U.S. Department
of Transportation

**Research and
Special Programs
Administration**

John A. Volpe
National Transportation
Systems Center

Kendall Square
Cambridge, Massachusetts 02142

August 29, 2000

Ted Farwell
Cessna Aircraft Company
7751 East Pawnee
Wichita, KS 67207

Re: Cessna 172R data for the Integrated Noise Model

Dear Mr. Farwell,

During the period 13-14 October 1999, personnel from the Cessna Aircraft Company (Cessna) and the Volpe National Transportation Systems Center (Volpe Center) conducted a joint field measurement study at Cessna's Wichita test facility. The study was conducted with the goal of determining reference noise and performance data for the Cessna 172R, 206H, and T206H aircraft. These reference data are slated for inclusion in a future release of the Federal Aviation Administration's (FAA) Integrated Noise Model (INM). This letter report describes the methods used to generate INM performance data for the Cessna 172R aircraft. At your convenience, please review these data. If you believe any of these data are in error, please contact me so I can correct the data prior to inclusion in the next release of the INM. Please note that the FAA plans to use the same methods to calculate the INM performance data for the Cessna 206H and T206H aircraft.

INM performance data is divided into thrust parameters and aerodynamic parameters. The first section of this letter report discusses the Cessna 172R thrust parameters and their sources. The next section discusses the Cessna 172R aerodynamic parameters and their sources. The letter report concludes with a discussion of how these parameters are used in the INM to model takeoff and landing performance of the Cessna 172R.

This memo does not address two aspects of aircraft performance due to limited available data. The first aspect is the impact of weight on aircraft performance. All the derived data contained in this letter report assume an aircraft operating at a maximum gross weight of 2450 lb. However, the INM database generally includes aircraft performance coefficients for more than one weight. The second aspect is the impact of altitude on aircraft performance. Other than a two-step approximation of the engine performance as a function of altitude, and an averaging of the cruise drag over lift ratio (both discussed below), no altitude-dependant variation of aircraft performance is assumed. This is done since engine/propeller performance data is only known at the elevation of the Wichita test site (1400 feet above Mean Sea Level, MSL). Knowing the engine/propeller performance data at a given altitude is a prerequisite to calculating the other aircraft performance parameters. Any insight you can provide into accounting for off-condition weights and altitudes would be very appreciated and helpful to both this and future analyses.

1. Thrust Parameters:

INM performance coefficients are based on the equations found in SAE-AIR-1845[1]. A primary parameter in the calculation of aircraft noise and performance in the (INM) is thrust. The INM uses the following equation to calculate thrust from horsepower and flight speed. This equation is the equivalent of SAE-AIR-1845 equation A4:

$$\frac{F}{\delta} = \frac{K\eta Hp}{V\delta} \qquad \text{Eq. 1}$$

where: F is the net thrust in pounds,
- δ is the non-dimensional pressure ratio,
- K is a constant to convert from Horsepower to foot-lb per second and knots to feet per second,
- η is the non-dimensional propeller efficiency,
- Hp is Horsepower, and
- V is true airspeed in knots.

The Brake Horsepower reported by Cessna in Attachment 1 (column 13, BHP TEST) is used as the horsepower input in the above equation. McCauley provided propeller efficiencies data for each aircraft configuration. True airspeed in knots (KTAS) is found from the calibrated airspeed in knots (KCAS) and the density ratio σ at the flight test altitude using the following equation:

$$KTAS = KCAS / \sqrt{\sigma}$$

In the INM, noise is found through the use of Noise-Power-Distance (NPD) look-up tables for each aircraft. Note that Power in the NPD is mis-named; the parameter used in the NPD tables in the INM is actually thrust. For all propeller aircraft (and some jet aircraft), thrusts are reported as a percentage of static thrust. Using a percentage of static thrust is more physically correct for jet-powered aircraft than for propeller aircraft since the thrust produced by a jet engine is less dependent on forward speed than the thrust produced by a propeller[2]. For this reason, I believe the static thrust is better defined as a reference thrust, and an in-flight reference thrust is a better predictor of propeller noise than a static condition reference thrust.

---

[1]Society of Automotive Engineers, "Procedure for the Calculation of Airplane Noise in the Vicinity of Airports," Aerospace Information Report 1845, Warrendale, Pennsylvania, March 1986.

[2]Lan and Roskam, "Airplane Aerodynamics and Performance", Roskam Aviation and Engineering, Ottawa, Kansas, 1981. The authors discuss the difference between propeller static and in-flight thrust in chapter seven.

For the Cessna 172R, I calculated an in-flight reference thrust based on the simulated takeoff conditions listed in the letter you sent to me on March 20, 2000 (Attachment 1) for the flight test (Passes 2 through 6 on Flight Number 411) conducted on October 13, 1999. The average brake horsepower during these five simulated takeoffs was 147.2 HP. The average airspeed was 78.72 KTAS. The average pressure ratio was 0.9363. The calculated average net corrected in-flight reference thrust was 511.8 lb. This is the net corrected thrust which I used as a reference for all percent thrust calculations. The equation below is an example which shows the usage of equation 1 for the data provided by Cessna for pass number 2. Note that the thrust of each pass was calculated separately, then the mean of these five passes was calculated to produce the average net corrected in-flight reference thrust.

$$\frac{F}{\delta} = \frac{K\eta Hp}{V\delta} = \frac{(325.87\ ^{lb\cdot kt}/_{HP})(0.67)(148.0HP)}{(79.35kt)(0.9370)} = 434.6lb$$

Using the procedure described above, the five simulated takeoffs (Passes 2 through 6 on Flight Number 411) by definition used an average thrust of 100% of the reference thrust. The six cruise climb configurations (Passes 7 through 11 on Flight Number 411) used an average thrust of 101.1%. The eleven cruise configurations (Passes 12 through 22 on Flight Number 411) used an average thrust of 59.6%. The simulated landings with 10 degrees of flaps (Pass 23 on Flight Number 411 and Passes 1 through 4 on Flight Number 412) averaged 26.6%. Note that Passes 5 and 6 are not included since the power reported on these passes was below the threshold of the power chart as noted in your March 20, 2000 letter. The simulated landings with 30 degrees of flaps (Passes 9 through 11 on Flight Number 412) averaged 58.2%. Table 1 below shows the averages of the parameters used in each of the flight procedures and the resulting percentage of reference thrust.

Table 1: Parameters used in the calculation of Percentage of Reference Thrust

Flight Condition	K	η	HP	KTAS	δ	F/δ	% of Reference Thrust
Takeoff	325.87	.67	147.2	78.72	.9363	436.0	100
Cruise Climb	325.87	.69	148.3	86.63	.9349	441.0	101.1
Cruise	325.87	.74	127.1	117.59	.9357	259.8	59.6
10° flaps approach	325.87	.69	42.1	87.20	.9350	116.0	26.6
30° flaps approach	325.87	.69	102.8	97.77	.9321	253.6	58.2

For modeling purposes, I used the 147.2 HP at the test altitude of 1800 feet MSL and the Lycoming data found in Attachment 2 to calculate a Sea Level power of 155 HP for the MaxTakeOff field in the INM. For the MaxClimb field in the INM, I used data provided by Lycoming to find the approximate power at 3000 feet MSL. I assumed a manifold pressure drop of 1 in. Hg for every 1000 foot increase in altitude and an approximate engine RPM of 2200. The Lycoming Altitude Performance chart, at the intersection of the 2200 RPM line and the 26.8

in. Hg line, gives a brake horsepower of approximately140 HP.

2. Aerodynamic Parameters:

The INM uses the coefficient of drag divided by lift (R) in the calculation of aircraft climb, cruise, and descent performance. The equation used to find the value of R for various flight conditions is based on equation A12 in SAE AIR 1845:

$$R = \frac{F/\delta}{W/\delta} - \frac{\sin\gamma}{0.95} \qquad \text{Eq. 2}$$

where R is the non-dimensional coefficient of drag divided by lift,
F is the net thrust in pounds,
W is the aircraft weight in pounds,
δ is the non-dimensional pressure ratio,
γ is the climb angle, and
0.95 is a factor used to correct the climb angle for flight into an assumed headwind.

Flaps Zero Climb:

To obtain the climb angle to use with a flaps up (zero degrees), full power takeoff, I used maximum rate of climb data found in Figure 5-6 of the 172R operating handbook (Dec 2/96, Attachment 3) and flight test data. From the figure, I interpolated a rate of climb of 623 FPM at 15°C at 1810 feet pressure altitude (the approximate conditions of the flight test). This climb rate at an airspeed of 80 KTAS (the approximate average true airspeed for passes 2 through 6 on Flight Number 411) corresponds to a climb angle of 4.6 degrees. Using equation 2 above, the calculated $R_{zero\text{-}c}$ value is 0.0831:

$$\gamma = \sin^{-1}\left(\frac{623\,FPM/60\,\mathrm{sec/min}}{80kt \times 1.6878\,feet/\mathrm{sec}/kt}\right) = 4.6^\circ$$

$$R_{zero-c} = \frac{F/\delta}{W/\delta} - \frac{\sin\gamma}{0.95} = \frac{436.0lb}{2450lb/0.9363} - \frac{\sin(4.6)}{0.95} = 0.0831$$

Flaps Ten Climb:

To calculate the climb angle to use with a 10° flaps, full power takeoff, I used the short field takeoff distance data found in Figure 5-5 of Attachment 3 and flight test data. For this condition, the aircraft is accelerating while climbing from the lift-off point (end of ground roll) to clearing a 50 foot obstacle. A re-ordered version of SAE-1845 equation A10 was used to determine the $R_{10\text{-}C}$ value. For the test conditions, an $R_{10\text{-}c}$ value of 0.1446 was found. This higher drag-to-lift ratio than $R_{zero\text{-}c}$ is expected since the short field takeoff technique is not intended to be aerodynamically efficient, but is rather to provide maximum lift at the expense of higher induced drag. The re-ordered version of SAE-1845 equation A10 used to solve for $R_{10\text{-}c}$ is the following:

$$R_{10-C} = \frac{F/\delta}{W/\delta} - \frac{V_Z}{V_{Avg}} - \frac{\frac{1}{(2g)}\left(V_{tb}^2 - V_{ta}^2\right)}{S_A}$$ Eq. 3

where F/δ is the net corrected thrust at the average true airspeed in pounds,
W/δ is the weight in pounds divided by the non-dimensional pressure ratio,
V_Z/V_{avg} is the non-dimensional climb gradient,
g is the gravitational constant in feet/second^2,
V_{tb} is the final acceleration airspeed in feet/second,
V_{ta} is the initial acceleration airspeed in feet/second, and
S_A is the distance in feet traveled during the acceleration.

The values actually used in the calculation of the R_{10-c} are found below. First, the thrust is calculated:

$$\frac{F}{\delta} = \frac{K\eta Hp}{V_{Final}\delta} = \frac{(325.87\ ^{lb\cdot kt}/_{HP})(0.67)(147.2HP)}{(55.8kt)(0.9363)} = 615.1lb$$

where 55.8 KTAS is the average of the 51 knot indicated airspeed (52.7 KTAS, 88.9 feet per second) at the lift-off point of the short field takeoff procedure and the 57 knot indicated airspeed (58.9 KTAS, 99.4 feet per second) at the end of the procedure when obstacles are cleared (50 feet AGL). Both airspeed values are found in Figure 5-5 of Attachment 3.

$$R_{10-C} = \frac{615.1lb}{2450lb/0.9363} - \frac{50ft}{892.3ft} - \frac{\left((99.4ft/\sec)^2 - (88.9ft/\sec)^2\right)}{2 \times 32.17ft/\sec^2(890.9ft)} = 0.1446$$

The distance of travel in the last term, 890.9 feet, is the difference between the total track distance to clear a 50 foot obstacle and the ground roll distance. Both of these distances are found by interpolating the data in the C-172R short field takeoff distance chart for the test day conditions of 15° C and 1810 feet pressure altitude (Figure 5-5, Attachment 3). For these conditions, the total distance to clear a 50 feet obstacle is 2011.4 feet and the ground roll distance is 1120.5 feet. Also, the climb gradient term, 50 ft/892.3 ft, is the height of the aircraft above the ground (the obstacle height) divided by the total distance which the aircraft travels once it leaves the ground. This total distance is the hypotenuse of a right triangle that has the 50 foot obstacle height and the 890.9 total track distance as the other two sides.

