 | YES | 1000-3000 | V2 | UP | 15 | MTO/FI | 12813 | OFF |
| 28 | | SINGLE ENGINE CLIMB PERFORMANCE | PARTIAL CLIMBS: ONE ENGINE MAXIMUM TO AND ONE ENGINE FLIGHT IDLE | 243 | 18 | YES | 1000-3000 | V2 | UP | 15 | FI/MTO | 12770 | OFF |
| 29 | | SINGLE ENGINE CLIMB PERFORMANCE | PARTIAL CLIMBS: ONE ENGINE MAXIMUM TO AND ONE ENGINE FLIGHT IDLE | 243 | 20 | YES | 1000-3000 | V2+10 | UP | 0 | MTO/FI | 12739 | OFF |

*Table 1: Continued*

| NUMBER | FAR | SUBJECT | DESCRIPTION OF TEST | REFERENCE FUGHT AND CONFIGURATION | | | ALTITUDE (FL OR FT) | IAS (KTS) | GEAR | FLAP | POWER | WEIGHT (LB) | YD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | FLT | REC | PHARUS | | | | | | | |
| 30 | | SINGLE ENGINE CLIMB PERFORMANCE | PARTIAL CUMBS; ONE ENGINE MAXIMUM TO AND ONE ENGINE FLIGHT IDLE | 243 | 22 | YES | 1000-3000 | V2+10 | UP | 0 | FI/MTO | 12682 | OFF |
| 31 | | SINGLE ENGINE CLIMB PERFORMANCE | PARTIAL CLIMBS; ONE ENGINE MAXIMUM TO AND ONE ENGINE FLIGHT IDLE | 243 | 24 | YES | 1000-3000 | V2+10 | UP | 0 | MTO/FI | 12676 | OFF |
| 32 | | SINGLE ENGINE CLLMB PERFORMANCE | PARTIAL CUMBS; ONE ENGINE MAXIMUM TO AND ONE ENGINE FLIGHT IDLE | 243 | 26 | YES | 1000-3000 | V2+10 | UP | 0 | FI/MTO | 12633 | OFF |
| 33 | | SINGLE ENGINE CLIMB PERFORM ANCE | PARTIAL CUMBS; ONE ENGINE MAXIMUM TO AND ONE ENGINE FLIGHT IDLE | 242 | 107 | YES | 1000-3000 | V2+10 | UP | 15 | MTO/FI | 11650 | OFF |
| 34 | | SINGLE ENGINE CLIMB PERFORMANCE | PARTIAL CLIMBS; ONE ENGINE MAXIMUM TO AND ONE ENGINE FLIGHT IDLE | 242 | 109 | YES | 1000-3000 | V2+10 | UP | 15 | FI/MTO | 11600 | OFF |
| 35 | | SINGLE ENGINE CLIMB PERFORMANCE | PARTIAL CUMBS; ONE ENGINE MAXIMUM TO AND ONE ENGINE FLIGHT IDLE | 243 | 23 | YES | 1000-3000 | V2+10 | UP | 15 | MTO/FI | 12603 | OFF |
| 36 | | SINGLE ENGINE CLIMB PERFORMANCE | PARTIAL CUMBS; ONE ENGINE MAXIMUM TO AND ONE ENGINE FLIGHT IDLE | 243 | 30 | YES | 1000-3000 | V2+10 | UP | 15 | FI/MTO | 12550 | OFF |
| 37 | 25.145a | LONGITUDINAL CONTROL | ADEQUACY OF ELEVATOR CONTROL TO RECOVER FROM STALL | 240 | 26 | YES | 10000 | l,2-> 1.1 VS | DWN | 0 | MCO | 12768 | ON |
| 3S | 25.145a | LONGITUDINAL CONTROL | ADEQUACY OF ELEVATOR CONTROL TO RECOVER FROM STALL | 240 | 28 | YES | 10000 | l,2-> 1.1 VS | DWN | 0 | FI | 12758 | ON |
| 39 | 25.145a | LONGITUDINAL CONTROL | ADEQUACY OF ELEVATOR CONTROL TO RECOVER FROM STALL | 240 | 30 | YES | 10000 | l,2-> 1,1 VS | DWN | 40 | MCO | 12728 | ON |