Flaps Zero Cruise:
In cruise configuration, R_{cruise} was found from the data in Figure 5-8, Cruise Performance (Attachment 3). For standard temperature conditions, R_{cruise} varies from 0.100 to 0.122 depending on altitude and power setting, where the altitudes of interest are from 4000 feet to 8000 feet. For the listed power settings, the average R_{cruise} was 0.096. This corresponds to power settings of about 70%. The following equation and Table 2 below shows how the data from Attachment 3

was used to generate the R_{cruise} values. For the horsepower term in the thrust equation, the percentage power is multiplied by the 160 HP rating of the Lycoming IO-360-L2A.

$$R_{cruise} = \frac{F/\delta}{W/\delta} - \frac{\sin\gamma}{0.95} = \frac{F/\delta}{W/\delta} - \frac{\sin(0)}{0.95} = \frac{(325.87)(0.74)(160HP)(\%HP/100)}{(2450lb)KTAS}$$

Table 2: Cruise Performance

Altitude (feet)	Engine RPM	% HP	KIAS	KTAS	R_{cruise}
4000	2300	79	110	117	.106
	2250	75	107	114	.104
	2200	70	105	111	.099
	2100	62	99	105	.093
	2000	55	92	98	.089
	1900	50	85	90	.087
6000	2350	80	110	120	.105
	2300	75	107	117	.101
	2250	71	104	114	.098
	2200	67	101	111	.095
	2100	60	95	104	.090
	2000	53	88	96	.087
8000	2400	80	108	122	.104
	2350	76	106	119	.101
	2300	71	103	116	.097
	2200	64	98	110	.091
	2100	57	90	102	.088
	2000	52	83	94	.087
				Average:	0.096

Approach Flaps:

Equations 1 and 2 were used to determine the R values for approach conditions. As seen in Table 1, during the 10 degree flaps approach, the power averaged 42.1 HP, and the airspeed averaged 87.2 KTAS, for a net corrected thrust of 132.3 lb. During the 30 degree flaps approaches, the power averaged 102.8 HP, and the airspeed averaged 97.8 KTAS. For these approaches, the flight path of the aircraft was determined from the video data taken during the flight test. The nominal flight path was 3 degrees down for both series of approaches. Using these data, $R_{D\text{-}10}$ was found to be 0.0994, while $R_{D\text{-}30}$ was found to be 0.1516. Note that the approaches flown at relatively high power, 85 KIAS, and 30 degree of flaps were not used, since Cessna personnel stated that these were non-standard approach conditions.

$$R_{D-10} = \frac{F/\delta}{W/\delta} - \frac{\sin\gamma}{0.95} = \frac{116.0lb}{2450lb/0.9350} - \frac{\sin(-3.0)}{0.95} = 0.0994$$

$$R_{D-30} = \frac{F/\delta}{W/\delta} - \frac{\sin\gamma}{0.95} = \frac{253.6lb}{2450lb/0.9321} - \frac{\sin(-3.0)}{0.95} = 0.1516$$

Takeoff Roll Distance:

The INM takeoff roll distance coefficient B was found using SAE AIR 1845 equation A6 and assuming Sea Level ISA conditions. The ground roll with 10 degrees of flaps was taken directly from the short field takeoff distance chart (Figure 5-5, Attachment 3). The initial climb speed for the 10 degrees flaps takeoff was listed in this figure as 51 KTAS (86.08 feet per second). For the zero flaps takeoff, the ground roll was calculated assuming a rotation speed of 55 KTAS (92.83 feet per second) as listed in the normal takeoff procedures section of the operators handbook (Page 4-14, Attachment 4). The following equations show the computation of the additional distance required to accelerate to this higher speed.

$$\frac{F}{\delta} = \frac{K\eta Hp}{V_{avg}\delta} = \frac{(325.87\,{}^{lb\cdot kt}/_{HP})(0.67)(147.2HP)}{(53kt)(1.0)} = 606.4lb$$

$$S_A = \frac{\frac{1}{2g}(0.95)\left(V_{tb}^2 - V_{ta}^2\right)}{\frac{F/\delta}{W/\delta} - R} = \frac{\frac{1}{2\times 32.17}(0.95)\left(92.83^2 - 86.08^2\right)}{\frac{606.4}{2450/1.0} - 0.0831} = 108.5\,feet$$

For the zero flap takeoff, the 108.5 foot distance is added to the 945 foot interpolated short field distance to give a total takeoff ground roll distance of 1053.5 feet. For Sea Level ISA conditions, the final thrust used in the calculation of the INM's zero flaps B coefficient, B_z is based on the reference thrust applied at the lift-off speed of 55 KTAS.

$$\frac{F}{\delta} = \frac{K\eta Hp}{V_{Final}\delta} = \frac{(325.87\,{}^{lb\cdot kt}/_{HP})(0.67)(147.2HP)}{(55kt)(1.0)} = 584lb$$

$$B_z = \frac{S\left(F/\delta\right)}{W^2} = \frac{1053.5ft \times 584lb}{(2450lb)^2} = 0.1025 \qquad \text{Eq. 4}$$

For the ten degree flaps takeoff, the 945 foot interpolated short field distance is used as the take-off ground roll in the computation of the B_{10} coefficient. The final thrust for this condition is the reference thrust applied at the lift-off speed of 51 knots (Figure 5-5, Attachment 3).

$$\frac{F}{\delta} = \frac{K\eta Hp}{V_{Final}\delta} = \frac{(325.87\ ^{lb\cdot kt}/_{HP})(0.67)(147.2HP)}{(51kt)(1.0)} = 630lb$$

$$B_{10} = \frac{S\left(F/\delta\right)}{W^2} = \frac{945ft \times 630lb}{(2450lb)^2} = 0.0992$$

Lift-off and Touch-down speeds:
The SAE-AIR-1845 equations used to set the lift-off and the touch-down speed coefficients are only a function of weight and the appropriate speed. The lift-off speed coefficient C is defined in SAE-AIR-1845 equation A7. The touch-down speed coefficient D is defined in SAE-AIR-1845 equation A13. The subscripts on the coefficients indicate the flap setting. Lift-off speeds have been discussed in previous sections of this letter report. Touch-down speeds are taken from page 4-16 of Attachment 4.

$$C_Z = \frac{V}{\sqrt{W}} = \frac{55kts}{\sqrt{2450lb}} = 1.1112 \qquad \text{Eq. 5}$$

$$C_{10} = \frac{V}{\sqrt{W}} = \frac{51kts}{\sqrt{2450lb}} = 1.0304$$

$$D_{10} = \frac{V}{\sqrt{W}} = \frac{65kts}{\sqrt{2450lb}} = 1.3132$$

$$D_{30} = \frac{V}{\sqrt{W}} = \frac{62kts}{\sqrt{2450lb}} = 1.2526$$

3. Modeling Takeoff and Approach in the INM:
Using the performance coefficients described above, I have entered a takeoff procedure and an approach procedure into the INM. The takeoff procedure is a normal takeoff, as described in the Normal Procedures section of the 172R Operators Handbook (Attachments 3 and 4). The approach procedure is a normal approach, as described in the Normal Procedures section. In general, when the Operators Handbook lists a range of speeds for a particular operation, I selected the midpoint of the range of speeds. In addition, graphs of the INM's calculated

approach procedure is a normal approach, as described in the Normal Procedures section. In general, when the Operators Handbook lists a range of speeds for a particular operation, I selected the midpoint of the range of speeds. In addition, graphs of the INM's calculated performance profiles for these operations are included.

Normal Takeoff:
The normal takeoff procedure for the Cessna 172R is detailed page 4-14 of Attachment 4. Flaps are assumed to be retracted throughout the procedure. The aircraft is rotated at 55 KIAS, then accelerates to a climb speed of 75 KIAS. The aircraft climbs at this speed until reaching 1000 Feet AGL, at which point the aircraft is accelerated to an en route climb speed of 80 KIAS (Enroute Climb, Page 4-15, Attachment 4). The aircraft climbs to an altitude of 8000 feet at this speed. The operators handbook recommends a full power en route climb. At three thousand feet, the engine power is changed from MaxTakeOff to MaxClimb. This change in modeled engine power takes into account the decrease in engine power with altitude. This modeled two-step change in power with altitude is an approximation of the true engine power change which is a continually varying function of altitude.

Normal Approach:
The normal landing procedure for the Cessna 172R is generally described in Attachment 3 on page 4-16. The aircraft begins the landing approach at 100 KIAS, 6000 feet AGL and a three degree glideslope. At 4000 feet AGL, the aircraft begins deceleration to 80 KIAS. At 1000 feet AGL, 10 degrees of flaps are applied. Between 600 and 500 feet AGL the aircraft decelerates to 70 KIAS. The aircraft touches down at 62 KIAS, and rolls 560 feet.

In addition to the normal takeoff and approach, data generated in this report is sufficient to generate non-standard takeoff and approach procedures. These procedures are not included here because they are subject to airport-specific variations.

Graphs showing altitude, true airspeed, and net corrected thrust for the three procedures listed above are presented on the following pages. The independent axis for the takeoff procedures is the distance from brake release; for approach, the independent axis is the distance from touchdown (negative before touchdown, positive after touchdown). The graphs assume standard temperature and a sea level airport. In addition, the NPD data are also included in this letter report in tabular form.

ACOUSTICS FACILITY

David Senzig, P.E.

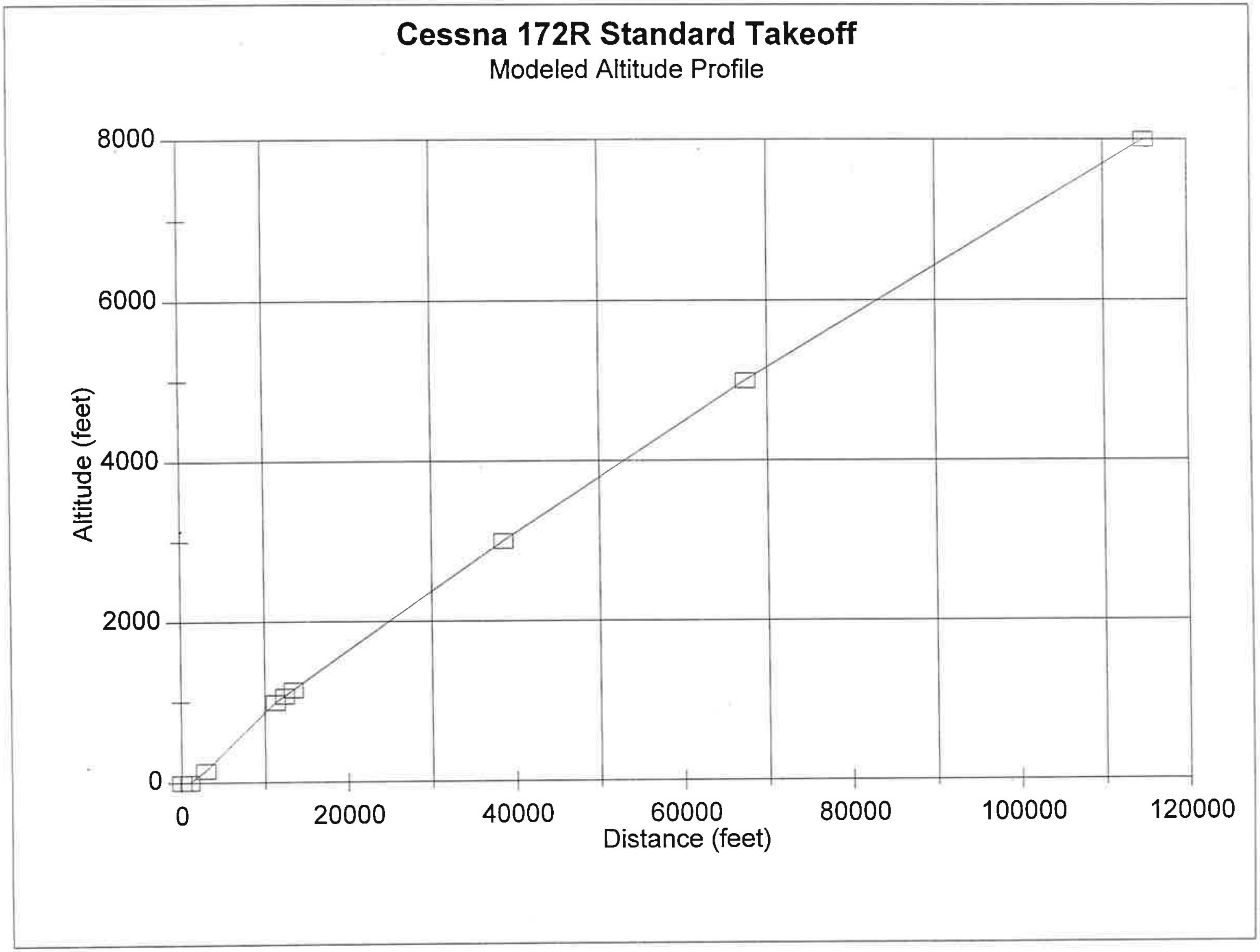
C: John Gulding, FAA

Summary of INM Data

```
STUDY AIRCRAFT
   C-172  User-defined
      Descrip    : Cessna 172R / Lycoming IO-360-L2A
      UserID     : GA
      WgtCat     : Small
      OwnerCat   : Gen-Aviation
      EngType    : Piston
      NoiseCat   : 9855388
      Type       : Prop
      NumEng     : 1
      NoiseId    :
      ATRS       : No
      TkoWgt     : 2450 lb
      LndWgt     : 2450 lb
      LndDist    : 1695 ft
      StaticThr  : 536 lb
   GASEPF Standard data

USER-DEFINED PROFILE IDENTIFIERS
      Op   Profile Stg  Weight(lb)
   C-172
      APP  STANDARD 1     2450
      DEP  STANDARD 1     2450

USER-DEFINED PROCEDURAL PROFILES
      #  StepType       Flap     ThrType          Alt/Clm     Speed(kt)    Ang/Thr/Dis
   C-172-APP-STANDARD-1
      1  Descend        ZERO-D   None            6000.0 ft      100.0         3.0 deg
      2  Descend        ZERO-D   None            4000.0 ft      100.0         3.0 deg
      3  Descend        ZERO-D   None            3000.0 ft       80.0         3.0 deg
      4  Descend        10-D     None            1000.0 ft       80.0         3.0 deg
      5  Descend        10-D     None             600.0 ft       80.0         3.0 deg
      6  Descend        10-D     None             500.0 ft       70.0         3.0 deg
      7  Land           10-D     None              30.0 ft        0.0         0.0
      8  Decelerate     10-D     None             530.0 ft       62.0        10.0 %
      9  Decelerate     -NONE-   None               0.0 ft       10.0        10.0 %

   C-172-DEP-STANDARD-1
      1  Takeoff        ZERO-C   MaxTakeOff         0.0           0.0         0.0
      2  Accelerate     ZERO-C   MaxTakeOff       500.0 fpm      75.0         0.0
      3  Climb          ZERO-C   MaxTakeOff      1000.0 ft        0.0         0.0
      4  Accelerate     ZERO-C   MaxTakeOff       500.0 fpm      80.0         0.0
      5  Climb          ZERO-C   MaxClimb        3000.0 ft        0.0         0.0
      6  Climb          ZERO-C   MaxClimb        5000.0 ft        0.0         0.0
      7  Climb          ZERO-C   MaxClimb        8000.0 ft        0.0         0.0
```

Summary of INM Coefficients

ACFT	OP	FLAP	COEFF_R	COEFF_CD	COEFF_B
C-172	D	10-C	0.144600	1.030400	0.099200
C-172	A	10-D	0.099400	1.313200	0.000000
C-172	A	30-D	0.151600	1.252600	0.000000
C-172	D	CRUISE	0.096000	0.000000	0.000000
C-172	D	ZERO-C	0.083100	1.111200	0.102500