*Table 1: Continued*

| NUMBER | FAR | SUBJECT | DESCRIPTION OF TEST | REFERENCE FUGHT AND CONFIGURATION | | | ALTITUDE (FL OR FT) | IAS (KTS) | GEAR | FLAP | POWER | WEIGHT (LB) | YD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | FLT | REC | PHARUS | | | | | | | |
| 40 | 25.145 a | LONGITUDINAL CONTROL | ADEQUACY OF ELEVATOR CONTROL TO RECOVER FROM STALL | 240 | 32 | YES | 10000 | 1,2-> 1.1VS | DWN | 40 | FI | 12708 | ON |
| 41 | 25.145a | LONGITUDINAL CONTROL | ADEQUACY OF ELEVATOR CONTROL TO RECOVER FROM STALL | 240 | 34 | YES | 10000 | 1,2-> 1.1VS | DWN | 0 | MCO | 12693 | ON |
| 42 | 25.145a | LONGITUDINAL CONTROL | ADEQUACY OF ELEVATOR CONTROL TO RECOVER FROM STALL | 240 | 36 | YES | 10000 | 1,2-> 1.1VS | DWN | 0 | FI | 12678 | ON |
| 43 | 25.145a | LONGITUDINAL CONTROL | ADEQUACY OF ELEVATOR CONTROL TO RECOVER FROM STALL | 240 | 38 | YES | 10000 | 1,2-> 1.1VS | DWN | 40 | MCO | 12658 | ON |
| 44 | 25.145a | LONGITUDINAL CONTROL | ADEQUACY OF ELEVATOR CONTROL TO RECOVER FROM STALL | 240 | 40 | YES | 10000 | 1,2-> 1.1VS | DWN | 40 | FI | 12618 | ON |
| 45 | 25.145 b1 | LONGITUDINAL CONTROL | SELCTING FLAPS TO 40° | 240 | 14 | YES | 10000 | 1.4 VS | DWN | 0->40 | FI | 12988 | ON |
| 46 | 25.145 b2 | LONGITUDINAL CONTROL | SELCTING FLAPS TO 0° | 240 | 16 | YES | 10000 | 1.4VS | DWN | 40->0 | FI | 12948 | ON |
| 47 | 25.145 b3 | LONGITUDINAL CONTROL | SELCTING FLAPS TO 0° | 240 | 18 | YES | 10000 | 1.4 VS | DWN | 40->0 | TOP | 12908 | ON |
| 4S | 25.145 b4 | LONGITUDLNAL CONTROL | APPLICATION OF POWER | 240 | 20 | YES | 10000 | 1.4 VS | DWN | 0 | FI-> TOP | 12898 | ON |
| 49 | 25.145 b5 | LONGITUDINAL CONTROL | APPLICATION OF POWER | 240 | 22 | YES | 10000 | 1.4 VS | DWN | 40 | FI-> TOP | 12868 | ON |
| 50 | 25.145 b6 | LONGITUDINAL CONTROL | DECELLERATION AND ACCELERATION | 240 | 24 | YES | 10000 | 1.4 -> 1.1-> 1.7 VS | DWN | 40 | FI | 12843 | ON |

*Table 1: Continued*

| NUMBER | FAR | SUBJECT | DESCRIPTION OF TEST | REFERENCE FLIGHT AND CONFIGURATION | | | ALTITUDE (FL OR FT) | IAS (KTS) | GEAR | FLAP | POWER | WEIGHT (LB) | YD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | FLT | REC | PHARUS | | | | | | | |
| 51 | 25.145c | LONGITUDINAL CONTROL | SIMULTANEOUS APPLICATION OF POWER AND SELECTING FLAPS UP | 240 | 68 | YES | 6000 | 1.2 VS | DWN | 40 >0 | PLF-TOP | 12218 | ON |
| 52 | 25.147a | DIRECTIONAL CONTROL | WINGS LEVEL HEADING CHANGES OF +/- 15 DEGREES BY ABRUPT RUDDER INPUTS. CHECK YAW DEMPER BEHAVIOUR. | 241 | 55 | YES | 6000 | I.4Vs | UP | 15 | PLF/F1 | 11925 | ON |
| 53 | 25.147a | DIRECTIONAL CONTROL | WINGS LEVEL HEADING CHANGES OF +/- 15 DEGREES BY ABRUPT RUDDER INPUTS. CHECK YAW DEMPER BEHAVIOUR. | 241 | 53 | YES | 6000 | l,4Vs | UP | 15 | PLF/F1 | 11940 | OFF |
| 54 | 25.147a | DIRECTIONAL CONTROL | WINGS LEVEL HEADING CHANGES OF +/- 15 DEGREES BY ABRUPT RUDDER INPUTS. CHECK YAW DEMPER BEHAVIOUR. | 241 | 57 | YES | 6000 | 1.4 Vs | UP | 15 | FI/PLF | 11910 | ON |
| 55 | 25.147a | DIRECTIONAL CONTROL | WINGS LEVEL HEADING CHANGES OF +/- 15 DEGREES BY ABRUPT RUDDER INPUTS. CHECK YAW DEMPER BEHAVIOUR. | 241 | 59 | YES | 6000 | 1,4 Vs | UP | 15 | FI/PLF | 11900 | OFF |
| 56 | 25.143 | DIRECTIONAL CONTROL | CONTROL SUDDEN LEFT ENGINE FAILURE | 240 | 70 | YES | 6000 | 120 | UP | 0 | MTO/ MTO | 12178 | ON |
| 57 | 25.143 | DIRECTIONAL CONTROL | CONTROL SUDDEN RIGHT ENGINE FAILURE | 240 | 72 | YES | 6000 | 120 | UP | 0 | MTO/ MTO | 12158 | ON |