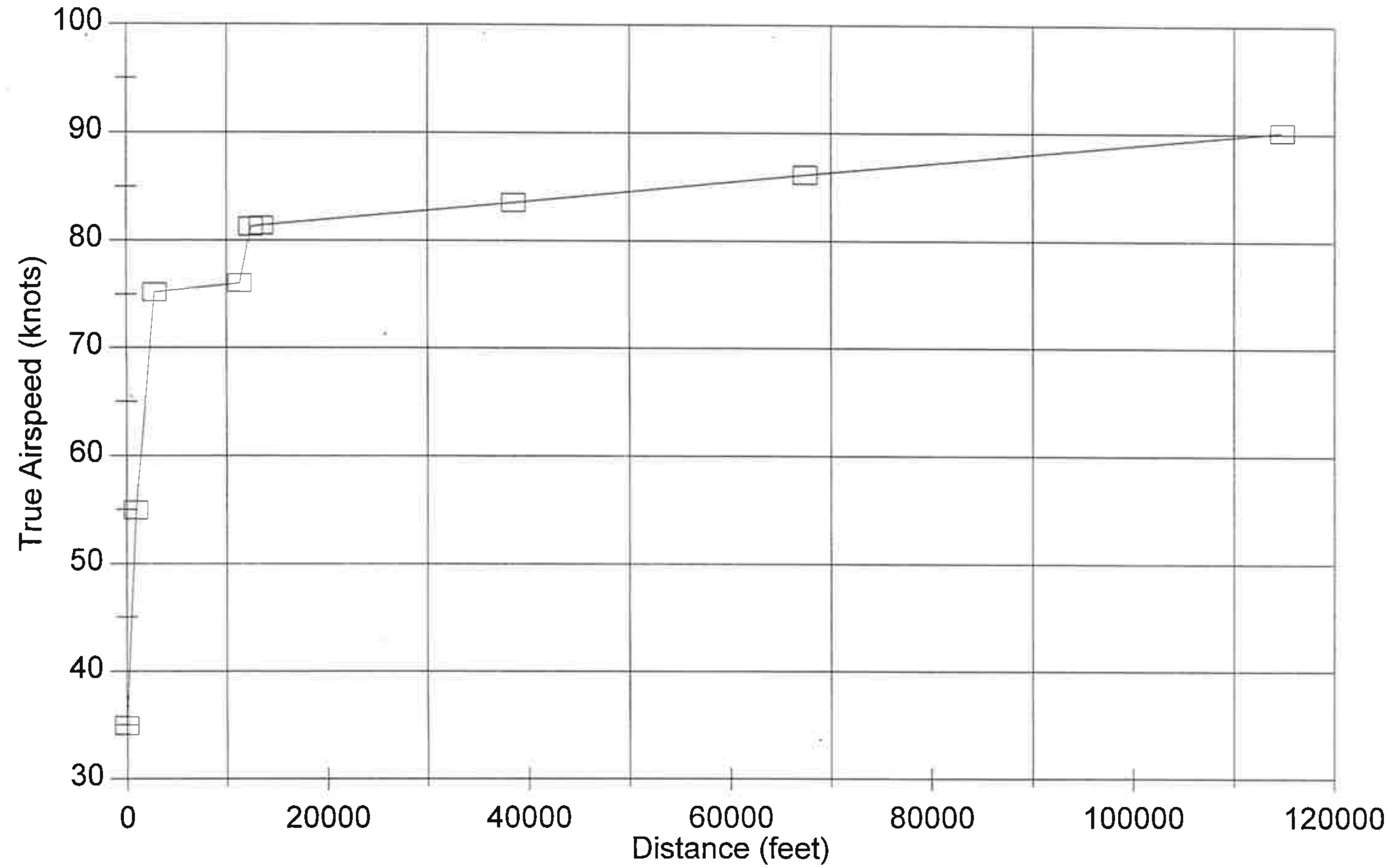


C:\Projects\Cessna\Basecase\prof_pts.qpw

08/29/00

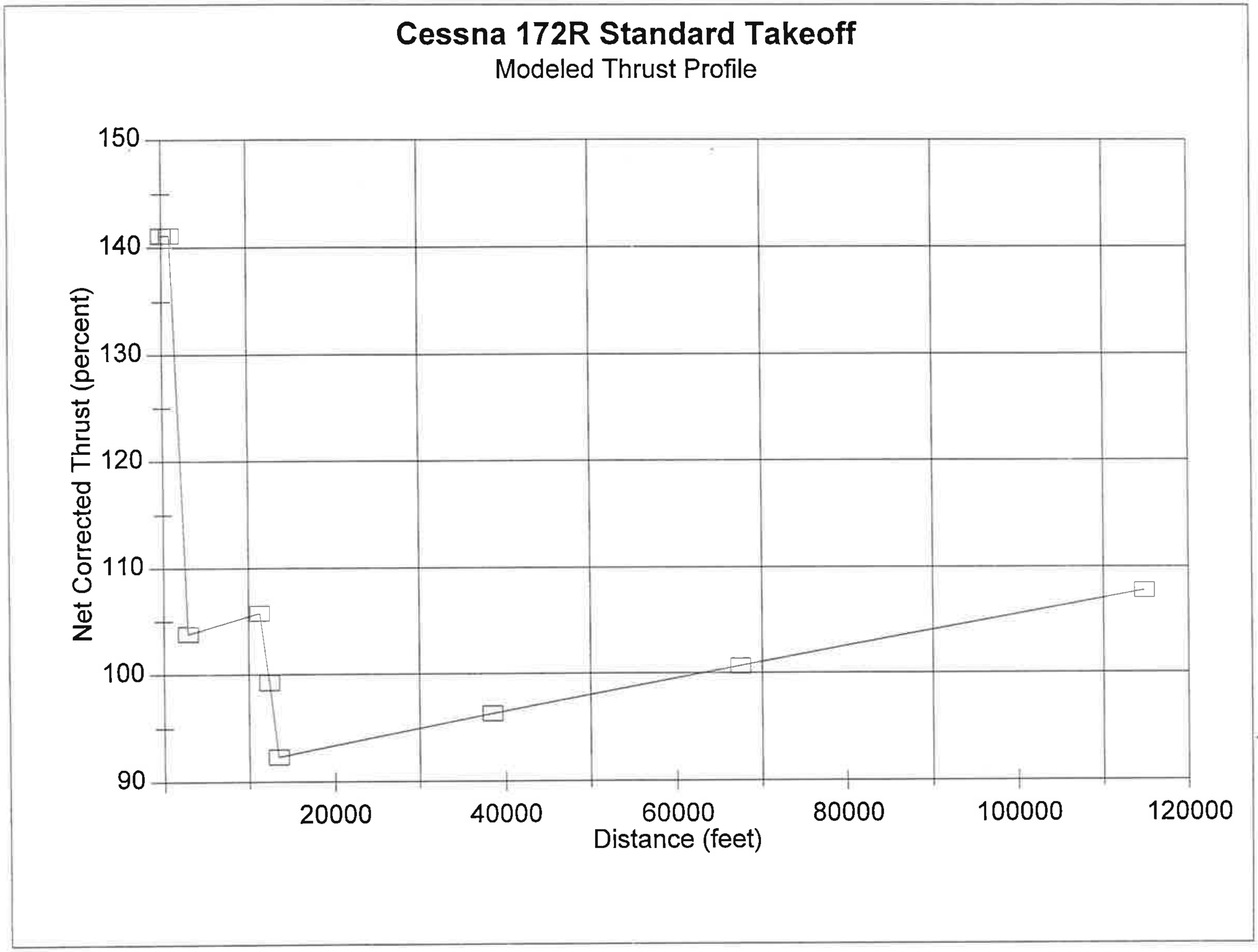
Cessna 172R Standard Takeoff

Modeled Speed Profile



C:\Projects\Cessna\Basecase\prof_pts.qpw

08/29/00

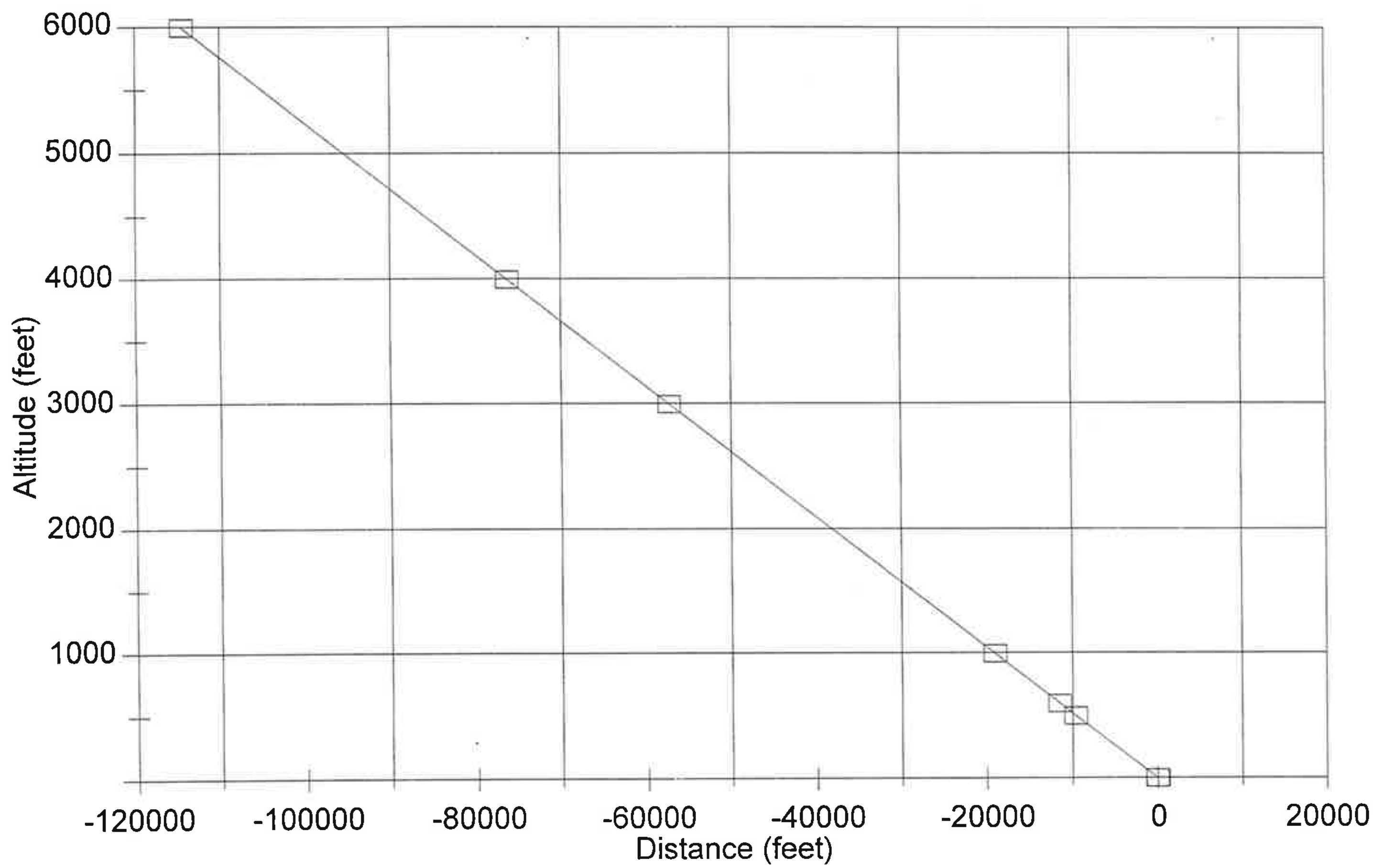


C:\Projects\Cessna\Basecase\prof_pts.qpw

08/29/00

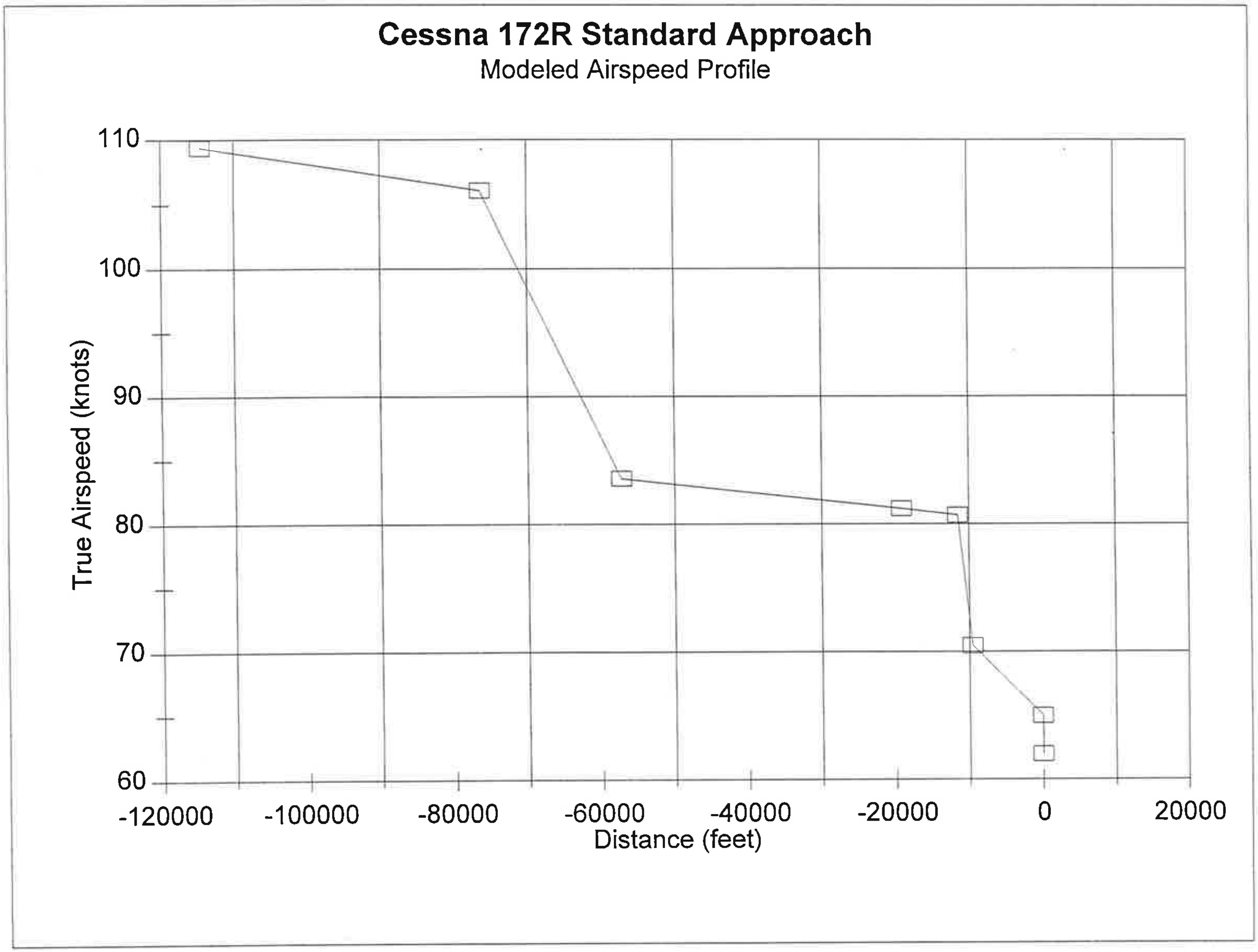
Cessna 172R Standard Approach

Modeled Altitude Profile



C:\Projects\Cessna\Basecase\prof_pts.qpw

08/29/00

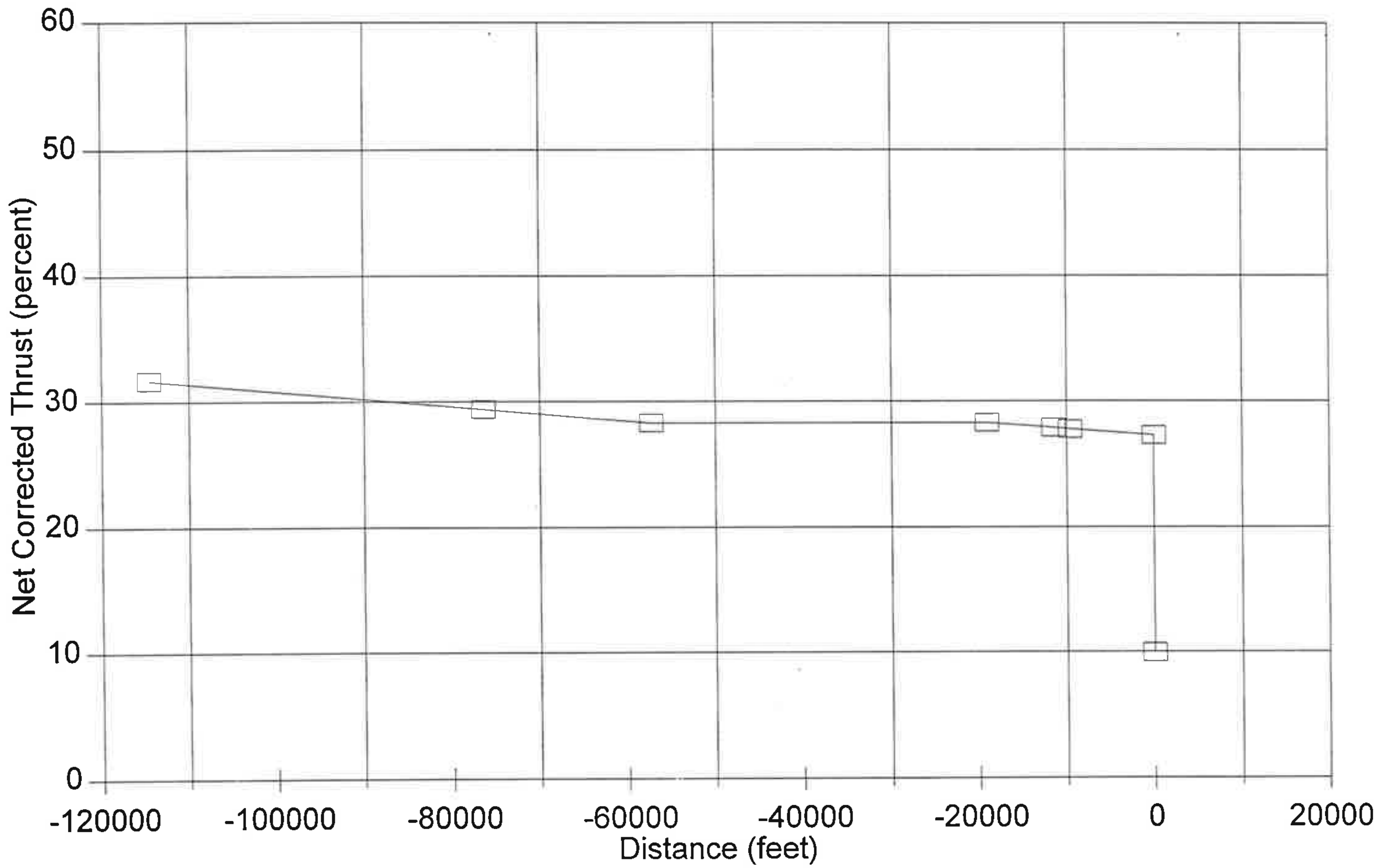


C:\Projects\Cessna\Basecase\prof_pts.qpw

08/29/00

Cessna 172R Standard Approach

Modeled Thrust Profile



C:\Projects\Cessna\Basecase\prof_pts.qpw 08/29/00

Cessna 172R Noise-Power-Distance Data

NOISE	OP_MODE	THR_SET	L_200	L_400	L_630	L_1000	L_2000	L_4000	L_6300	L_10000	L_16000	L_25000
E	A	26.60	78.7	73.6	70.2	66.6	60.3	52.4	45.8	37.9	24.5	11.9
E	A	58.20	85.7	80.6	77.3	73.6	67.4	60.0	53.9	46.5	35.6	19.9
E	D	59.60	88.4	84.3	81.2	77.9	72.1	65.3	59.9	53.2	44.2	32.6
E	D	100.00	90.2	86.3	83.3	79.9	74.2	67.2	61.9	55.2	47.2	34.0
M	A	26.60	71.6	64.2	59.7	55.0	47.7	39.8	34.4	28.5	22.4	16.9
M	A	58.20	78.8	72.2	67.7	62.9	55.2	46.7	40.7	34.1	27.0	20.3
M	D	59.60	82.7	75.6	71.1	66.4	58.9	50.8	45.0	38.6	31.7	24.5
M	D	100.00	84.6	77.8	73.2	68.2	60.4	52.0	46.2	39.9	33.5	25.6
P	A	26.60	86.6	79.4	74.4	69.1	60.3	49.8	41.3	32.1	18.3	2.5
P	A	58.20	93.8	86.6	81.6	76.0	67.2	57.3	49.7	40.8	29.3	13.5
P	D	59.60	97.4	90.6	85.9	80.7	72.3	63.0	56.1	48.2	37.8	25.2
P	D	100.00	100.2	93.0	87.7	82.2	73.6	64.2	57.2	49.4	40.3	27.0
S	A	26.60	73.0	68.7	65.8	63.0	58.6	53.6	50.0	46.2	42.4	38.8
S	A	58.20	79.3	75.3	72.7	69.9	65.1	59.6	55.5	51.1	46.3	43.0
S	D	59.60	83.5	79.8	77.2	74.4	69.7	64.1	59.9	55.3	50.3	45.8
S	D	100.00	84.9	81.4	78.9	76.0	71.2	65.5	61.3	56.5	51.8	46.3