*Table 1: Continued*

| NUMBER | FAR | SUBJECT | DESCRIPTION OF TEST | REFERENCE FUGHT AND CONFIGURATION | | | ALTITUDE (FL OR FT) | IAS (KTS) | GEAR | FLAP | POWER | WEIGHT (LB) | YD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | FLT | REC | PHARUS | | | | | | | |
| 58 | 25.143 | DIRECTIONAL CONTROL | CONTROL SUDDEN LEFT ENGINE FAILURE | 240 | 74 | YES | 6000 | 110 | DWN | 40 | MTO/ MTO | 12118 | ON |
| 59 | 25.143 | DIRECTIONAL CONTROL | CONTROL SUDDEN RIGHT ENGINE FAILURE | 240 | 76 | YES | 6000 | 110 | DWN | 40 | MTO/ MTO | 12088 | ON |
| 60 | 25.147c | LATERAL CONTROL | TURNS WITH 20 DEGREES BANK. WITH AND AGAINST THE INOPERATIVE ENGINE IN STEADY CLIMB. | 241 | 7 | YES | 6000 | 1.4 Vs | UP | 0 | MCP/FI | 12950 | OFF |
| 61 | 25.147c | LATERAL CONTROL | TURNS WITH 20 DEGREES BANK. WITH AND AGAINST THE INOPERATIVE ENGINE LN STEADY CLIMB. | 241 | 9 | YES | 6000 | 1.4 Vs | UP | 0 | FI/MCP | 12925 | OFF |
| 62 | 25.147c | LATERAL CONTROL | TURNS WITH 20 DEGREES BANK. WITH AND AGAINST THE INOPERATIVE ENGINE IN STEADY CLIMB. | 241 | 11 | YES | 6000 | 1,4 Vs | DWN | 0 | MCP/FI | 12880 | OFF |
| 63 | 25.147c | LATERAL CONTROL | TURNS WITH 20 DEGREES BANK. WITH AND AGAINST THE INOPERATIVE ENGINE IN STEADY CLIMB. | 241 | 13 | YES | 6000 | 1.4Vs | DWN | 0 | FI/MCP | 12850 | OFF |
| 64 | 25.149 | VMCA | COMPARISON OF DEFLECTIONS BETWEEN FLIGHTS WITH AND WITHOUT PHARUS STORE AND WITH SAME AIRSPEED AND ENGINE POWER. | 238 | 59 | NO | 6000 | 1.2 Vs | UP | 0 | MTO/FI | 11700 | OFF |
| 65 | 25.149 | VMCA | COMPARISON OF DEFLECTIONS BETWEEN FLIGHTS WITH AND WITHOUT PHARUS STORE AND WITH SAME AIRSPEED AND ENGINE POWER. | 241 | 61 | YES | 6000 | 1.2 Vs | UP | 0 | MTO/FI | 11850 | OFF |

*Table 1: Continued*

| NUMBER | FAR | SUBJECT | DESCRIPTION OF TEST | REFERENCE FLIGHT AND CONFIGURATION | | | ALTITUDE (FL OR FT) | US (KTS) | GEAR | FLAP | POWER | WEIGHT (LB) | YD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | FLT | REC | PHARUS | | | | | | | |
| 66 | 25.149 | VMCA | COMPARISON OF DEFLECTIONS BETWEEN FLIGHTS WITH AND WITHOUT PHARUS STORE AND WITH SAME AIRSPEED AND ENGINE POWER. | 238 | 61 | NO | 6000 | 1.2Vs | UP | 0 | FI/MTO | 11700 | OFF |
| 67 | 25.149 | VMCA | COMPARISON OF DEFLECTIONS BETWEEN FLIGHTS WITH AND WITHOUT PHARUS STORE AND WITH SAME AIRSPEED AND ENGINE POWER. | 241 | 65 | YES | 6000 | 1.2Vs | UP | 0 | FI/MTO | 11790 | OFF |
| 68 | 25.149 | VMCA | COMPARISON OF DEFLECTIONS BETWEEN FLIGHTS WITH AND WITHOUT PHARUS STORE AND WITH SAME AIRSPEED AND ENGINE POWER. | 238 | 63 | NO | 6000 | 1.1Vs | UP | 0 | MTO/FI | 11700 | OFF |
| 69 | 25.149 | VMCA | COMPARISON OF DEFLECTIONS BETWEEN FLIGHTS WITH AND WITHOUT PHARUS STORE AND WITH SAME AIRSPEED AND ENGINE POWER. | 241 | 63 | YES | 6000 | 1.1 Vs | UP | 0 | MTO/FI | 11820 | OFF |
| 70 | 25.149 | VMCA | COMPARISON OF DEFLECTIONS BETWEEN FUGHTS WITH AND WITHOUT PHARUS STORE AND WITH SAME AIRSPEED AND ENGINE POWER. | 238 | 65 | NO | 6000 | 1.1Vs | UP | 0 | FI/MTO | 11700 | OFF |

*Table 1: Continued*

| NUMBER | FAR | SUBJECT | DESCRIPTION OP TEST | REFERENCE FLIGHT AND CONFIGURATION | | | ALTITUDE (FL OR FT) | IAS (KTS) | GEAR | FLAP | POWER | WEIGHT (LB) | YD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | FLT | REC | PHARUS | | | | | | | |
| 71 | 25.149 | VMCA | COMPARISON OF DEFLECTIONS BETWEEN FLIGHTS WITH AND WITHOUT PHARUS STORE AND WITH SAME AIRSPEED AND ENGINE POWER. | 241 | 67 | YES | 6000 | 1.1Vs | UP | 0 | FI/MTO | 11780 | OFF |
| 72 | 25.149 incl f | VMCA/L | COMPARISON OF DEFLECTIONS BETWEEN FLIGHTS WITH AND WITHOUT PHARUS STORE AND WITH SAME AIRSPEED AND ENGINE POWER: LANDING FLAPS; GEAR UP IS OPTION. | 241 | 69 | YES | 6000 | 1.1Vs | UP | 40 | MTO/FI | 11750 | OFF |
| 73 | 25.149 incl f | VMCA/L | COMPARISON OF DEFLECTIONS BETWEEN FLIGHTS WITH AND WITHOUT PHARUS STORE AND WITH SAME AIRSPEED AND ENGINE POWER; LANDING FLAPS: GEAR UP IS OPTION. | 241 | 71 | YES | 6000 | 1.1Vs | UP | 40 | FI/MTO | 11720 | OFF |
| 74 | 25.161 | TRIMS | IN PHARUS CONFIGURATION NO DIFFICULTY TO TRIM THE AIRCRAFT HANDS-OFF IN OPERATING ENVELOPE. | | | YES | | | | | | | |
| 75 | 25.175 | STATIC LONGITUDINAL STABILITY | CHECK OF POSITIVE LONGITUDINAL CONTROL FORCE STABILITY IN TURNS WITH UP TO 45° OF BANK | 240 | 12 | YES | 10000 | 160 | UP | 0 | PLF | 13000 | ON |

*Table 1: Continued*

| NUMBER | FAR | SUBJECT | DESCRIPTION OF TEST | REFERENCE FUGHT AND CONFIGURATION | | | ALTITUDE (FL OR FI") | IAS (KTS) | GEAR | FLAP | POWER | WEIGHT (LB) | YD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | FLT | REC | PHARUS | | | | | | | |
| 76 | 25.175b | STATIC LONGITUDINAL STABILITY | STARTING AT A TRIM SPEED OF 180 KTS SPEED WAS REDUCED AND STABILIZED AT 170 AND 160 KTS. STICK-FREE RETURN TO TRIM SPEED CONDITIONS. | 241 | 15 | YES | 6000 | 180 | UP | 0 | PLF | 12750 | ON |
| 77 | 25.175b | STATIC LONGITUDLNAL STABILITY | STARTING AT A TRIM SPEED OF 180 KTS SPEED WAS INCREASED AND STABILIZED AT 190 AND 200 KTS. STICK-FREE RETURN TO TRIM SPEED CONDITIONS. | 241 | 17 | YES | 6000 | 180 | UP | 0 | PLF | 12660 | ON |
| 78 | 25.177 | STATIC DIRECTIONAL STABILITY. | SLOW RUDDER INPUT AND MAINTAIN WINGS LEVEL WITH AILERON; CHECK FOR RUDDER LOCK. | 242 | 21 | YES | 30000 | 235 | UP | 0 | PLF | 13150 | OFF |
| 79 | 25.177 | STATIC LATERAL STABILITY. | SLOW AILERON INPUT AND MAINTAIN HEADING WITH RUDDER. | 242 | 23 | YES | 30000 | 235 | UP | 0 | PLF | 13130 | OFF |
| 80 | 25.177 | STATIC DIRECTIONAL STABILITY. | SLOW RUDDER INPUT AND MAINTAIN WINGS LEVEL WITH AILERON; CHECK FOR RUDDER LOCK. | 242 | 47; 49 | YES | 6000 | 1.2 Vs 112 | UP | 0 | PLF | 12830 | OFF |
| 81 | 25.177 | STATIC LATERAL STABILITY. | SLOW AILERON INPUT AND MAINTAIN HEADING WITH RUDDER. | 242 | 53; 55 | YES | 6000 | 1.2 Vs 112 | UP | 0 | PLF | 12800 | OFF |
| 82 | 25.177 | STATIC DIRECTIONAL STABILITY. | SLOW RUDDER INPUT-AND MAINTAIN WINGS LEVEL WITH AILERON; CHECK FOR RUDDER LOCK. | 242 | 57; 59 | YES | 6000 | 1.3 Vs 110 | DWN | 40 | PLF | 12760 | OFF |

*Table 1: Continued*

| NUMBER | FAR | SUBJECT | DESCRIPTION OF TEST | REFERENCE FLIGHT AND CONFIGURATION | | | ALTITUDE (FL OR FT) | IAS (KTS) | GEAR | FLAP | POWER | WEIGHT (LB) | YD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | FLT | REC | PHARUS | | | | | | | |
| 83 | 25.177 | STATIC LATERAL STABILITY. | SLOW AILERON INPUT AND MAINTAIN HEADING WITH RUDDER. | 242 | 61; 63 | YES | 6000 | 1.3 Vs 110 | DWN | 40 | PLF | 12730 | OFF |
| 84 | 25.177 | STATIC DIRECTIONAL STABILITY. | SLOW RUDDER INPUT AND MAINTAIN WINGS LEVEL WITH AILERON; CHECK FOR RUDDER LOCK. | 242 | 65 | YES | 6000 | 176 | DWN | 40 | PLF | | OFF |
| 85 | 25.177 | STATIC LATERAL STABILITY. | SLOW AILERON INPUT AND MAINTAIN HEADING WITH RUDDER. | 242 | 67; 69 | YES | 6000 | 176 | DWN | 40 | PLF | | OFF |
| 86 | 25.177 | STATIC DIRECTIONAL STABILITY. | SLOW RUDDER INPUT AND MAINTAIN WINGS LEVEL WITH AILERON; CHECK FOR RUDDER LOCK. | 242 | 71 | YES | 6000 | 235 | UP | 0 | PLF | 12530 | OFF |
| 87 | 25.177 | STATIC LATERAL STABILITY. | SLOW AILERON INPUT AND MAINTAIN HEADING WITH RUDDER. | 242 | 75; 77; 79 | YES | 6000 | 235 | UP | 0 | PLF | 12500 | OFF |
| 88 | 25.181a | DYN. LONG. STAB. | SHORT PULSED DOUBLETS TO CHECK THE SHORT PERIOD CHARACTERISTICS. | 241 | 19 | YES | 10000 | 140 | UP | 0 | PLF | 12550 | ON |
| 89 | 25.181a | DYN. LONG. STAB. | SHORT PULSED DOUBLETS TO CHECK THE SHORT PERIOD CHARACTERISTICS. | 241 | 21 | YES | 10000 | 200 | UP | 0 | PLF | 12500 | ON |
| 90 | 25.181a | DYN. LONG. STAB. | SHORT PULSED DOUBLETS TO CHECK THE SHORT PERIOD CHARACTERISTICS. | 241 | 23 | YES | 10000 | 180 | UP | 15 | PLF | 12470 | ON |
| 91 | 25.181a | DYN. LONG. STAB. | SHORT PULSED DOUBLETS TO CHECK THE SHORT PERIOD CHARACTERISTICS. | 241 | 25 | YES | 10000 | 130 | UP | 15 | PLF | 12450 | ON |