Attachment 1

Data from Ted Farwell's March 20, 2000 letter

SPEED POWER AND FUEL CONSUMPTION DATA REDUCTION

PREPARED BY:	Ted Farwell
DATE:	03/20/2000
MODEL:	172R
AIRPLANE	6786R
FLIGHT NO:	411
FLIGHT DATE:	10/13/1999
CONFIGURATION	FLYOVER NOISE- VOLPE CENTER
REMARKS	

[redacted]

		2		9	11		1	7	15	3	4	5	10	12	13
PASS NO.	INDICATED H_P	OAT °F	INDICATED MANIFOLD PRES "Hg	ENGINE RMP	IAT °F	INDICATED AIRSPEED (kias)	CALIBRATED H_P	CALIBRATED MANIFOLD PRES "Hg	CALIBRATED AIR SPEED - kts	T_{STD} - STD TEMP @1 - °F	H_d - DENSITY ALT @ 1,2 - ft	$(\rho/\rho_0)^{0.5} = \sigma^{0.5}$	BHP CHART	TEMP CORR	BHP TEST
2	1790	59	28.2	2218	64	78	1790	28.20	76.81	52.62	2208	0.9680	149.6	0.989	148.0
3	1880	59	28.0	2217	64	78	1880	28.00	76.81	52.30	2319	0.9664	148.3	0.989	146.6
4	1800	59	28.2	2218	64	78	1800	28.20	76.81	52.58	2220	0.9678	149.6	0.989	148.0
5	1800	59	28.0	2209	64	75	1800	28.00	73.62	52.58	2220	0.9678	147.7	0.989	146.1
6	1780	59	28.2	2200	64	78	1780	28.20	76.81	52.65	2195	0.9682	148.7	0.989	147.1
7	1890	58	28.0	2240	63	85	1890	28.00	84.27	52.26	2266	0.9671	149.4	0.990	147.8
8	1880	58	28.0	2260	63	85	1880	28.00	84.27	52.30	2254	0.9673	150.3	0.990	148.7
9	1830	58	28.3	2192	63	85	1830	28.30	84.27	52.47	2192	0.9682	149.1	0.990	147.6
10	1830	58	28.2	2230	63	85	1830	28.20	84.27	52.47	2192	0.9682	150.3	0.990	148.7
11	1830	58	28.2	2230	63	83	1830	28.20	82.14	52.47	2192	0.9682	150.3	0.990	148.7
12	1800	59	25.5	2250	63	114	1800	25.50	115.16	52.58	2220	0.9678	130.9	0.990	129.6
13	1830	61	24.7	2240	66	112	1830	24.70	113.03	52.47	2386	0.9654	124.6	0.987	123.0
14	1850	61	25.3	2260	66	113	1850	25.30	114.09	52.40	2411	0.9651	129.9	0.987	128.2
15	1820	61	25.4	2250	66	113	1820	25.40	114.09	52.51	2374	0.9656	130.2	0.987	128.5
16	1810	61	25.3	2255	66	112	1810	25.30	113.03	52.55	2362	0.9658	129.6	0.987	128.0
17	1820	61	25.2	2260	66	112	1820	25.20	113.03	52.51	2374	0.9656	129.1	0.987	127.4
18	1840	61	25.2	2250	66	112	1840	25.20	113.03	52.44	2399	0.9652	128.7	0.987	127.1
19	1840	61	25.1	2240	66	112	1840	25.10	113.03	52.44	2399	0.9652	127.6	0.987	126.0
20	1840	62	25.2	2250	67	113	1840	25.20	114.09	52.44	2463	0.9643	128.7	0.986	127.0
21	1830	62	25.2	2248	67	112	1830	25.20	113.03	52.47	2451	0.9645	128.6	0.986	126.9
22	1830	62	25.1	2260	67	112	1830	25.10	113.03	52.47	2451	0.9645	128.4	0.986	126.6
23	1700	62	16.0	1680	67	85	1700	16.00	84.27	52.94	2291	0.9668	44.8	0.987	44.2
SEA LEVEL	0	59	29.4	2210	64		0	29.40	-6.27	59.00	0	1.0000	153.3	0.995	152.6

SPEED POWER AND FUEL CONSUMPTION DATA REDUCTION

PREPARED BY:	Ted Farwell
DATE:	03/20/2000
MODEL:	172R
AIRPLANE	6786R
FLIGHT NO:	412
FLIGHT DATE:	10/14/1999
CONFIGURATION	FLYOVER NOISE- VOLPE CENTER
REMARKS	

[redacted]

PASS NO.	INDICATED H_p	2 OAT °F	INDICATED MANIFOLD PRES "Hg	9 ENGINE RMP	11 IAT °F	INDICATED AIRSPEED (kias)	1 CALIBRATED H_p	7 CALIBRATED MANIFOLD PRES "Hg	15 CALIBRATED AIR SPEED - kts	3 T_{STD} - STD TEMP @1 - °F	4 H_d - DENSITY ALT @ 1,2 - ft	5 $(\rho/\rho_0)^{0.5} = \sigma^{0.5}$	10 BHP CHART	12 TEMP CORR	13 BHP TEST
1	1830	58	15.1	1660	63	85	1830	15.10	84.27	52.47	2192	0.9682	40.0	0.990	39.6
2	1900	59	16.0	1622	64	85	1900	16.00	84.27	52.22	2343	0.9660	44.5	0.989	44.0
3	1860	59	16.5	1654	64	85	1860	16.50	84.27	52.37	2294	0.9667	47.3	0.989	46.8
4	1950	60	14.0	1660	65	85	1950	14.00	84.27	52.05	2470	0.9642	34.4	0.988	34.0
5	1950	60	14.3	1590	65	85	1950	14.30	84.27	52.05	2470	0.9642	#VALUE!	0.988	#VALUE! *
6	1940	60	13.0	1545	65	85	1940	13.00	84.27	52.08	2457	0.9644	#VALUE!	0.988	#VALUE! *
7	2130	60	21.0	2130	65	85	2130	21.00	84.27	51.40	2691	0.9610	93.9	0.987	92.7
8	1930	60	22.8	2002	65	85	1930	22.80	84.27	52.12	2445	0.9646	100.3	0.988	99.1
9	1980	61	23.2	2040	66	95	1980	23.20	94.92	51.94	2571	0.9628	105.1	0.987	103.6
10	1900	61	22.8	2004	66	93	1900	22.80	92.79	52.22	2473	0.9642	100.4	0.987	99.0
11	1920	61	23.0	2024	66	95	1920	23.00	94.92	52.15	2497	0.9638	102.8	0.987	101.4
SEA LEVEL	0	59	29.4	2210	64		0	29.40	-6.27	59.00	0	1.0000	153.3	0.995	152.6

$T_{std} = 59 - 0.0035661615 \times H$

$H_d = (((1-6.87535*10^{-6}*H_p)^{5.2561}(518.688/(T_{amb}+459.688)))^{0.235}-1)/(-6.87535*10^{-6})$

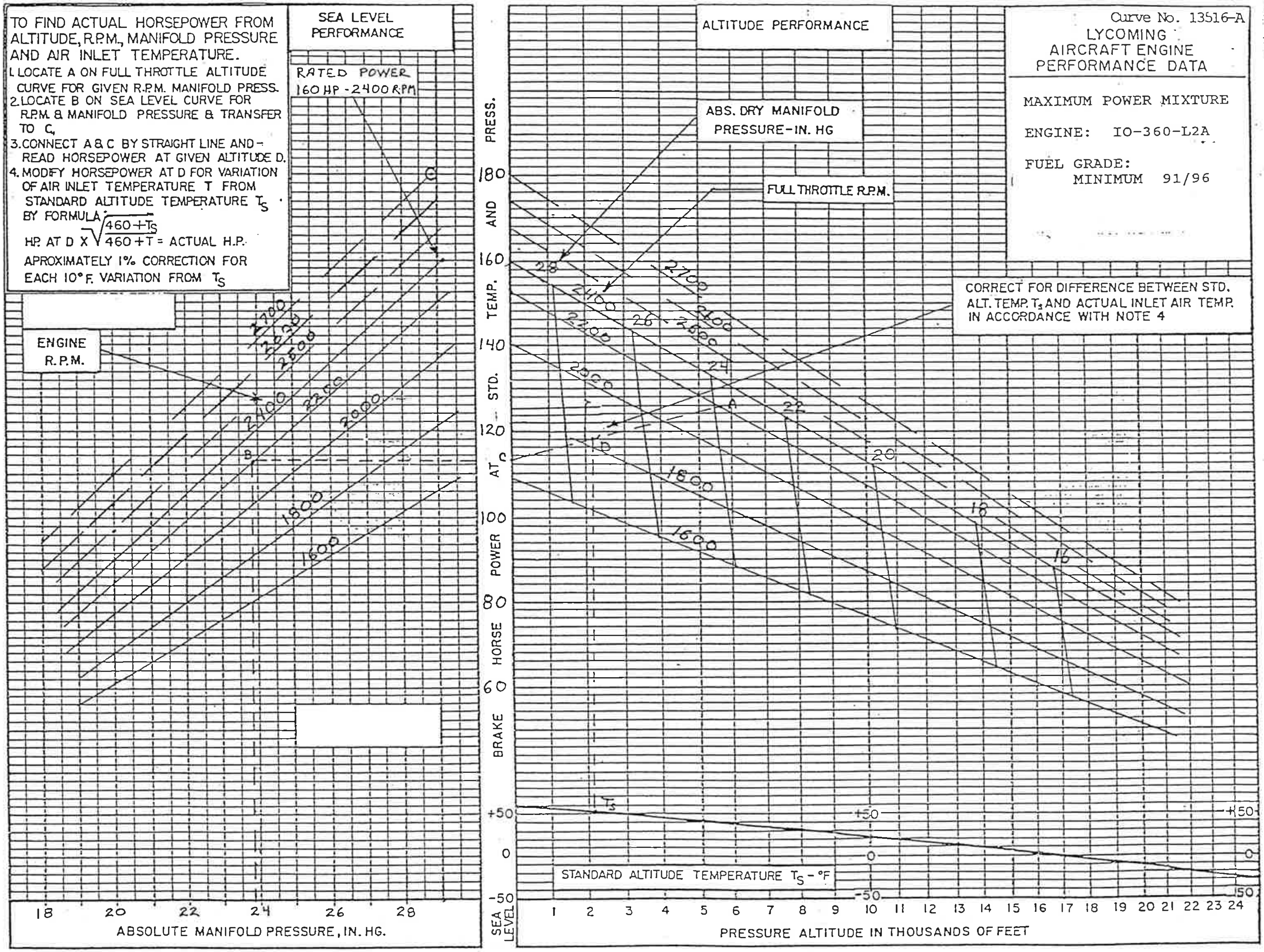
$\sigma^{0.5} = ((518.688(1-6.87535 \times 10^{-6}H_p)^{5.2561})/(T_{amb} + 459.688))^{0.5}$