*Table 1: Continued*

| NUMBER | FAR | SUBJECT | DESCRIPTION OF TEST | REFERENCE FUGIIT AND CONFIGURATION | | | ALTITUDE (FL OR FD | IAS (KTS) | GEAR | FLAP | POWER | WEIGHT (LB) | YD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | FLT | REC | PHARUS | | | | | | | |
| 92 | 25.181a | DYN. LONG. STAB. | SHORT PULSED DOUBLETS TO CHECK THE SHORT PERIOD CHARACTERISTICS. | 241 | 27 | YES | 10000 | 120 | UP | 40 | PLF | 12430 | ON |
| 93 | 25.181a | DYN. LONG. STAB. | SHORT PULSED DOUBLETS TO CHECK THE SHORT PERIOD CHARACTERISTICS. | 241 | 29 | YES | 10000 | 160 | UP | 40 | PLF | 12400 | ON |
| 94 | 25.181b | LATERAL DIR. DYN. STABILITY. | RUDDER DOUBLETS TO EXITE DUTCH ROLL | 242 | 9; 13 | YES | 30000 | 1.2Vs 115 | UP | 0 | PLF | 13320 | OFF /ON |
| 95 | 25.181b | LATERAL DIR. DYN. STABILITY. | RUDDER DOUBLETS TO EXITE DUTCH ROLL | 242 | 17; 19 | YES | 30000 | 235 | UP | 0 | PLF | 13220 | OFF /ON |
| 96 | 25.181b | LATERAL DIR. DYN. STABILITY. | RUDDER DOUBLETS TO EXITE DUTCH ROLL | 242 | 33; 35 | YES | 10000 | 140 | UP | 0 | PLF | 13030 | OFF /ON |
| 97 | 25.181b | LATERAL DIR. DYN. STABILITY. | RUDDER DOUBLETS TO EXITE DUTCH ROLL | 242 | 37 | YES | 10000 | 130 | UP | 15 | PLF | 13020 | OFF /ON |
| 98 | 25.181b | LATERAL DIR. DYN. STABILITY. | RUDDER DOUBLETS TO EXITE DUTCH ROLL | 242 | 39 | YES | 10000 | 120 | UP | 40 | PLF | 13000 | OFF /ON |
| 99 | 25.181b | LATERAL DIR. DYN. STABILITY. | RUDDER DOUBLETS TO EXITE DUTCH ROLL | 242 | 41 | YES | 10000 | 200 | UP | 0 | PLF | 12950 | OFF /ON |
| 100 | 25.181b | LATERAL DIR. DYN. STABILITY. | RUDDER DOUBLETS TO EXITE DUTCH ROLL | 242 | 43 | YES | 10000 | 180 | UP | 15 | PLF | 12900 | OFF /ON |
| 101 | 25.181b | LATERAL DIR. DYN. STABILITY. | RUDDER DOUBLETS TO EXITE DUTCH ROLL | 242 | 45 | YES | 10000 | 160 | UP | 40 | PLF | 12880 | OFF /ON |
| 102 | | HIGH SPEED | BUFFET AND UNUSUAL NOISE | 241 | 31 | YES | 10000 | 210 | UP | 0 | PLF | 12330 | ON |
| 103 | | HIGH SPEED | BUFFET AND UNUSUAL NOISE | 241 | 33 | YES | 10000 | 220 | UP | 0 | PLF | 12310 | ON |

*Table 1: Continued*

| NUMBER | FAR | SUBJECT | DESCRIPTION OF TEST | REFERENCE FUGHT AND CONFIGURATION | | | ALTITUDE (FL OR FT) | IAS (KTS) | GEAR | FLAP | POWER | WEIGHT (LB) | YD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | FLT | REC | PHARUS | | | | | | | |
| 104 | | HIGH SPEED | BUFFET AND UNUSUAL NOISE | 241 | 35 | YES | 10000 | 230 | UP | 0 | PLF | 12290 | ON |
| 105 | | HIGH SPEED | BUFFET AND UNUSUAL NOISE | 241 | 37 | YES | 10000 | 240 | UP | 0 | PLF | 12260 | ON |
| 106 | | HIGH SPEED | BUFFET AND UNUSUAL NOISE | 241 | 39 | YES | 10000 | 250 | UP | 0 | PLF | 12200 | ON |
| 107 | 25.253 | HIGH SPEED | AIRCRAFT TRIMMED AT 200 KTS; PITCH 6° NOSE DOWN; 15° BANK; MAINTAIN ATTITUDE FOR 3 SECONDS. RECOVER AND CHECK AIRSPEED. | 241 | 41 | YES | 10000 | 200 TO 220 | UP | 0 | PLF | 12125 | ON |
| 108 | 25.253 | HIGH SPEED | AIRCRAFT TRIMMED AT 210 KTS; PITCH 6° NOSE DOWN; 15° BANK; MAINTAIN ATTITUDE FOR 3 SECONDS. RECOVER AND CHECK AIRSPEED. | 241 | 43 | YES | 10000 | 210 TO 228 | UP | 0 | PLF | 12090 | ON8 |
| 109 | 25.253 | HIGH SPEED | AIRCRAFT TRIMMED AT 220 KTS; PITCH 6° NOSE DOWN; 15° BANK; MAINTAIN ATTITUDE FOR 3 SECONDS. RECOVER AND C1IECK AIRSPEED. | 241 | 45 | YES | 10000 | 220 TO 232 | UP | 0 | PLF | 12060 | ON |
| 110 | 25.253 | HIGH SPEED | AIRCRAFT TRIMMED AT 230 KTS; PITCH 6° NOSE DOWN; 15° BANK; MAINTAIN ATTITUDE FOR 3 SECONDS. RECOVER AND CHECK AIRSPEED. | 241 | 47 | YES | 10000 | 230 TO 239 | UP | 0 | PLF | 12030 | ON |

*Table 1: Continued*

| NUMBER | FAR | SUBJECT | DESCRIPTION OF TEST | REFERENCE FLIGHT AND CONFIGURATION | | | ALTITUDE (FL OR FT) | IAS (KTS) | GEAR | FLAP | POWER | WEIGHT (LB) | YD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | FLT | REC | PHARUS | | | | | | | |
| 111 | 25.253 | HIGH SPEED | AIRCRAFT TRIMMED AT 230 KTS; PITCH 6° NOSE DOWN; 15° BANK; MAINTAIN ATTITUDE FOR 3 SECONDS. RECOVER AND CHECK AIRSPEED. | 241 | 49 | YES | 10000 | 240 TO 252 | UP | 0 | PLF | 12000 | ON |
| 112 | 25.251 | VIB. BUFF. | HIGH ALTITUDE 45° BANK TURN AT MAXIMUM OPERATING SPEED WITH PHARUS (LEFT) | 242 | 5 | YES | 30000 | 235 | UP | 0 | PLF | 13400 | ON |
| 113 | 25.251 | VIB. DUFF. | HIGH ALTITUDE 45° BANK TURN AT MAXLMUM OPERATING SPEED WITH PHARUS (RIGHT) | 242 | 7 | YES | 30000 | 235 | UP | 0 | PLF | 13380 | ON |

*Table 2: Ground- and flight tests*

| FLIGHT NR. | DATE | PHARUS | ZERO FUEL | | | TAKE-OFF FUEL | WEIGHT & BALANCE | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | WEIGHT (LBS) | MOM/l00 (IN.LBS) | Xcg (INCH) | | TOW (LBS) | MOM/100 (IN.LBS) | Xcg (INCH) |
| GROUND RUN | 95/07/14 | YES | 9750 | | | 1300 | 11050 | | |
| 238 | 95/07/07 | NO | 9677 | 27117 | 280.2 | 4000 | 13677 | 38535.2 | 281.7 |
| 239 | 95/07/20 | YES | 10008 | 28004.5 | 279.8 | 2000 | 12008 | 33714.4 | 280.8 |
| 240 | 95/08/09 | YES | 10008 | 28004.5 | 279.8 | 3500 | 13508 | 37987.9 | 281.4 |
| 241 | 95/08/15 | YES | 10008 | 28004.5 | 279.8 | 3400 | 13408 | 37701.4 | 281.2 |
| 242 | 95/08/24 | YES | 10008 | 28004.5 | 279.8 | 4200 | 14208 | 39997.8 | 281.5 |
| 243 | 95/09/22 | YES | 10334 | 28996.4 | 280.6 | 3950 | 14284 | 40276.4 | 282.0 |

*Table 3: Comparison of left and right airspeed indicators and altimeters*

| FLIGHT | RECORD | ALTITUDE (FT) | AIRCRAFT CONFIGURATION | | ANGLE OF YAW | OBSERVED AIRSPEED INDICATIONS (KTS) | | OBSERVED ALTIMETER INDICATIONS (FT) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | GEAR | FLAP | | LEFT | RIGHT | LEFT | RIGHT |
| 239 | | 5000 | UP | 0° | 0 | 159 | 159 | 4990 | 4990 |
| 239 | | 5000 | UP | 0° | RE | 156 | 154 | 5010 | 4950 |
| 239 | | 5000 | UP | 0° | LE | 157 | 157 | 5010 | 5060 |
| 239 | 59 | 5000 | DWN | 40° | 0 | 129 | 128 | 5120 | 5130 |
| 239 | 59 | 5000 | DWN | 40° | RE | 130 | 129 | 5160 | 5140 |
| 239 | 59 | 5000 | DWN | 40° | LE | 127 | 127 | 5140 | 5180 |
| 239 | 61 | 5000 | UP | 15° | 0 | 127 | 125 | 4980 | 4980 |
| 239 | 61 | 5000 | UP | 15° | RE | 126 | 121 | 4980 | 4940 |
| 239 | 61 | 5000 | UP | 15° | LE | 124 | 124 | 4970 | 5020 |
| 239 | 79 | 5000 | DWN | 40° | 0 | 115 | 114 | 5040 | 5040 |
| 239 | 79 | 5000 | DWN | 40° | RE | 116 | 113 | 5140 | 5100 |
| 239 | 79 | 5000 | DWN | 40° | LE | 112 | 113 | 4990 | 5020 |
| 239 | 81 | 5000 | UP | 15° | 0 | 115 | 115 | 5050 | 5030 |
| 239 | 81 | 5000 | UP | 15° | RE | 115 | 112 | 5020 | 4970 |
| 239 | 81 | 5000 | UP | 15° | LE | 112 | 114 | 4920 | 4980 |