$[12] = (([3]+460)/([11]+460))^{0.5}$

* VALUES ARE BELOW BOTTOM LIMIT OF POWER CHART; ≅ 25 BHP

Attachment 2

Lycoming data for the IO-360-L2A engine


TO FIND ACTUAL HORSEPOWER FROM ALTITUDE, R.P.M., MANIFOLD PRESSURE AND AIR INLET TEMPERATURE.
1. LOCATE A ON FULL THROTTLE ALTITUDE CURVE FOR GIVEN R.P.M. MANIFOLD PRESS.
2. LOCATE B ON SEA LEVEL CURVE FOR R.P.M. & MANIFOLD PRESSURE & TRANSFER TO C,
3. CONNECT A & C BY STRAIGHT LINE AND READ HORSEPOWER AT GIVEN ALTITUDE D.
4. MODIFY HORSEPOWER AT D FOR VARIATION OF AIR INLET TEMPERATURE T FROM STANDARD ALTITUDE TEMPERATURE T_S BY FORMULA
HP. AT D X $\sqrt{\frac{460+T_S}{460+T}}$ = ACTUAL H.P.
APROXIMATELY 1% CORRECTION FOR EACH 10°F. VARIATION FROM T_S
SEA LEVEL PERFORMANCE
RATED POWER
160 HP - 2400 RPM
ENGINE R.P.M.
2700
2600
2500
2400
2200
2000
1800
1600
A
B
C
D
18
20
22
24
26
28
ABSOLUTE MANIFOLD PRESSURE, IN. HG.
ALTITUDE PERFORMANCE
ABS. DRY MANIFOLD PRESSURE - IN. HG
FULL THROTTLE R.P.M.
Curve No. 13516-A
LYCOMING
AIRCRAFT ENGINE
PERFORMANCE DATA
MAXIMUM POWER MIXTURE
ENGINE: IO-360-L2A
FUEL GRADE:
MINIMUM 91/96
CORRECT FOR DIFFERENCE BETWEEN STD. ALT. TEMP. T_S AND ACTUAL INLET AIR TEMP. IN ACCORDANCE WITH NOTE 4
BRAKE HORSE POWER AT STD. TEMP. AND PRESS.
180
160
140
120
100
80
60
28
26
24
22
20
18
16
STANDARD ALTITUDE TEMPERATURE T_S - °F
+50
0
-50
SEA LEVEL
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
PRESSURE ALTITUDE IN THOUSANDS OF FEET

13516-A

Attachment 3

172R Operators Handbook, Section 5: Performance

INTRODUCTION

Performance data charts on the following pages are presented so that you may know what to expect from the airplane under various conditions, and also, to facilitate the planning of flights in detail and with reasonable accuracy. The data in the charts has been computed from actual flight tests with the airplane and engine in good condition and approximating average piloting techniques.

It should be noted that performance information presented in the range and endurance profile charts allows for 45 minutes reserve fuel at the specified power setting. Fuel flow data for cruise is based on the recommended lean mixture setting at all altitudes. Some indeterminate variables such as mixture leaning technique, fuel metering characteristics, engine and propeller condition, and air turbulence may account for variations of 10% or more in range and endurance. Therefore, it is important to utilize all available information to estimate the fuel required for the particular flight and to flight plan in a conservative manner.

USE OF PERFORMANCE CHARTS

Performance data is presented in tabular or graphical form to illustrate the effect of different variables. Sufficiently detailed information is provided in the tables so that conservative values can be selected and used to determine the particular performance figure with reasonable accuracy.

SAMPLE PROBLEM

The following sample flight problem utilizes information from the various charts to determine the predicted performance data for a typical flight. Assume the following information has already been determined:

AIRPLANE CONFIGURATION:	
Takeoff weight	2450 Pounds
Usable fuel	53 Gallons
TAKEOFF CONDITIONS:	
Field pressure altitude	1500 Feet
Temperature	28°C
Wind component along runway	12 Knot Headwind
Field length	3500 Feet

CRUISE CONDITIONS:	
Total distance	320 Nautical Miles
Pressure altitude	5500 Feet
Temperature	20°C
Expected wind enroute	10 Knot Headwind
LANDING CONDITIONS:	
Field pressure altitude	2000 Feet
Temperature	25°C
Field length	3000 Feet

TAKEOFF

The takeoff distance chart, Figure 5-5, should be consulted, keeping in mind that distances shown are based on the short field technique. Conservative distances can be established by reading the chart at the next higher value of weight, altitude and temperature. For example, in this particular sample problem, the takeoff distance information presented for a weight of 2450 pounds, pressure altitude of 2000 feet and a temperature of 30°C should be used and results in the following:

Ground roll	1275 Feet
Total distance to clear a 50-foot obstacle	2290 Feet

These distances are well within the available takeoff field length. However, a correction for the effect of wind may be made based on Note 3 of the takeoff chart. The correction for a 12 knot headwind is:

$$\frac{12 \text{ Knots}}{9 \text{ Knots}} \text{ X } 10\% = 13\% \text{ Decrease}$$

This results in the following distances, corrected for wind:

Ground roll, zero wind	1275
Decrease in ground roll (1275 feet X 13%)	-166
Corrected ground roll	1109 Feet

Total distance to clear a 50-foot obstacle, zero wind	2290
Decrease in total distance (2290 feet X 13%)	-298
Corrected total distance to clear 50-foot obstacle	1992 Feet

CRUISE

The cruising altitude should be selected based on a consideration of trip length, winds aloft, and the airplane's performance. *A typical cruising altitude and the expected wind enroute have been given for this sample problem. However, the power setting selection for cruise must be determined based on* several considerations. These include the cruise performance characteristics presented in Figure 5-8, the range profile chart presented in Figure 5-9, and the endurance profile chart presented in Figure 5-10.

The relationship between power and range is illustrated by the range profile chart. Considerable fuel savings and longer range result when lower power settings are used. For this sample problem, a cruise power of approximately 65% will be used.

The cruise performance chart, Figure 5-8, is entered at 6000 feet altitude and 20°C above standard temperature. These values most nearly correspond to the planned altitude and expected temperature conditions. The engine speed chosen is 2200 RPM, which results in the following:

Power	64%
True airspeed	109 Knots
Cruise fuel flow	7.3 GPH

FUEL REQUIRED

The total fuel requirement for the flight may be estimated using the performance information in Figure 5-7 and Figure 5-8. For this sample problem, Figure 5-7 shows that a climb from 2000 feet to 6000 feet requires 1.4 gallons of fuel. The corresponding distance during the climb is 10 nautical miles. These values are for a standard temperature and are sufficiently accurate for most flight planning purposes. However, a further correction for the effect of temperature may be made as noted on the climb chart. The approximate effect of a non-standard temperature is to increase the time, fuel, and distance by 10% for each 10°C above standard temperature, due to the lower rate of climb. In this case, assuming a temperature 13°C above standard (28°C - 15°C), the correction would be:

$$\frac{13°C}{10°C} \times 10\% = 13\% \text{ Increase}$$

With this factor included, the fuel estimate would be calculated as follows:

Fuel to climb, standard temperature	1.4
Increase due to non-standard temperature (1.4 X 13%)	0.2
Corrected fuel to climb	1.6 Gallons

Using a similar procedure for the distance to climb results in 12 nautical miles. (10 nm using chart + 1.2 nm to correct for higher than standard temperature = 11.2 nm. Rounded up to 12 nm.)

The resultant cruise distance is:

Total distance	320
Climb distance	-12
Cruise distance	308 nm

With an expected 10 knot headwind, the ground speed for cruise is predicted to be:

109
-10

99 Knots

Therefore, the time required for the cruise portion of the trip is:

$$\frac{308 \text{ Nautical Miles}}{99 \text{ Knots}} = 3.1 \text{ Hours}$$

The fuel required for cruise is:

3.1 hours X 7.3 gallons/hour = 22.7 Gallons

A 45-minute reserve requires:

$$\frac{45}{60} \times 7.3 \text{ gallons / hour} = 5.5 \text{ Gallons}$$

The total estimated fuel required is as follows:

Engine start, taxi, and takeoff	1.1
Climb	1.6
Cruise	22.7
Reserve	5.5
Total fuel required	30.9 Gallons

Once the flight is underway, ground speed checks will provide a more accurate basis for estimating the time enroute and the corresponding fuel required to complete the trip with ample reserve.

LANDING

A procedure similar to takeoff should be used for estimating the landing distance at the destination airport. Figure 5-11 presents landing distance information for the short field technique. The distances corresponding to 2000 feet and 30°C are as follows:

Ground roll	625 Feet
Total distance to clear a 50-foot obstacle	1410 Feet

A correction for the effect of wind may be made based on Note 2 of the landing chart, using the same procedure as outlined for takeoff.

DEMONSTRATED OPERATING TEMPERATURE

Satisfactory engine cooling has been demonstrated for this airplane with an outside air temperature 23°C above standard. This is not to be considered as an operating limitation. Reference should be made to Section 2 for engine operating limitations.

AIRSPEED CALIBRATION

NORMAL STATIC SOURCE

CONDITION:

Power required for level flight or maximum rated RPM dive.

FLAPS UP												
KIAS	50	60	70	80	90	100	110	120	130	140	150	160
KCAS	56	62	70	79	89	98	107	117	126	135	145	154
FLAPS 10°												
KIAS	40	50	60	70	80	90	100	110	---	---	---	---
KCAS	49	55	62	70	79	89	98	108	---	---	---	---
FLAPS 30°												
KIAS	40	50	60	70	80	85	---	---	---	---	---	---
KCAS	47	53	61	70	80	84	---	---	---	---	---	---

Figure 5-1. Airspeed Calibration (Sheet 1 of 2)

AIRSPEED CALIBRATION

ALTERNATE STATIC SOURCE

HEATER OFF, VENTS AND WINDOWS CLOSED

FLAPS UP											
NORMAL KIAS	50	60	70	80	90	100	110	120	130	140	---
ALTERNATE KIAS	51	61	71	82	91	101	111	121	131	141	---
FLAPS 10°											
NORMAL KIAS	40	50	60	70	80	90	100	110	---	---	---
ALTERNATE KIAS	40	51	61	71	81	90	99	108	---	---	---
FLAPS 30°											
NORMAL KIAS	40	50	60	70	80	85	---	---	---	---	---
ALTERNATE KIAS	38	50	60	70	79	81	---	---	---	---	---

HEATER ON, VENTS OPEN AND WINDOWS CLOSED

FLAPS UP											
NORMAL KIAS	40	50	60	70	80	90	100	110	120	130	140
ALTERNATE KIAS	36	48	59	70	80	89	99	108	118	128	139
FLAPS 10°											
NORMAL KIAS	40	50	60	70	80	90	100	110	---	---	---
ALTERNATE KIAS	38	49	59	69	79	88	97	106	---	---	---
FLAPS 30°											
NORMAL KIAS	40	50	60	70	80	85	---	---	---	---	---
ALTERNATE KIAS	34	47	57	67	77	81	---	---	---	---	---

WINDOWS OPEN

FLAPS UP											
NORMAL KIAS	40	50	60	70	80	90	100	110	120	130	140
ALTERNATE KIAS	26	43	57	70	82	93	103	113	123	133	143
FLAPS 10°											
NORMAL KIAS	40	50	60	70	80	90	100	110	---	---	---
ALTERNATE KIAS	25	43	57	69	80	91	101	111	---	---	---
FLAPS 30°											
NORMAL KIAS	40	50	60	70	80	85	---	---	---	---	---
ALTERNATE KIAS	25	41	54	67	78	84	---	---	---	---	---

Figure 5-1. Airspeed Calibration (Sheet 2 of 2)

TEMPERATURE CONVERSION CHART

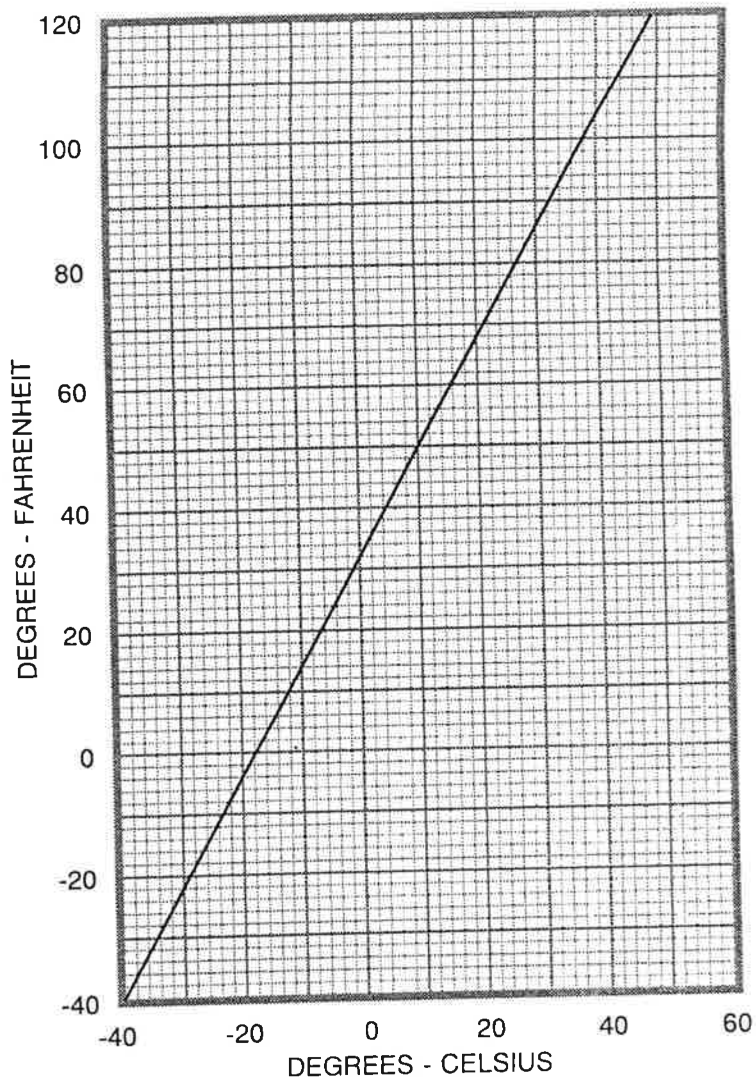


Figure 5-2. Temperature Conversion Chart

STALL SPEEDS AT 2450 POUNDS

Conditions:
Power Off

MOST REARWARD CENTER OF GRAVITY

FLAP SETTING	ANGLE OF BANK							
	0°		30°		45°		60°	
	KIAS	KCAS	KIAS	KCAS	KIAS	KCAS	KIAS	KCAS
UP	44	51	48	55	53	61	63	73
10°	35	48	38	52	42	58	50	69
30°	33	47	36	50	40	56	47	66

MOST FORWARD CENTER OF GRAVITY

FLAP SETTING	ANGLE OF BANK							
	0°		30°		45°		60°	
	KIAS	KCAS	KIAS	KCAS	KIAS	KCAS	KIAS	KCAS
UP	44	52	48	56	53	62	63	74
10°	37	50	40	53	44	59	53	70
30°	33	47	36	50	40	56	47	66

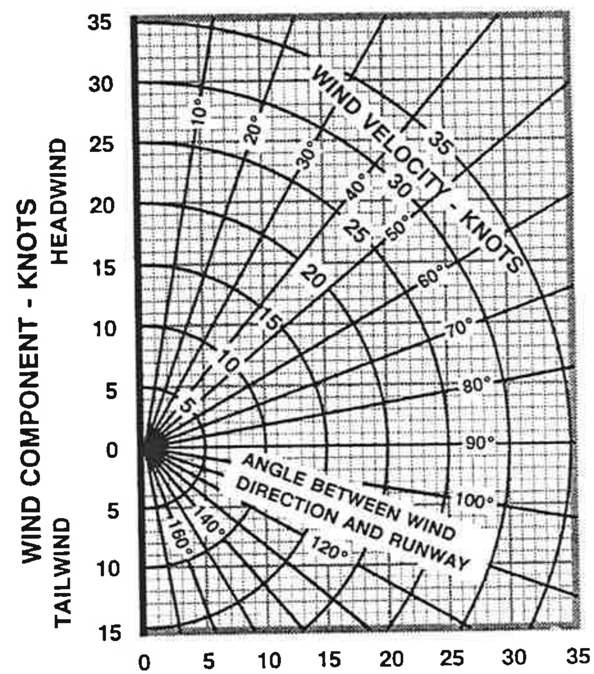
NOTES:

1. Altitude loss during a stall recovery may be as much as 230 feet.
2. KIAS values are approximate.

Figure 5-3. Stall Speeds

WIND COMPONENTS

NOTE:
Maximum demonstrated crosswind velocity is 15 knots (not a limitation).



0585C1003

Figure 5-4. Crosswind Components

SHORT FIELD TAKEOFF DISTANCE AT 2450 POUNDS

CONDITIONS:

Flaps 10°
Full Throttle Prior to Brake Release
Paved, level, dry runway
Zero Wind
Lift Off: 51 KIAS
Speed at 50 Ft: 57 KIAS

Press Alt In Feet	0°C		10°C		20°C		30°C		40°C	
	Grnd Roll Ft	Total Ft To Clear 50 Ft Obst	Grnd Roll Ft	Total Ft To Clear 50 Ft Obst	Grnd Roll Ft	Total Ft To Clear 50 Ft Obst	Grnd Roll Ft	Total Ft To Clear 50 Ft Obst	Grnd Roll Ft	Total Ft To Clear 50 Ft Obst
S. L.	845	1510	910	1625	980	1745	1055	1875	1135	2015
1000	925	1660	1000	1790	1075	1925	1160	2070	1245	2220
2000	1015	1830	1095	1970	1185	2125	1275	2290	1365	2455
3000	1115	2020	1205	2185	1305	2360	1400	2540	1505	2730
4000	1230	2245	1330	2430	1435	2630	1545	2830	1655	3045
5000	1355	2500	1470	2715	1585	2945	1705	3175	1830	3430
6000	1500	2805	1625	3060	1750	3315	1880	3590	2020	3895
7000	1660	3170	1795	3470	1935	3770	2085	4105	2240	4485
8000	1840	3620	1995	3975	2150	4345	2315	4775	---	---

NOTES:

1. Short field technique as specified in Section 4.
2. Prior to takeoff from fields above 3000 feet elevation, the mixture should be leaned to give maximum RPM in a full throttle, static runup.
3. Decrease distances 10% for each 9 knots headwind. For operation with tail winds up to 10 knots, increase distances by 10% for each 2 knots.
4. For operation on dry, grass runway, increase distances by 15% of the "ground roll" figure.
5. Where distance value has been deleted, climb performance is minimal.

Figure 5-5. Short Field Takeoff Distance

MAXIMUM RATE-OF-CLIMB AT 2450 POUNDS

CONDITIONS:

Flaps Up
Full Throttle

PRESS ALT FT	CLIMB SPEED KIAS	RATE OF CLIMB - FPM			
		-20°C	0°C	20°C	40°C
S.L.	79	830	770	705	640
2000	77	720	655	595	535
4000	76	645	585	525	465
6000	74	530	475	415	360
8000	72	420	365	310	250
10,000	71	310	255	200	145
12,000	69	200	145	---	---

NOTE:

1. Mixture leaned above 3000 feet for maximum RPM.

Figure 5-6. Maximum Rate of Climb

TIME, FUEL AND DISTANCE TO CLIMB AT 2450 POUNDS

CONDITIONS:

Flaps Up
Full Throttle
Standard Temperature

PRESS ALT FT	TEMP °C	CLIMB SPEED KIAS	RATE OF CLIMB FPM	FROM SEA LEVEL		
				TIME IN MIN	FUEL USED GAL	DIST NM
S.L.	15	79	720	0	0.0	0
1000	13	78	670	1	0.4	2
2000	11	77	625	3	0.7	4
3000	9	76	575	5	1.2	6
4000	7	76	560	6	1.5	8
5000	5	75	515	8	1.8	11
6000	3	74	465	10	2.1	14
7000	1	73	415	13	2.5	17
8000	-1	72	365	15	3.0	21
9000	-3	72	315	18	3.4	25
10,000	-5	71	270	22	4.0	29
11,000	-7	70	220	26	4.6	35
12,000	-9	69	170	31	5.4	43

NOTES:

1. Add 1.1 gallons of fuel for engine start, taxi and takeoff allowance.
2. Mixture leaned above 3000 feet for maximum RPM.
3. Increase time, fuel and distance by 10% for each 10°C above standard temperature.
4. Distances shown are based on zero wind.

Figure 5-7. Time, Fuel and Distance to Climb

CRUISE PERFORMANCE

CONDITIONS:
2450 Pounds
Recommended Lean Mixture At All Altitudes (Refer to Section 4, Cruise)

PRESS ALT FT	RPM	20°C BELOW STANDARD TEMP			STANDARD TEMPERATURE			20°C ABOVE STANDARD TEMP		
		% BHP	KTAS	GPH	% BHP	KTAS	GPH	% BHP	KTAS	GPH
2000	2250	---	---	---	79	115	9.0	74	114	8.5
	2200	79	112	9.1	74	112	8.5	70	111	8.0
	2100	69	107	7.9	65	106	7.5	62	105	7.1
	2000	61	101	7.0	58	99	6.6	55	97	6.4
	1900	54	94	6.2	51	91	5.9	50	89	5.8
4000	2300	--	---	---	79	117	9.1	75	117	8.6
	2250	80	115	9.2	75	114	8.6	70	114	8.1
	2200	75	112	8.6	70	111	8.1	66	110	7.6
	2100	66	106	7.6	62	105	7.1	59	103	6.8
	2000	58	100	6.7	55	98	6.4	53	95	6.2
	1900	52	92	6.0	50	90	5.8	49	87	5.6
6000	2350	--	---	---	80	120	9.2	75	119	8.6
	2300	80	117	9.2	75	117	8.6	71	116	8.1
	2250	76	115	8.7	71	114	8.1	67	113	7.7
	2200	71	112	8.1	67	111	7.7	64	109	7.3
	2100	63	105	7.2	60	104	6.9	57	101	6.6
	2000	56	98	6.4	53	96	6.2	52	93	6.0

NOTE:

1. Cruise speeds are shown for an airplane equipped with speed fairings. Without speed fairings, decrease speeds shown by 2 knots.