*Table 4: Stall speeds (IAS) with and without PHARUS, with and without flow pattern visualization and values from the Airplane Flight Manual*

| CONFIGURATION | NO PHARUS | | | | NO PHARUS | | | | PHARUS WITH FLOW VISUALIZATION | | | | PHARUS NO FLOW VISUALIZATION | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WEIGHT (LBS) | IAS AFM (KTS) | IAS BUFF (KTS) | IAS STALL (KTS) | WEIGHT (LBS) | IAS AFM (KTS) | IAS BUFF (KTS) | IAS STALL (KTS) | WEIGHT (LBS) | IAS AFM (KTS) | IAS BUFF (KTS) | IAS STALL (KTS) | WEIGHT (LBS) | IAS AFM (KTS) | IAS BUFF (KTS) | IAS STALL (KTS) |
| GEAR UP FLAPS 0 | 12990 | 94 | 104 | 100 | 11590 | 89 | 98 | 94 | 12543 | 93 | 104 | 99 | 13100 | 94 | 104 | 98 |
| GEAR UP FLAPS 15 | 12930 | 91 | 98 | 95 | 11570 | 85 | 91 | 85 | 12488 | 89 | 98 | 94 | | | | |
| GEAR DWN FLAPS 0 | 12880 | 94 | 105 | 101 | 11550 | 89 | 97 | 93 | 12438 | 93 | 106 | 102 | | | | |
| GEAR DWN FLAPS 15 | 12820 | 90 | 100 | 95 | 11540 | 85 | 94 | 86 | 12363 | 89 | 98 | 94 | 13060 | 91 | 100 | 94 |
| GEAR DWN FLAPS 40 | 12700 | 84 | | 88 | 11540 | 80 | 86 | 82 | 12308 | 83 | 90 | 87 | | | | |

*Table 5: Yawing moment coefficients $C_n$ due to asymmetric power and rudder deflection*

| FLIGHT | RECORD | WEIGHT (LBS) | AIRCRAFT CONFIGURATION | | | ALTITUDE (FT) | IAS (KTS) | TAS (KTS) | AILERON DEFLECTION $\delta a$ | RUDDER DEFLECTION $\delta r$ | THRUST ENG 1 (LBS) *) | THRUST ENG 2 (LBS) *) | $C_n$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | GEAR | FLAPS | PHARUS | | | | | | | | |
| 238 | 59 | 11700 | UP | 0 | NO | 6300 | 114.5 | 128 | -0.5 | 9.65 | 1444 | 138 | 0.057 |
| 238 | 61 | 11700 | UP | 0 | NO | 5700 | 112.5 | 125 | 1.5 | -9.95 | 143 | 1492 | -0.061 |
| 238 | 63 | 11700 | UP | 0 | NO | 6500 | 105.5 | 118 | 1.25 | -11.75 | 144 | 1467 | -0.068 |
| 238 | 65 | 11700 | UP | 0 | NO | 5800 | 106.5 | 118 | 0 | 14.25 | 1477 | 151 | 0.067 |
| 241 | 61 | 11850 | UP | 0 | YES | 6100 | 109 | 121 | -0.85 | 14.75 | 1649 | 67 | 0.077 |
| 241 | 65 | 11790 | UP | 0 | YES | 6400 | 109 | 121 | 1.7 | -12.5 | 71 | 1669 | -0.078 |
| 241 | 63 | 11820 | UP | 0 | YES | 6800 | 99 | 111 | -1 | 15.75 | 1621 | 78 | 0.091 |
| 241 | 67 | 11780 | UP | 0 | YES | 6900 | 99 | 112 | 1.5 | -15.5 | 79 | 1644 | -0.091 |
| 241 | 69 | 11750 | UP | 40 | YES | 6300 | 90 | 101 | -0.5 | 17.5 | 1687 | 76 | 0.113 |
| 241 | 71 | 11720 | UP | 40 | YES | 6450 | 89 | 100 | 2 | -21.25 | 78 | 1689 | -0.116 |

*) Thrust values do not account for installation losses, etc.