Figure 5-8. Cruise Performance (Sheet 1 of 2)

CRUISE PERFORMANCE

CONDITIONS:
2450 Pounds
Recommended Lean Mixture At All Altitudes (Refer to Section 4, Cruise)

PRESS ALT FT	RPM	20°C BELOW STANDARD TEMP			STANDARD TEMPERATURE			20°C ABOVE STANDARD TEMP		
		% BHP	KTAS	GPH	% BHP	KTAS	GPH	% BHP	KTAS	GPH
8000	2400	--	---	---	80	122	9.2	76	121	8.7
	2350	81	120	9.3	76	119	8.7	71	118	8.2
	2300	76	117	8.7	71	116	8.2	68	115	7.8
	2200	68	111	7.7	64	110	7.3	61	107	7.0
	2100	60	104	6.9	57	102	6.6	55	99	6.4
	2000	54	96	6.2	52	94	6.0	51	91	5.9
10,000	2350	76	119	8.8	72	118	8.2	68	117	7.8
	2300	72	116	8.3	68	115	7.8	65	113	7.4
	2250	68	113	7.8	65	112	7.4	61	109	7.1
	2200	65	110	7.4	61	108	7.0	59	105	6.7
	2100	58	102	6.6	55	100	6.4	54	97	6.2
	2000	52	94	6.1	51	91	5.9	50	88	5.8
12,000	2350	73	119	8.3	69	117	7.9	65	115	7.5
	2300	69	115	7.9	65	113	7.5	62	111	7.1
	2250	65	112	7.5	62	109	7.1	59	107	6.8
	2200	62	108	7.1	59	105	6.8	57	103	6.6
	2100	56	100	6.4	54	97	6.2	53	94	6.1

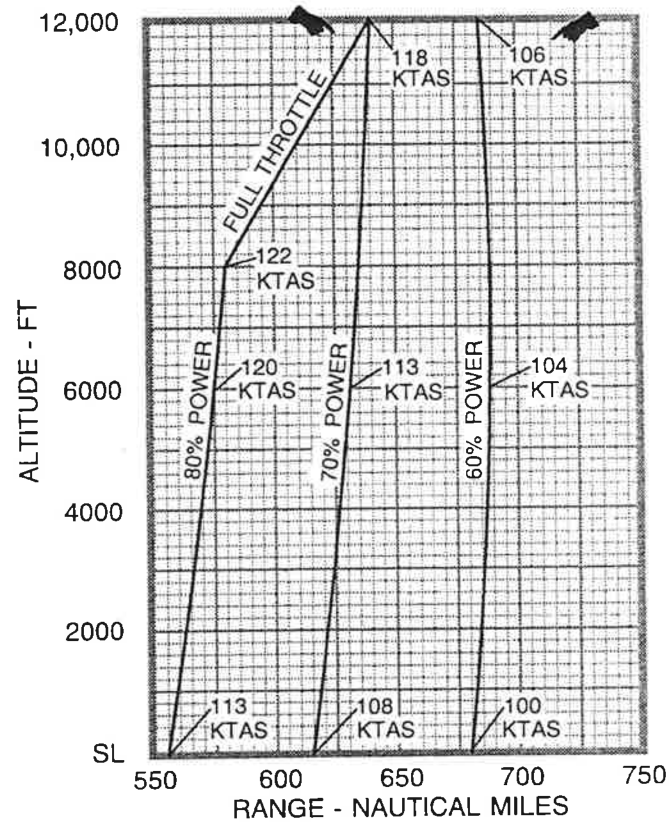
NOTE:

1. Cruise speeds are shown for an airplane equipped with speed fairings. Without speed fairings, decrease speeds shown by 2 knots.

Figure 5-8. Cruise Performance (Sheet 2 of 2)

RANGE PROFILE
45 MINUTES RESERVE
53 GALLONS USABLE FUEL

CONDITIONS:
2450 Pounds
Recommended Lean Mixture for Cruise At All Altitudes
Standard Temperature
Zero Wind

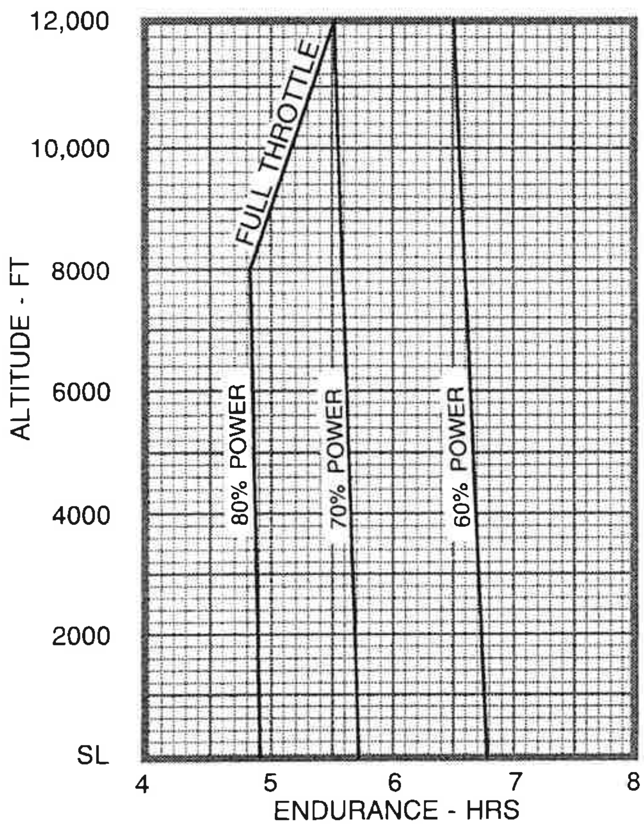


NOTES:
1. This chart allows for the fuel used for engine start, taxi, takeoff and climb, and the distance during climb.
2. Performance is shown for an airplane equipped with speed fairings, which increase the cruise speeds by approximately two knots.

Figure 5-9. Range Profile

ENDURANCE PROFILE
45 MINUTES RESERVE
53 GALLONS USABLE FUEL

CONDITIONS:
2450 Pounds
Recommended Lean Mixture for Cruise At All Altitudes
Standard Temperature



NOTE:
1. This chart allows for the fuel used for engine start, taxi, takeoff and climb, and the time during climb.

Figure 5-10. Endurance Profile

SHORT FIELD LANDING DISTANCE AT 2450 POUNDS

CONDITIONS:

Flaps 30°
Power Off
Maximum Braking
Paved, level, dry runway
Zero Wind
Speed at 50 Ft: 62 KIAS

Press Alt In Feet	0°C		10°C		20°C		30°C		40°C	
	Grnd Roll Ft	Total Ft To Clear 50 Ft Obst	Grnd Roll Ft	Total Ft To Clear 50 Ft Obst	Grnd Roll Ft	Total Ft To Clear 50 Ft Obst	Grnd Roll Ft	Total Ft To Clear 50 Ft Obst	Grnd Roll Ft	Total Ft To Clear 50 Ft Obst
S. L.	525	1250	540	1280	560	1310	580	1340	600	1370
1000	545	1280	560	1310	580	1345	600	1375	620	1405
2000	565	1310	585	1345	605	1375	625	1410	645	1440
3000	585	1345	605	1380	625	1415	650	1445	670	1480
4000	605	1380	630	1415	650	1450	670	1485	695	1520
5000	630	1415	650	1455	675	1490	700	1525	720	1560
6000	655	1455	675	1490	700	1530	725	1565	750	1605
7000	680	1495	705	1535	730	1570	755	1610	775	1650
8000	705	1535	730	1575	755	1615	780	1655	810	1695

NOTES:

1. Short field technique as specified in Section 4.
2. Decrease distances 10% for each 9 knots headwind. For operation with tail winds up to 10 knots, increase distances by 10% for each 2 knots.
3. For operation on dry, grass runway, increase distances by 45% of the "ground roll" figure.
4. If landing with flaps up, increase the approach speed by 7 KIAS and allow for 35% longer distances.

Figure 5-11. Short Field Landing Distance

Attachment 4

172R Operators Handbook, Section 4: Normal Procedures

INTRODUCTION

Section 4 provides checklist and amplified procedures for the conduct of normal operation. Normal procedures associated with optional systems can be found in Section 9.

AIRSPEEDS

AIRSPEEDS FOR NORMAL OPERATION

Unless otherwise noted, the following speeds are based on a maximum weight of 2450 pounds and may be used for any lesser weight.

Takeoff:	
Normal Climb Out	70-80 KIAS
Short Field Takeoff, Flaps 10°, Speed at 50 Feet	57 KIAS
Enroute Climb, Flaps Up:	
Normal, Sea Level	75-85 KIAS
Normal, 10,000 Feet	70-80 KIAS
Best Rate-of-Climb, Sea Level	79 KIAS
Best Rate-of-Climb, 10,000 Feet	71 KIAS
Best Angle-of-Climb, Sea Level	60 KIAS
Best Angle-of-Climb, 10,000 Feet	65 KIAS
Landing Approach:	
Normal Approach, Flaps Up	65-75 KIAS
Normal Approach, Flaps 30°	60-70 KIAS
Short Field Approach, Flaps 30°	62 KIAS
Balked Landing:	
Maximum Power, Flaps 20°	55 KIAS
Maximum Recommended Turbulent Air Penetration Speed:	
2450 Lbs	99 KIAS
2000 Lbs	92 KIAS
1600 Lbs	81 KIAS
Maximum Demonstrated Crosswind Velocity:	
Takeoff or Landing	15 KNOTS

6. Flight Instruments -- CHECK and SET.
7. Fuel Quantity -- CHECK.
8. Mixture -- RICH.
9. Fuel Selector Valve -- RECHECK BOTH.
10. Elevator Trim -- SET for takeoff.
11. Throttle -- 1800 RPM.
    a. Magnetos -- CHECK (RPM drop should not exceed 150 RPM on either magneto or 50 RPM differential between magnetos).
    b. Suction Gage -- CHECK.
    c. Engine Instruments and Ammeter -- CHECK.
12. Annunciator Panel -- Ensure no annunciators are illuminated.
13. Throttle -- 1000 RPM or LESS.
14. Throttle Friction Lock -- ADJUST.
15. Strobe Lights -- AS DESIRED.
16. Radios and Avionics -- SET.
17. Autopilot (if installed) -- OFF.
18. Wing Flaps -- SET for takeoff (0°-10°).
19. Brakes -- RELEASE.

TAKEOFF

NORMAL TAKEOFF

1. Wing Flaps -- 0°-10°.
2. Throttle -- FULL OPEN.
3. Mixture -- RICH (above 3000 feet, LEAN to obtain maximum RPM).
4. Elevator Control -- LIFT NOSE WHEEL (at 55 KIAS).
5. Climb Speed -- 70-80 KIAS.

SHORT FIELD TAKEOFF

1. Wing Flaps -- 10°.
2. Brakes -- APPLY.
3. Throttle -- FULL OPEN.
4. Mixture -- RICH (above 3000 feet, LEAN to obtain maximum RPM).
5. Brakes -- RELEASE.
6. Elevator Control -- SLIGHTLY TAIL LOW.
7. Climb Speed -- 57 KIAS (until all obstacles are cleared).

ENROUTE CLIMB

1. Airspeed -- 70-85 KIAS.

NOTE

If a maximum performance climb is necessary, use speeds shown in the Rate Of Climb chart in Section 5.

2. Throttle -- FULL OPEN.
3. Mixture -- RICH (above 3000 feet, LEAN to obtain maximum RPM).

CRUISE

1. Power -- 2000-2400 RPM (No more than 80% is recommended).
2. Elevator Trim -- ADJUST.
3. Mixture -- LEAN.

DESCENT

1. Power -- AS DESIRED.
2. Mixture -- ADJUST for smooth operation (full rich for idle power).
3. Fuel Selector Valve -- BOTH.

BEFORE LANDING

1. Pilot and Passenger Seat Backs -- MOST UPRIGHT POSITION.
2. Seats and Seat Belts -- SECURED and LOCKED.
3. Fuel Selector Valve -- BOTH.
4. Mixture -- RICH.
5. Landing/Taxi Lights -- ON.
6. Autopilot (if installed) -- OFF.

LANDING

NORMAL LANDING

1. Airspeed -- 65-75 KIAS (flaps UP).
2. Wing Flaps -- AS DESIRED (0°-10° below 110 KIAS, 10°-30° below 85 KIAS).
3. Airspeed -- 60-70 KIAS (flaps DOWN).
4. Touchdown -- MAIN WHEELS FIRST.
5. Landing Roll -- LOWER NOSE WHEEL GENTLY.
6. Braking -- MINIMUM REQUIRED.

SHORT FIELD LANDING

1. Airspeed -- 65-75 KIAS (flaps UP).
2. Wing Flaps -- FULL DOWN (30°).
3. Airspeed -- 62 KIAS (until flare).
4. Power -- REDUCE to idle after clearing obstacle.
5. Touchdown -- MAIN WHEELS FIRST.
6. Brakes -- APPLY HEAVILY.
7. Wing Flaps -- RETRACT.

BALKED LANDING

1. Throttle -- FULL OPEN.
2. Wing Flaps -- RETRACT TO 20°.
3. Climb Speed -- 55 KIAS.
4. Wing Flaps -- 10° (until obstacles are cleared).
   RETRACT (after reaching a safe altitude and 60 KIAS).

AFTER LANDING

1. Wing Flaps -- UP.

SECURING AIRPLANE

1. Parking Brake -- SET.
2. Avionics Power Switch, Electrical Equipment, Autopilot (if installed) -- OFF.
3. Mixture -- IDLE CUT OFF (pulled full out).
4. Ignition Switch -- OFF.
5. Master Switch -- OFF.
6. Control Lock -- INSTALL.
7. Fuel Selector Valve -- LEFT or RIGHT to prevent cross feeding.