*Table 6: Partial climb results with PHARUS, corrected for flight idle thrust and wind milling drag, and gradients estimated from the Airplane Flight Manual*

| FLIGHT | RECORD | WEIGHT (LBS) | FLAPS | V2/V2+10 | IAS (KTS) | ALT (FT) | ENGINE | | ROC-UNCORR. (FT/M) | TAS (KTS) | GRADIENT UNCORR. (%) | THRUST-FI (LBS) | DRAG WIND MILL (LBS) | GRADIENT CORR. (%) | GRADIENT (%) *) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | LEFT | RIGHT | | | | | | | |
| 243 | 8 | 13000 | 0 | V2 | 119 | 1700 | MTO | FI | 1084 | 124 | 8.6 | 72 | 211 | 6.4 | 7.4 |
| 243 | 10 | 12950 | 0 | V2 | 119 | 2000 | FI | MTO | 1148 | 124 | 9.1 | 71 | 211 | 6.9 | 7.4 |
| 243 | 12 | 12900 | 0 | V2 | 118 | 1850 | MTO | FI | ! 055 | 120 | 8.7 | 74 | 198 | 6.6 | 7.5 |
| 243 | 14 | 12860 | 0 | V2 | 118 | 1400 | FI | MTO | 1087 | 121 | 8.9 | 72 | 201 | 6.8 | 7.6 |
| 242 | 103 | 11750 | 15 | V2 | 108 | 2700 | MTO | FI | 970 | 113 | 8.5 | 89 | 175 | 6.3 | 7.3 |
| 242 | 105 | 11700 | 15 | V2 | 108 | 3000 | FI | MTO | 1023 | 115 | 8.8 | 73 | 182 | 6.6 | 7.2 |
| 243 | 16 | 12813 | 15 | V2 | 113 | 1750 | MTO | FI | 912 | 114 | 7.9 | 77 | 175 | 5.9 | 6.8 |
| 243 | 18 | 12770 | 15 | V2 | 112 | 1400 | FI | MTO | 839 | 115 | 7.2 | 76 | 182 | 5.2 | 6.8 |
| 243 | 20 | 12739 | 0 | V2+10 | 127 | 1400 | MTO | FI | 1180 | 129 | 9.0 | 68 | 228 | 6.7 | 7.8 |
| 243 | 22 | 12682 | 0 | V2+10 | 127 | 1400 | FI | MTO | 1067 | 129 | 8.2 | 71 | 228 | 5.9 | 7.8 |
| 243 | 24 | 12676 | 0 | V2+10 | 127 | 1400 | MTO | FI | 1122 | 127 | 8.7 | 73 | 221 | 6.4 | 7.8 |
| 243 | 26 | 12633 | 0 | V2+10 | 127 | 1350 | FI | MTO | 1209 | 129 | 9.2 | 67 | 228 | 6.9 | 7.8 |
| 242 | 107 | 11650 | 15 | V2+10 | 118 | 3000 | MTO | FI | 1052 | 122 | 8.5 | 69 | 204 | 6.2 | 7.3 |
| 242 | 109 | 11600 | 15 | V2+10 | 118 | 2800 | FI | MTO | 1135 | 124 | 9.0 | 68 | 211 | 6.6 | 7.4 |
| 243 | 28 | 12603 | 15 | V2+10 | 122 | 1400 | MTO | FI | 948 | 122 | 7.8 | 78 | 204 | 5.6 | 6.9 |
| 243 | 30 | 12550 | 15 | V2+10 | 122 | 1300 | FI | MTO | 958 | 124 | 7.6 | 73 | 211 | 5.3 | 7.1 |

*) This column includes a subtracted factor of 0.8%.

*Table 7: Measured rudder deflections for steady sideslip with wings level.*

| FLIGHT | RECORD | ALTITUDE (FT) | IAS (KTS) | 1st MEASUREMENT | | 2nd MEASUREMENT | | 3rd MEASUREMENT | | 4th MEASUREMENT | | COMMENT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | δr(°) | yaw (°) | δr(°) | yaw (°) | δr(°) | yaw (°) | δr(°) | yaw (°) | |
| 242 | 21 | 29000 | 235 | -7 | -3 | -10 | -4 | +8 | +4 | +8 | +7 | POSSITIVE STABILITY |
| 242 | 47;49 | 6100 | 112 | -15 | -10 | -18 | -13 | + 12 | +8 | + 11 | +9 | POSSITIVE STABILITY |
| 242 | 57;59 | 6100 | 111 | -12 | -9 | -18 | -12 | +9 | +9 | + 12 | + 11 | POSSITIVE STABILITY |
| 242 | 65 | 6050 | 167 | -8 | -6 | +9 | +8 | | | | | POSSITIVE STABILITY |
| 242 | 71 | 6100 | 236 | -7 | -4 | +7 | +4 | | | | | POSSITIVE STABILITY |

*Table 8: Dutch roll period and number of oscillations to stabilize*

| FLIGHT | RECORD | ALTITUDE (FT) | IAS (KTS) | FLAPS | YAW DAMPER | PERIOD (SEC) | NUMBER OF PERIODS TO STABILIZE |
|---|---|---|---|---|---|---|---|
| 242 | 9 | 30000 | 125 | 0 | OFF | 4.5 | 5 |
| 242 | 13 | 30200 | 120 | 0 | ON | 4.3 | 2 |
| 242 | 17 | 29000 | 235 | 0 | OFF | 4.65 | 9 |
| 242 | 19 | 28300 | 236 | 0 | ON | 3.5 | 2 |
| 242 | 33 | 10100 | 139 | 0 | OFF | 3.68 | 4 |
| 242 | 35 | 10000 | 140 | 0 | ON | 4.4 | 1 |
| 242 | 37 | 10300 | 130 | 15 | OFF | 4.2 | 4 |
| 242 | 39 | 10200 | 117 | 40 | OFF | 4.4 | 3 |
| 242 | 41 | 10100 | 200 | 0 | OFF | 2.7 | 5 |
| 242 | 43 | 10200 | 176 | 15 | OFF | 2.9 | 5 |
| 242 | 45 | 10200 | 158 | 40 | OFF | 3.1 | 5 |